The IEEE International Conference on
Industrial Informatics (INDIN 2008)
DCC, Daejeon, Korea July 13-16, 2008

Multi Sensor Data Fusion Method Based on Fuzzy Neural Network

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***Abstract*- With the uncertainty of the multi sensor data of the fuzzy neural network fusion, the measure data from sensors is used to as the input of the fuzzy neural network and then is fuzzed. Next the data is analyzed and disposed by the neural network rule. Finally it is output after defuzzification. Confronting with the input fuzzification with uncertain membership function, we adopt the golden partition method to decide the initial center and width of membership functions of the fuzzification layer. The way of the model fuzzification and the improved BP network study rule is introduced to the network judging rule, and the judging result is output after defuzzification according to the weight rule .The article gives a general method of the multi sensor data gaining based on fuzzy neural network. The structure of network is rational and has rather quick training speed. It also has good generalization ability .**

***Keywords*- data fusion; fuzzy; neural network; rule**

I INTRODUCTION

With the development of the technology, the approach of obtaining information is continuously increasing. The needing of using and disposing information is higher and higher, and the multi information fusion technology makes the information disposing exacter and more timely. In the production check in the industrial manufacture, it needs to check the production quality exactly in time. The final result of quality check is gained through analyzing and judging the multi characteristic checking index of the production. The multi sensor fusion technology can analyze relatively and dispose attribute data of all accepts of the production. The FNN can simulate the thought of human's brain to build a parallel information disposing model which has the functions of association, memory, anti-noising and anti-jamming. It is also good in fault-tolerant and robustness [1]. The multi sensor network model with fuzzy neural network has the ability of quick parallel information disposing and the functions of completing complex information gaining and disposing in time. It has an important assistant effect to intelligent judging and correction. At the same time the complex study and training course of large data-base can be left out. So it has an important significance to the production detection in the industrial manufacture.

The way that industrial detection system checks the quality of manufacture is generally classified into two kinds. One is the traditional method represented by time list [2]. It is quite mature, whose algorithm is simple and speed is high. But it is the method of linear model essentially which can't reflect the actual characteristic of the detected manufacture truly because of its many shortcomings and localization. The other is the method using artificial intelligence including artificial neural network, fuzzy reasoning, expert system, genetic algorithm and etc. Artificial neural network is studied much in recent ten years, but applying it into detecting and judging needs much history data training [3]. What's more, the ability of learning and disposing uncertain information is low.

Artificial neural network and fuzzy theory are two kinds of very effective prediction technology [4]. Artificial neural network has the ability of information distributing storing and concurrent and collaborative disposing. It can operate collectively and self-adapt study. Fuzzy theory imitating the logic thought of human's brain expresses the operator's experience by the form of rule and puts them into the algorithm which can run in the computer. Fuzzy neural network has the fuzzy logic embedded into neural network. It gathers the power knowledge expression ability of fuzzy system and strong study ability of neural network, which makes fuzzy neural network fusion technology superior to normal neural network in the aspects of studying time, training step and precision. By now the neural network can be classified into two kinds [5]: the one according to the calculation of fuzzified value [5-9], the other based on the course of reasoning fuzzy rule [10-13]. In the first kind fuzzy neural network, its structure follows ordinary multilayer forward network, but the input and output are fuzzy linguistic value and the weight value chooses fuzzified value or clear value, so the algorithm of regulating the weight value picks up the improved BP algorithm basing on the calculating characteristic of the fuzzified value, which is mainly used in simulating the fuzzy rule set and reasoning approximately. In the second kind fuzzy neural network, its

input and output are precise value. It generally includes fuzzification, reasoning and clearing. Owing to the multiformity of the rule expressing form and agility in network simulation, this network brings many kinds of structure and algorithm, which is mainly used in time list prediction, multi data fusion and etc.

Because the ordinary fuzzy neural network has many technology difficult in the course of design such as choosing fuzzy membership function well, fuzzy logic reasoning, optimum fuzzy calculating, defuzzification calculating and so on [14], the article put forward fuzzifying the data from sensors after pretreatment which is called compensating fuzzify course. What's more, we can simulate and diagnose the detection system effectively by after-compensating fuzzy neural network study algorithm with quick study ability. Furthermore, this method can be applied in multi sensor detecting data fusion realizing fusing the uncertain input data. Fuzzifying the data from sensors after pretreatment in the system can fast the study speed of neural network and have good adaptability in detection system. The control strategy and algorithm in the system is the core.

II. MULTI SENSOR DATA FUSION

Multi sensor fusion is that it makes the best of multi sensor information resource with different time and space and uses computer technology to analyze, colligate, dominate and use the multi sensor information in a certain rule, then obtains the coincident explain and description of the measured target, so as to complete the needed decision and the evaluating mission, which make the system get better performance [15-16].

The multi sensor fusion course can be divided into five classes in the view of the information fusing function [17~18]. There are detection layer fusion, state layer fusion, attribute layer fusion, situation evaluation and threat evaluation. The situation evaluation and threat evaluation is mainly used in military affairs field.

1.1 Detection layer fusion

The function of detection layer fusion is to judge the existence of target. It is much closed to the collocation of sensors. There are three topologies basically: parallel topology, serial topology and tree routing topology [17].

1.2 State layer fusion

The state layer fusion is to evaluate the state of the target. It is divided into three basic structures: centralized, distributed and classified, which can make of different mix structure.

The centralized structure sends the information from the sensors in different place into fusion center to dispose directly. It hasn't the necessary contact between the low layer sensors, so its structure is simple and has high precision. It is similar to single stage processing in fusion algorithm. But it can fuse the information after receiving the data from all the sensors. Therefore the burden of communication is heavy, the speed of fusing is low and the viability of system is bad.

