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Design and optimization system for hydroponic cucumbers by neural network and fuzzy logic

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Abstract:
The best way to achieve high agricultural production of low soil, using a protected area from temperature and climate, In order to increase production per unit area to produce a product with the desired quality and quantity over the years. Early fault detection and identification plays an important role in plant production systems.
System diagnostics and fault detection to avoid costly repairs and long-term disorders could be used in production. Hydroponic plant production system is a complex biological process involving plants and micro-organisms with complex mathematical models. In this study, an adaptive fuzzy neural inference to identify the drivers and faulty sensors in hydroponic plants have been developed. The system combines a neural network and fuzzy logic that benefits both ways - the knowledge of fuzzy logic andthe ability of neural networks. the initial error diagnosis system is using clusters that relatively large decline by the training is decreasing error rate. Root mean square error during the training period showed that after the hundredth repetition of errors and error learning drops to 0.04 converge.

Keywords: fault detection and identification system, the nervous system Adaptive fuzzy inference, hydroponic plants production, mechanical defects.

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1 INTRODUCTION

Hydroponic production systems is required to produce high-quality products, such as surveillance and control over the food system environmental variables (such as PH, temperature, electric conductivity, EC) and the ambient air Greenhouse. Therefore, nowadays, computers and digital controller will be used in the automation of operations.
there are Two methods to diagnose malfunction in the system: 1)redundancy method 2) Interaction With Other Variables. The redundancy detection method using components and additional sensor for detect faults. For example, in a system with an additional sensor, there are different outputs that indicate the existence of flaw in one of the sensors or both of them. In the other method, fault detection is directly. In this paper will be developed an Adaptive fuzzy neural inference system for detection and identification of defective sensors and actuators in hydroponic plant production system. Another innovation of this research, it is based on fuzzy failure diagnosis and identification system-proposed will be applied in a nervous signal output to detect and identify types of fault systems simultaneously.
Early identification and diagnosis of fault system plays an important role in the production of the plant. Flaw detection and identification system can be applied to avoid lengthy disruptions in production and the cost of repair. Hydroponic plant production system, the system is a complex biological process that it includes plants and microorganisms with a mathematical model is complex. In this research, a fuzzy-neural system has been selected for flaw detection and implementate identification system. This method is called soft computing methods. A fuzzy-combination of a nervous system neural network and fuzzy logic system that benefits both ways – the knowledge of fuzzy logic and neural network learning feature-capable.
Also in this paper, a nervous conclusion have been developed for adaptive fuzzy system to detect and identify faulty sensors and actuators in hydroponic plant production systems . Another innovation in this research that identified the flaw detection system and suggested a neural-fuzzy output signal

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will be used to detect and identify the types of imperfections in the system simultaneously.

Many believe that hydroponics were started as the hanging gardens of Babel, one of the ancient world wonders, the first scientist who ad proved plants do not use ground for the growth was John van helmont in the year 1600 [1].

John wood discovered the solution of hydroponic food [2]. Joseph Priestley in 1792 discovered carbon dioxide that plants also need. he puted the plant in a chimney, but two years later Jane has proven that if the chimney against the sunlight will get the better results. a plant also needs the addition of carbon dioxide to the sun light[3].

In the year 1804, Nicholas de sasur suggested that plants are a combination of organic and mineral elements that they got them from water, soil and air[4].

In the year 1856, salmhorsmar showed that plants can grow in wet environment with water and dissolved nutrients[5]. knop founded the agricultural methods with organic materials in 1861. Because of many tests done with water, people called him the father of water cultivation.[6]

In 1860 Professor Julie can be discovered the first standard formulas for making food that cannot be solved in the water but they are attracted by the plant. [7].

In the late 1920 's and early 1930 's Dr William Creek from the University of California did several experiments with the soil without plant cultivation method. He brought this way of the lab to commercial applications. also he called hydroponic to culvitation system with food solution. The word is derived from two Greek words. "Hydro" means water and "punos» means a work.

