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A Study on the Air Cleaning System of Beauty Saloon by Artificial Intelligence

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ABSTRACT : *A practical application is given of a fuzzy - neuro control system for an air cleaning system of beauty saloon, and the result of simulation are presented. Fuzzy - neuro production rules that sum up people's common sense and experience, a fuzzy - neuro control system is able to manage the multivariable system. The paper present us the fuzzy - neuro control system and the result of simulation.*

KEY WORDS : Air cleaning system, Fuzzy logic neuron, Fuzzy logic neural inference, Fuzzy relation, Defuzzification.

1. Introduction

The fuzzy logic neural inference uses the fuzzy relation and the compositional rule of inference method. But there is a difficulty in representing complex knowledge and complicated control rules in fuzzy - neuro control systems. The fuzzy logic neural inference in this paper is realized as such a process flow along a compound inference systems from the top(precedence) to the end(antecedence). The method presented in this paper is flexible and represents knowledge and control rules for fuzzy -neuro control, this approach carries out the fuzzy logic neural inference effectively[1]. The fuzzy logic neural implication is the expression of the human knowledge, but sometimes it is very complicated. The antecedence may not be directly related to the precedence, there may be many branches which cross each other. That is to say, the framework of knowledge is a complicated network. The important thing of this method is that the output of one system can be the input to the other. The systems can link each other and hence forming an inference network among which there may be many media relay station of the value transformation. By the way, the complex knowledge of control rules in fuzzy - neuro controller can be represented effectively. For example,* a process may have several different sections each person. When describing the control strategy of the system each person can only note down the behavior of a section and he does not know the relation between the inputs and outputs of the whole system. Then we need some median variables.

In this paper, an inference method for a multivariable multilevel fuzzy - neuro control system for its use in a compound system is developed.

2. Fuzzy - Neuro Control System

In order to develop a fuzzy - neuro control system, first we present some basic mathematical operations pertinent to such systems.

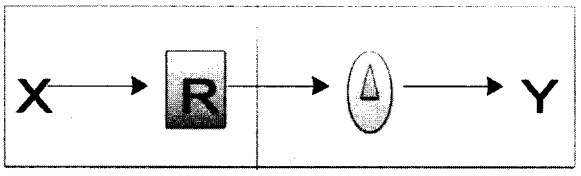

Fig. 1 Single - input single - output open - loop fuzzy logic neuron

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A single - input, single - output open - loop fuzzy logic neuron is illustrated in Fig. 1.

where ⓐ is neural operations between input X and output Y, and R is the relation between input X and output Y.[2]

Suppose that an operator provides a hypothetical verbal description of this process in the form of fuzzy implications connected by the conjunction ALSO:

$$\begin{aligned}&\text{IF } X_{(1)} \text{ THEN } Y_{(1)}\\&\text{ALSO}\\&\text{IF } X_{(2)} \text{ THEN } Y_{(2)}\\&\text{ALSO}\\&\cdots\\&\text{IF } X_{(i)} \text{ THEN } Y_{(i)}\\&\cdots\\&\text{ALSO}\\&\text{IF } X_{(n)} \text{ THEN } Y_{(n)}\end{aligned} \tag{1}$$

where $X_{(i)}$ is the fuzzy value of the i_{th} process input and $Y_{(i)}$ is corresponding fuzzy value of the process output. i = 1,2,....n

To calculate the output Y, given the input X and the fuzzy relation R, the compositional rule of inference is used

$$Y = X \circ R \tag{2}$$

where ∘ is the max - min composition of fuzzy relations.

A multivariable fuzzy logic neuron is shown in Fig. 2.

This system has four input and two output.

Therefore, a linguistic description of the process is as follows:

Suppose that the input and output signals are of a fuzzy nature, and let the neuron be trained by the following set of fuzzy rules:[3]

$$\begin{aligned}&\text{IF } X^1_{(i)} \text{ and } X^2_{(i)} \text{ and } X^3_{(i)} \text{ and } X(i)^4\\&\qquad THEN\ Y^1_{(i)} \text{ and } Y^2_{(i)}, ALSO\\&i = 1,2,3\ldots,I\end{aligned} \tag{3}$$

where $X^1_{(i)}$, $X^2_{(i)}$, $X^3_{(i)}$, $X^4_{(i)}$ are the fuzzy values of the input variables X^1, X^2, X^3, X^4 defined in the universe of discourses X_1, X_2, X_3, X_4 respectively; and $Y^1_{(i)}$, $Y^2_{(i)}$ are the fuzzy values of the output variable Y^1, Y^2 defined in the universe of discourse Y_1, Y_2 ; i = 1,2,3,...,I is the number of fuzzy rules, and ALSO is the linguistic connector.