The hydroponics do not need to natural soil and only need about 40% of water from the traditional method and by this metod can grow a large number of plant in a small area. [8].

In 1986 by Hydro cultural company was used to the rooftops of homes for cultivated hydroponics plants for the first time. In this system, a biological errors, such as root or shoot errors in plants can reveal with using neural network system [9].

In 1991 Sorsa reported three different types of neural network systems to be able to control with action [10]. Debug with neural network was named by Eming in 1994 and Eming worked in the field of error detection and neural network with plant chemical solution in 1997. [11].

In 1999 for control greenhouse hydroponic system was used lab view software and monitored the parameters such as PH, water temperature, conductivity and dissolved oxygen in insoluble substances.

in the year 2002, ferish checked out the biological model of neural network by troubleshooting[12]. In the years 2002, 2003, 2004 Sanchez Guzman and Martin did a lot of automation and control for agricultural development.

Remote Labs produced by Guzman in 2003 and virtual by Rodriguez in 2004 in order to learn how to control the climatic conditions greenhouses for undergraduate and doctoral students, for example: development of automation in agriculture[13]. Today, hydroponics is one of the most important branch of agriculture that can use to produce many food for the millions .

2 METHODOLOGY

ANFIS architecture has been shown for a system with two inputs and one output for a better understanding of its working. A fuzzy inference system will be considered with two input x, y & a singleton output f. a first-order sogeno model are shown below a set of general rules with fuzzy if-then rules.

$$Rule1: IF\ x\ is\ A_1\ and\ y\ is\ B_1\ THEN\ z = f_1 = p_0^1 + p_1^1 x + p_2^1 y \quad (1)$$

Rule1:IF x is A1 and y is b1THEN z=f1=p1+p1x+p2y

$$Rule2: IF\ x\ is\ A_2\ and\ y\ is\ B_2\ THEN\ z = f_2 = p_0^2 + p_1^2 x + p_2^2 y$$

(a)

Figure1:(a)TS fuzzy rules (b) ANFIS corresponding TS model

3 HYBRID LEARNING ALGORITHM

When the values of the parameters are assumed constant, output shows as linear combinations of the Tali parameters.

(2)

$$\begin{aligned} f &= \frac{w_1}{w_1+w_2} f_1 + \frac{w_2}{w_1+w_2} f_2 \\ &= \bar{w}_1 f_1 + \bar{w}_2 f_2 \\ &= \bar{w}_1 (p_0^1 + p_1^1 x + p_2^1 y) + \bar{w}_2 (p_0^2 + p_1^2 x + p_2^2 y) \\ &= (\bar{w}_1) p_0^1 + (\bar{w}_1 x) p_1^1 + (\bar{w}_1 y) p_2^1 + (\bar{w}_2) p_0^2 + (\bar{w}_2 x) p_1^2 + (\bar{w}_2 y) p_2^2 \end{aligned}$$

Here $p_0^1, p_1^1, p_2^1, p_0^2, p_0^2, p_0^2$ are linear Taliparameters.Tali parameters can be obtained by using these formulas.

(3)

$$\begin{bmatrix} \bar{w}_1^{(1)} & \bar{w}_1^{(1)} x^{(1)} & \bar{w}_1^{(1)} y^{(1)} & \bar{w}_2^{(1)} & \bar{w}_2^{(1)} x^{(1)} & \bar{w}_2^{(1)} y^{(1)} \\ \bar{w}_1^{(2)} & \bar{w}_1^{(2)} x^{(2)} & \bar{w}_1^{(2)} y^{(2)} & \bar{w}_2^{(2)} & \bar{w}_2^{(2)} x^{(2)} & \bar{w}_2^{(2)} y^{(2)} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \bar{w}_1^{(n)} & \bar{w}_1^{(n)} x^{(n)} & \bar{w}_1^{(n)} y^{(n)} & \bar{w}_2^{(n)} & \bar{w}_2^{(n)} x^{(n)} & \bar{w}_2^{(n)} y^{(n)} \end{bmatrix} \begin{bmatrix} p_0^1 \\ p_1^1 \\ p_2^1 \\ p_0^2 \\ p_1^2 \\ p_2^2 \end{bmatrix} = \begin{bmatrix} r^{(1)} \\ r^{(2)} \\ \vdots \\ \vdots \\ \vdots \\ r^{(n)} \end{bmatrix}$$

Here $[(x^{(k)}, y^{(k)}), d^{(k)}]$ are a couple of training for k = 1, 2, ..., n and $\bar{w}_1^{(k)}, \bar{w}_2^{(k)}$ are third layer of the outputs, which are proportional to the input.

The equation above can be expressed in the form of matrix-vector.

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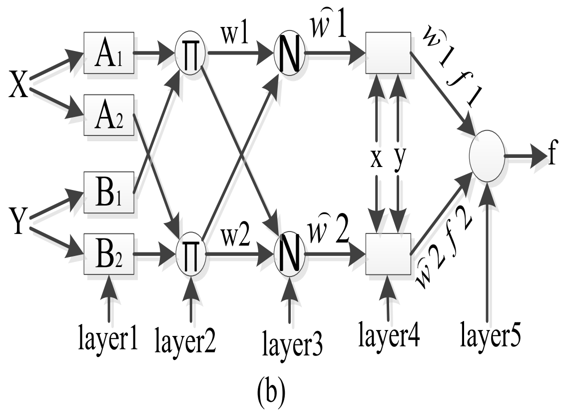

3-1-Membership function

As soon as you select the entries for the flaw detection should be determined input by membership functions. this feature used to Simplification learning process in a neural fuzzy system . This function can be assumed as follows.

$$\mu(x) = e^{-\frac{(x-m)^2}{2\sigma^2}}$$

Optimal Gaussian function with an appropriate choice of parameters m and σ is obtained. And σ is the width parameter m represents the center of the Gaussian function.

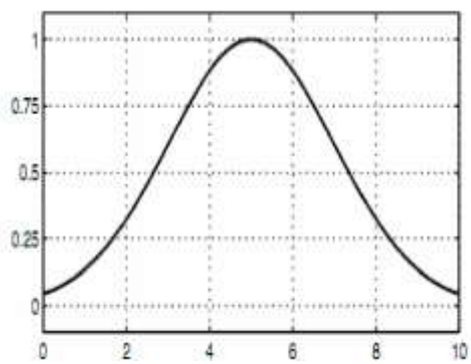

Figure2.Gussian membership function m=5 , *2σ*=.1

3-2-Schematic designed circuits to build hydroponic system

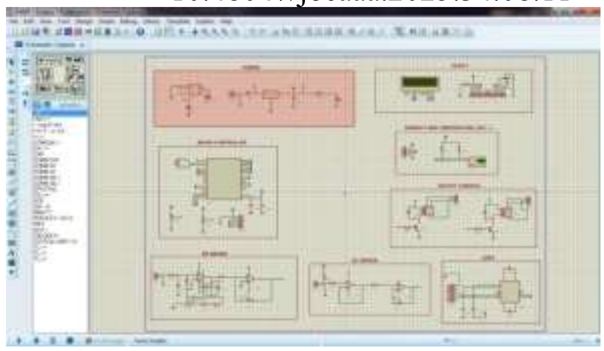

Figure3.Proteus software with circuits.