To obtain the present outputs Y_1, Y_2, given the current inputs X_1, X_2, X_3, X_4, the following compositional rule of inference may be used

$$Y = X_1 \circ X_2 \circ X_3 \circ X_4 \circ R \tag{4}$$

The result of the composition is a compound fuzzy set Y in the universe $Y_1 \times Y_2$, where × is the Cartesian product.

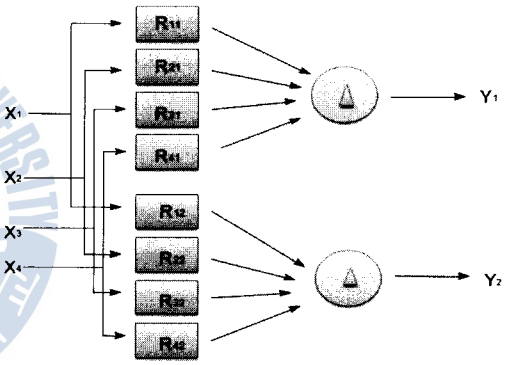
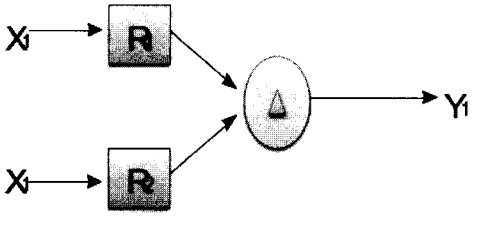


Fig. 2 Multi - input multi - output fuzzy logic neuron.

3. Multivariable Multilevel Compound Fuzzy - Neuro Control System

In fuzzy logic neuron, the following system rules is proposed as illustrated in the Fig. 3.

1) $X_1 AND X_2 THEN Y_1$:



2) $X_1 AND Y_1 THEN Y_2$:

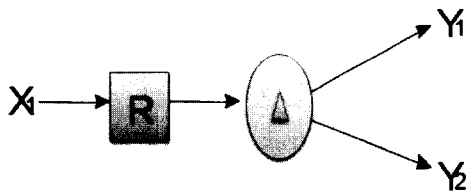


Fig. 3 Mulitivariable fuzzy logic neuron.

Consider a set of rules in compound fuzzy - neuro control system as follows.

$$\begin{aligned}
&IF\ X_1 AND X_6 THEN Z_2 AND Y_2\\
&IF\ X_2 AND X_4 THEN Y_2 AND Y_3\\
&IF\ X_3 AND Z_1 AND Y_1\\
&IF\ Z_1 AND X_5 THEN Y_3\\
&IF\ Z_2 AND X_4 THEN Y_1
\end{aligned} \tag{5}$$

where $X = \{ X_1, X_2, X_3, X_4, X_5, X_6 \}$, $Z = \{ Z_1, Z_2 \}$ and $Y = \{ Y_1, Y_2, Y_3 \}$,
X is linguistic variable of the input, Z is the median variable and Y is the output of the system.

The block diagram of compound fuzzy - neuro control system using this compound system rules is given in Fig. 4[4].

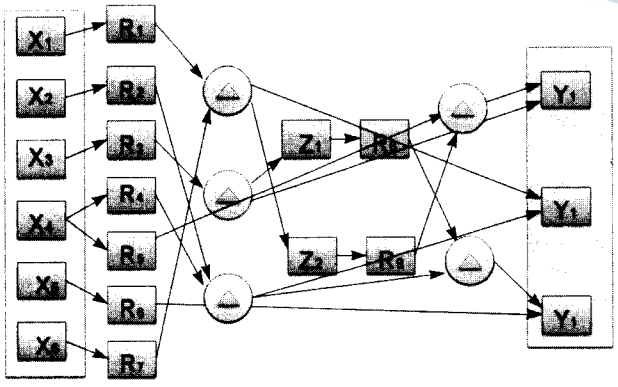


Fig. 4 The block diagram of compound fuzzy - neuro control system

4. Output Signal of a Compound Fuzzy - neuro Control System

The multivariable multilevel fuzzy logic neuron in a compound fuzzy neuro control system can now be described by the following fuzzy equations:

$$\begin{aligned}
Z_2 &= \{X_1 \circ R_1\} \triangle \{X_6 \circ X_7\}\\
Y_2 &= \{X_2 \circ R_2\} \triangle \{X_4 \circ X_4\}\\
Y_3 &= \{X_2 \circ R_2\} \triangle \{X_4 \circ X_4\}\\
Z_1 &= \{X_3 \circ R_3\}\\
Y_1 &= \{X_3 \circ R_3\}\\
Y_1 &= \{X_4 \circ R_5\} \triangle \{Z_2 \circ R_9\}\\
Y_3 &= \{X_5 \circ R_6\} \triangle \{Z_1 \circ R_8\}
\end{aligned} \tag{6}$$

where $X_1, X_2, X_3, X_4, X_5, X_6$, Z_1 and Z_2 are the current input of each system rules, and Z_1, Z_2, Y_1, Y_2 and Y_3 are the present output of each system rules.