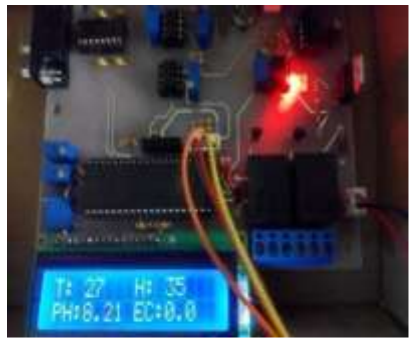

Figure4.Hydroponic Hardware system

Figure5.PH sensor

Figure6.PH measuring sensor

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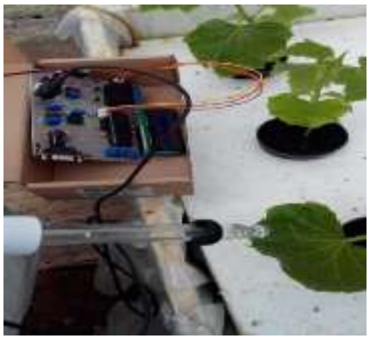

Figure7.Measuring PH & EC

3-3- Using F test or analysis of variance to compare the rate of growth in a hydroponic greenhouse in two modes, using neuro-fuzzy controller and without any controller

This test is modified t-test to assess equal or not equal two or more of the population is employed. In this test, the total variance of the primary factors to be analyzed. For this reason, we called ANOVA to this test.

When we want to instead of the two communities, several community similarity, we compared both of these tests are used, the comparison difficult Sample t-test. For this test we use the table below.

Source of changes	The sum of squares	Degrees of freedom	Average of squares	F
Between groups	ssk	k-1	MSK	$\frac{MSK}{MSE}$
In the groups	sse	n-k	MSE	
Total	sst	n-1		

Figure8.ANOVA Method

3-4-Duncan's multiple range test to compare the averages

Another method that is widely used to compare the average of all pairs is Duncan test (1955). To run this test first treatment means for increasing regular and standard error of the mean for ($\overline{s}$yi = √ (MSE / n) is determined. For samples with different size too, n the average harmonic {ni}, ie nh = a / (Σ_ (i = 1) ^ a ⟦(1 / ni)⟧) replaced, then Batryf Rp = ra (p, f) syi, p = 2,3, ..., a, a comparison between the average and do a. The values (ra (p, f), significant level of α with f degrees of freedom (DOF equal error), obtained from the range of meaningful Duncan.

Test the difference between the average of the difference between the largest and smallest mean that we start with the least significant range of Ra compared, then the difference between the largest and the second is smaller than all the calculated average compared with Ra-1, this procedure until all (a (a-1)) / 2 pair averages continue to be examined. If a significant difference in the minimum range is large, we conclude that the average of the pair have shown a significant difference.

4 RESULTS

4-1-ANFIS network in this section can be configured in order to diagnose and troubleshoot a hydroponics system

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Parameters	Type
Weather tempetature	Input
The amount of acidity and amount of the previous (pH)	Input
Electrical conductivity and amount of the previous (EC)	Input
Relative humidity (RH)	Input
System mode	Input