It is more convenient to express the perception process in terms of the vector - matrix notation

The output signals of the neuron can be expressed as

$$\begin{bmatrix} Z_2 \\ Y_2 \end{bmatrix}^T = [X_1 X_6] * \begin{bmatrix} R_1 & R_1 \\ R_7 & R_7 \end{bmatrix} \tag{7}$$

$$\begin{bmatrix} Y_2 \\ Y_3 \end{bmatrix}^T = [X_2 X_4] * \begin{bmatrix} R_2 & R_2 \\ R_4 & R_4 \end{bmatrix} \tag{8}$$

$$\begin{bmatrix} Z_1 \\ Y_1 \end{bmatrix}^T = X_3 * [R_3 \ R_3] \tag{9}$$

$$Y_1 = [X_4 Z_2] * \begin{bmatrix} R_5 \\ R_9 \end{bmatrix} \tag{10}$$

$$Y_3 = [X_5 Z_1] * \begin{bmatrix} R_6 \\ R_8 \end{bmatrix} \tag{11}$$

where * means the ($\circ$, $\triangle$) composition, the superscript T in the above equations denotes transpose.

The fuzzy relations R_1, R_2, ... , R_9 are defined by the following mapping

$$\begin{aligned}
R_1&: \{X_1 \times Z_2\}\ UNDEROVER \wedge \{X_1 \times Y_2\} \rightarrow [0,1]\\
R_2&: \{X_2 \times Y_2\}\ UNDEROVER \wedge \{X_2 \times Y_3\} \rightarrow [0,1]\\
R_3&: \{X_3 \times Z_1\}\ UNDEROVER \wedge \{X_3 \times Y_1\} \rightarrow [0,1]\\
R_4&: \{X_4 \times Y_2\}\ UNDEROVER \wedge \{X_4 \times Y_3\} \rightarrow [0,1]\\
R_5&: X_4 \times Y_1 \rightarrow [0,1]\\
R_6&: X_5 \times Y_3 \rightarrow [0,1]
\end{aligned}$$

R_7: $\{X_6 \times Z_2\}$ UNDEROVER $\wedge$ $\{X_6 \times Y_2\} \rightarrow [0,1]$

R_8: $Z_1 \times Y_3 \rightarrow [0,1]$

R_9: $Z_2 \times Y_1 \rightarrow [0,1]$ (12)

where $\times$ is the Cartesian product, $\circ$ is the max - min composition, $\triangle$ is the contribution operator, and $\wedge$ is the min operator.

The output of fuzzy - neuro controller is a fuzzy set of control.

A piratical process for control requires a nonfuzzy value of control.

5. Defuzzification

$$U_0 = \text{defuzzifier}(U) \quad (13)$$

U : fuzziness value of inference, U_0 : defuzzification value of control.

Typical methods of defuzzification are the maximum criterion method, the mean of maximum method and the center of area method, and in this paper we used the mean of maximum method[5]

5.1 The maximum criterion method

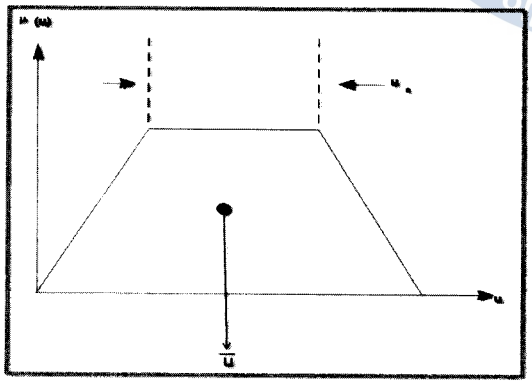


Fig. 5 Defuzzification of the max criterion method.

$$U_0 \in \{ U : \mu(u) = MAX_U \mu(u) \} \quad (14)$$

where U_0 is the defuzzification value of the control, $\mu(u)$ is the membership function and U is the element.

5.2 The mean of maximum method

$$u_0 = \sum_{j=1}^{k} \frac{u_j}{k} \quad (15)$$

where U_0 is the defuzzification value of the control, U_j is the control value of the maximum membership value and k is the number of control value in the maximum membership value.

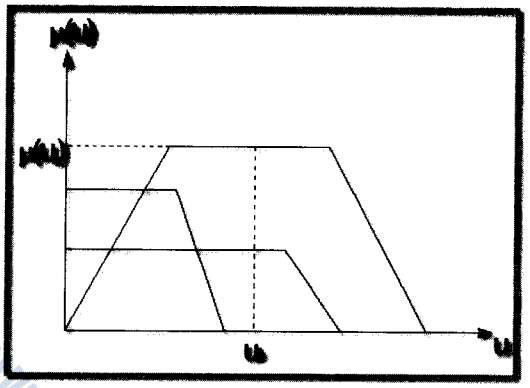


Fig. 6 Defuzzification of the mean of maximum method.

5.3 The center of area method

$$u_0 = \frac{\sum_{j=1}^{n} \mu(u_j) \cdot u_j}{\sum_{j=1}^{n} \mu(u_j)} \quad (16)$$

where U_0 is the defuzzification value of the control, $\mu(u_j)$ is the membership function and U_j is the element.

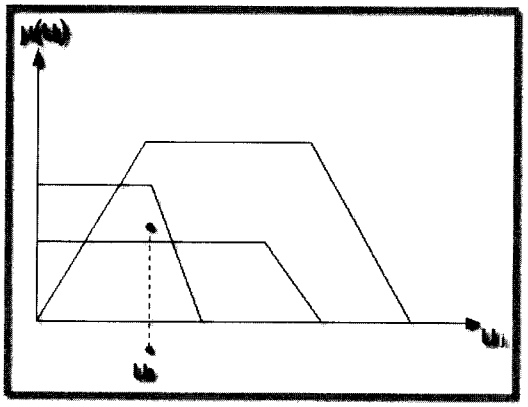


Fig. 7 Defuzzification of the center of area method.

6. Air cleaning system of beauty saloon

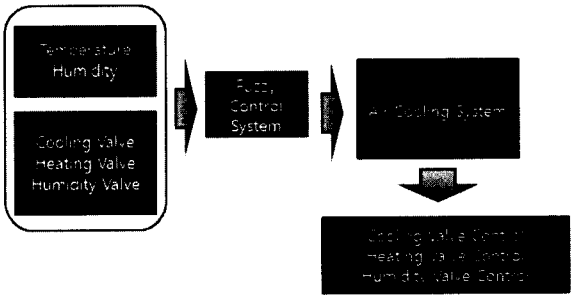


Fig. 8 Structure of artificial intelligent air cooling system

The structure of Fig. 8 on the air cooling system.

In Fig. 9, we have the input and output variables of fuzzy - neuro control for a air cleaning system with the following variables.

Input variables :

X_1 : temperature state.
X_2 : humidity state.
X_3 : cooling valve state.
X_4 : heating valve state.
X_5 : humidity valve state.

Output variables :

Y_1 : cooling valve control value.
Y_2 : heating valve control value.
Y_3 : humidity valve control value.

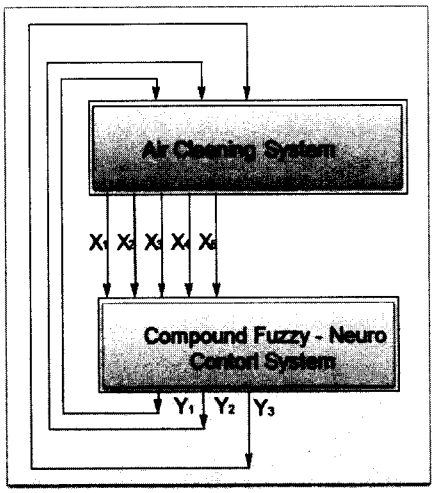


Fig. 9 The basic control structure for a air cleaning system

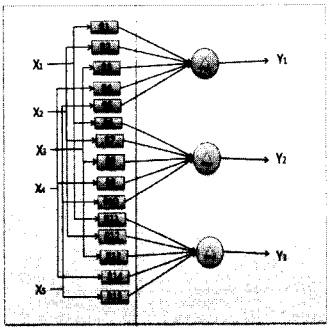


Fig. 10 The block diagram of compound fuzzy - neuro control system in an air cleaning system.

A block diagram structure of the relation is depicted in Fig. 10. The control algorithm of each system in beauty saloon air cleaning is described using

'IF...THEN..." fuzzy - neuro control rules.