Figure9.Input parameters and main parameter in ANFIS constructure

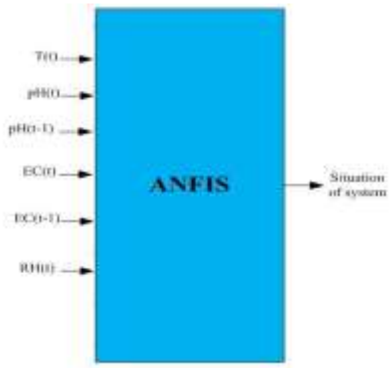

Figure10.Inputs and outputs of ANFIS model for detecting faults

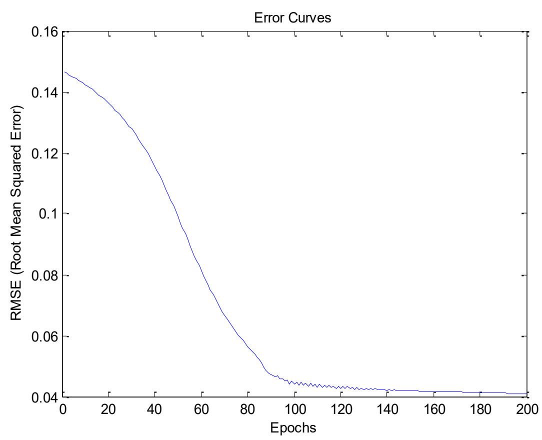

Figure11.The average minimum square error over the course of training

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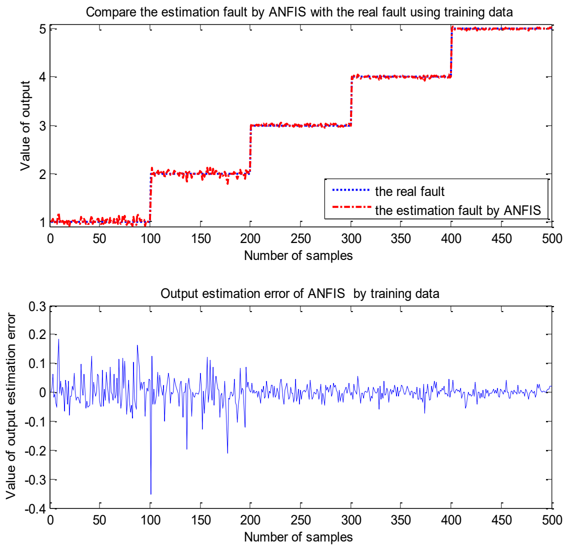

Figure12.Comparing the State of the system with the actual status of the estimated (figure above), the absolute value of the ratio of actual to estimated error (figure below)

4-2-EC and PH values and the impact on plant growth nutrient solution

In this paper, the amount of change based on the changes of PH and EC plant growth nutrient solution was evaluated in figure13.

PPM	PH	Grow Rate
1	5/6	1/035
1/2	5/7	1/023
1/4	5/8	0/89
1/6	6/3	0/96
1/7	6/4	1/091
1/9	6/5	1/027

Figure13.relation between(PH) plant growth nutrient solution with controller

EC(µs/cm)	Growth rate(cm/day)
1851	0/871
1779	0/927
1623	0/938
1659	0/984
1766	0/923
1663	0/957

Figure14. relation between plant growth with electrical conductivity (EC) of nutrient solution by controller

4-3-diagram of EC and PH nutrient solution and influence on plant growth

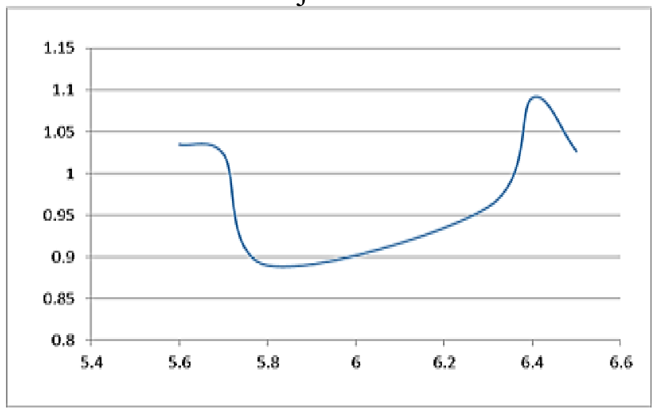

Figure15.Diagram based on changes in plant growth by PH of nutrient solution

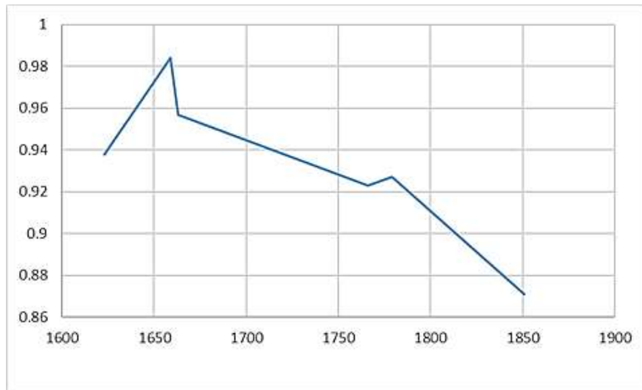

Figure 16. Diagram based on changes in plant growth by EC of nutrient solution

In this chapter, a neuro-fuzzy system provided for mechanical fault diagnosis and detection of hydroponics. conclusion from design of this system can use to produce a persistent residual effect of turbulence or noise from a distinct disadvantage and is less sensitive to them, However, it remains to be most sensitive to defect. Among the advantages of the proposed method can generate high-resolution.

Then the degree of importance was evaluated for each input in order to identify flaws in the system. At this stage, it was observed that environmental variables such as temperature and humidity are the most influence on the training error.

Finally, after training proposed system to evaluate its work, ANFIS network was tested and it was observed that the system as well as a breakdown of FDI and identify errors.

5 CONCLUSION

The system is designed to be used with data that can be obtained via sensors faults and imperfections hydroponic system using neuro-fuzzy analysis predicts.

During the growth curve for this system is obtained, it can be seen that growth stage of the plant to fruition control products performed very well on the hydroponic solution.

The system was designed at a time when one of the sensors with drift, will able to detect and isolate faulty sensor length.

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The system generates an output signal to determine the type of fault charts hydroponic systems.

Interactions between plants and microorganisms affect nutrient and population variables and the complexity of the solution.

REFERENCES

1-Walton, Michael T. "Boyle and Newton on the transmutation of water and air, from the root of Helmont's tree." *Ambix* 27.1 (1980): 11-18.

2-Alvarez, Eduardo A. "A hydroponic garden in the Hospicio San Vicente de Paul: A productive aging project." *Ageing International* 19.2 (1992): 22-25.

5-Landmeyer, James E. "Fundamentals of Plant Anatomy and Physiology Related to Water Use." *Introduction to Phytoremediation of Contaminated Groundwater*.Springer Netherlands, 2012.43-93.

4-Meidner, Hans. "Historical Sketches 4 CO2-ASSIMILATION." *Journal of Experimental Botany* 36.4 (1985): 694-695.

5-Klein, Richard M., et al. "Precipitation as a source of assimilable nitrogen: a historical survey." *American journal of botany* (1988): 928-937.

6-Hawkins, H-J., and E. George. "Hydroponic culture of the mycorrhizal fungus Glomusmosseae with Linumusitatissimum L., Sorghum bicolor L. and Triticumaestivum L." *Plant and soil* 196.1 (1997):
143-149.

7-Alvarez, Eduardo A. "A hydroponic garden in the Hospicio San Vicente de Paul: A productive aging project." *Ageing International* 19.2 (1992): 22-25.

8-Johnson, Delphine Ainslie, and Rowland Marcus Woodman. "Plant growth with nutrient solutions: I. A brief review of existing work." *The Journal of Agricultural Science* 36.02 (1946): 69-79.

9-Van Assche, C., &Vangheel, M. (1989, May).Plant protection in hydroponics. In *International Symposium on Growth and Yield Control in Vegetable Production 260* (pp. 363-376).

10-Ferentinos, K. P., L. D. Albright, and B. Selman. "Neural network-based detection of mechanical, sensor and biological faults in deep-trough hydroponics." *Computers and Electronics in Agriculture* 40.1 (2003): 65-85.

11-Wang, Huanhua, et al. "Physiological effects of magnetite (Fe3O4) nanoparticles on perennial ryegrass (Loliumperenne L.) and pumpkin (Cucurbitamixta) plants." *Nanotoxicology* 5.1 (2011): 30-42.

12-Ferentinos, Konstantinos P. "Biological engineering applications of feedforward neural networks designed and parameterized by genetic algorithms." *Neural networks* 18.7 (2005): 934-950.

13- Niizu, Patricia Y., and Delia B. Rodriguez-Amaya. "New data on the carotenoid composition of raw salad vegetables." *Journal of Food Composition and Analysis* 18.8 (2005): 739-749.