〈1〉 IF X_1 = B AND X_2 = ZM AND X_3 = ZM AND X_4 = M *AND* X_5 = *M* THEN Y_1 = ZP AND Y_2 = NZ

ALSO

〈2〉 IF X_1 = ZAND X_2 = MB AND X_3 = Z AND X_4 = ZM *AND* X_5 = *ZM* THEN Y_1 = ZP AND Y_2 = P

ALSO

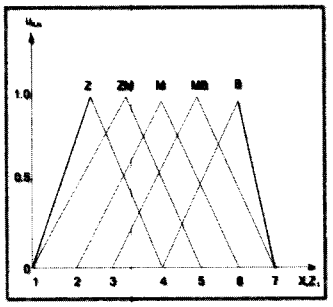
〈3〉 IF X_1 = ZM AND X_2 = M AND X_3 = MB AND X_4 = *MB AND* X_5 = *M* THEN Y_1 = Z AND Y_2 = ZP

ALSO

〈4〉 IF X_1 = MB AND X_2 = M AND X_3 = ZM AND X_4 = M B *AND* X_5 = *ZM* THEN Y_1 = NZ AND Y_2 = Z

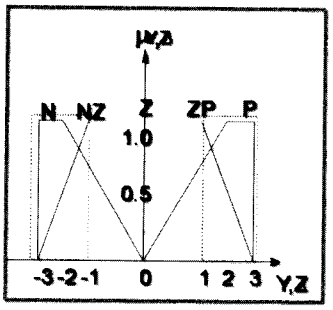
ALSO

The membership functions of the input variables and output variables are shown in Figs. 11 and Figs. 12, respectively



Z = Zero, ZM = between Zero and Medium, M = Medium, MB = between Medium and Big, B = Big.

Fig. 11 Membership function of the input variables in each system.



N = Negative, NZ = between Negative and Zero, Z = Zero, ZP = between Zero and Positive, P = Positive.

Fig. 12 Membership function of the output variables in each system.

7. Simulation Results

A fuzzy - neuro program performing fuzzy - neuro control in a air cleaning system is programed.

The results of these simulation show that the multivariable multilevel compound fuzzy - neuro control system operate well enough in the air cleaning system.

Example 1.

In the first case, the following input signals were used :

X_1=MB, X_2=ZM, X_3=MB, X_4=B, X_5=Z

The output signals were

Y_1 = [1.0,1.0,1.0,1.0,0.5,0.5,0.5] ≅ NZ

Y_2 = [0.5,0.5,0.5,0.5,1.0,1.0,1.0] ≅ ZP

Y_3 = [1.0,1.0,1.0,0.5,0.5,0.5,0.5] ≅ NZ

and the defuzzification values were

Y_1 = -1.5

Y_2 = 2.0

Y_3 = -2.0

This is explained as follows.

IF temperature state is between Medium and Big, humidity state is between Zero and Medium, cooling valve state is between Medium and Big, heating valve state is Big, humidity valve state is Zero, THEN cooling valve control value is closed by control value of motor speed of -1.5 level, heating valve control value is by control value of 2.0 level, humidity valve control value is closed by control of -2.0 level.

Where the control value range is the limits from minimum value (-3) to maximum value (+3) as shown in Fig.12.

Example 2.

In the second case the following input signals were used :

X_1=B, X_2=MB, X_3=ZM, X_4=M, X_5=B,

The output signals were

Y_1 = [1.0,1.0,1.0,1.0,0.5,0.5,0.5] ≅ ZP

Y_2 = [0.5,0.5,0.5,0.5,1.0,1.0,1.0] ≅ NZ

Y_3 = [1.0,1.0,1.0,0.5,0.5,0.5,0.5] ≅ Z

and output defuzzification values

Y_1 = 2.0

Y_2 = -2.0

Y_3 = 0.0

This is explained as follows,

IF temperature state is Big, humidity state is between Medium and Big, cooling valve state is between Zero and Medium, heating valve state is Medium, humidity valve state is Big, THEN cooling valve control value is opened by control value of 2.0 level, heating valve control value is closed by control value of -2.0 level, humidity value control value is not change.

Where the control value range is the limits from minimum value (-3) to maximum value (+3) as shown in Fig. 12.

8. Conclusions

In this paper, a compound fuzzy - neuro control system has been presented and used for the control of a air cleaning system in Beauty saloon efficiently. From the results of the simulations, the compound fuzzy - neuro control system was found to be effective for this multivariable multilevel control system of air cleaning system in Beauty saloon.

A fuzzy logic neuron has been outlined in this paper in terms of the temporal vector - matrix fuzzy equations. The method presented in this paper allows an analysis and synthesis of a multivariable multilevel compound fuzzy - neuro control system.

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