In the classified structure the information participates in disposing from low layer to high layer one by one. The node in high layer receives the fusing result from low layer. When there is a feedback, the information in high layer also takes part in the fusion processing of the node in low layer.

The distributed structure needn't using a controller to manage and vindicate the biggish centralized data-base. Every sensor node has itself processing unit and communication equipment, which can make the decision to the system by itself. The fusing speed is high and the burden of communication is light. What's more, the normal work of the whole system isn't affected by the invalidation of some sensor [19~20]. So it has high dependability and fault-tolerant, but the fusing precision is lower than the centralized structure.

1.3 Attribute layer fusion

The purpose of the attribute layer fusion is to certain the target's identity. According to the three layers of data abstract, the attribute layer fusion can classify into data layer fusion, characteristic layer fusion and decision-making layer fusion [20-23].

The data layer fusion fuses the data from the same kind of sensor directly. The course that the initial data from each sensor is sent to fuse without pretreatment is completed by picking up an eigenvalue vector from the initial data. Then the attribute is judged by the eigenvalue vector. The data layer fusion can provide the highest precise result, but it needs big communication bandwidth.

The characteristic layer fusion is belonged to the middle layer. At first, each sensor picks up the characteristic from its initial information, and then carries through analyzing synthetically and disposing the characteristic information. That is to say that it connects the many character vectors into a single vector after picking them up from observing data, then carries on identifying finally.

The decision-making layer fusion is a high layer fusion. According to each sensor's single resource data, the sensor makes the decisions. Then the decisions go on to be further fused into the final decisions. It is the best in the performance of real time and mainly resolves the problems such as multi target identify, situation evaluation, threat evaluation and so on [20].

III FUZZY NEURAL NETWORK

The fuzzy neural network includes the merits of the fuzzy logic and neural network. It can imitate the logic thought of the human's brain and the function of nerve cells as well. The problems with fuzzy also can be described by the network. What's more, it has strong abilities of study and direct data processing. Otherwise its ability of knowledge description and nature linguistic processing is rather powerful. Furthermore the fault-tolerant capability is quite strong [24]. Using the distributed integrating connectionist of the fuzzy neural

network to describe the knowledge implicitly, it can realize joining the knowledge description, storage and reasoning as one. It has obvious advantages in knowledge obtaining, parallel processing, the fault-tolerant ability of the self-adapt studying, associating and reasoning and so on.

The multi sensor data fusion technology based on the fuzzy neural network describes the analog value acquired by sensor using fuzzy membership functions, and then expresses the sensors' state distributing by distribution of the connecting weight value by neural cell. It gains knowledge in the course of training by given method and finishes the reasoning course from the state to the result. The best way is that the final conclusion is decided by the result of reasoning. The fuzzy neural network is generally used in the decision-making layer of the multi sensor fusion [25].

According to characteristics of the fuzzy logic and neural network, the fuzzy neural network is built as follows. At first, we have the detected state signal fuzzed based on the fuzzy method, so as to make the training sample preciser. Next we go on to detect the state and reason based on the BP neural network. Finally, the result is ratiocinated clearly.

The structure of the fuzzy neural network is made up of three models.

Input fuzzification model. It completes the course from character signal to network input mode. That is to say that we have the detected state signal transform into a fuzzy value set expressed by membership function.

Study reasoning model. It completes the course from detecting the state to reasoning based on the BP neural network.

Input clearness model. It completes the course from the output mode of neural network to the defuzzification of the detected result, in other words it decides the final conclusion by the output vector of ANN.

IV MULTI SENSOR NEURAL NETWORK FUSION MODEL

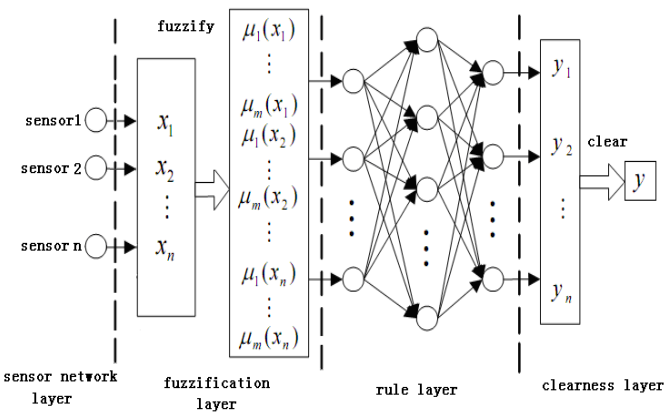

Fig. 1 the structure of the multi sensor fuzzy neural network.

In the detecting system the following model is obtained by joining the multi sensor and fuzzy neural network together. The sensor network layer consists of sensor in the scene which output the detected analog value.

4.1 Fuzzification layer

The acquired input value is the precise value generally. If using the method of fuzzy logic reasoning, we must have the precise input value fuzzified. The course corresponds to the fuzzification layer in the network. The function to be completed is to use the linguistic value with fuzzy instead of the precise value. The linguistic values of the variables are "small, medium, big" or "bad, little bad, medium, little good, good". The method of fuzzification is too many. The golden partition is an optimum partition model which is widely used and takes on nature and harmonious. In the condition of unknowing the membership degree, the golden partition model can get a quite good result. The distributing of the linguistic values' membership function should correspond to the golden partition rate. If we use the bell membership function, the closer to the center of the universe, the smaller of the cover range. In the adjacent linguistic value, the entropy of the linguistic value which is closer to the center is 0.618 times of the one which is further. Supposing xmin is the minimum and xmax is the maximum, there are three linguistic variables, the article decides the fuzzified weight value Aij and Bij referring to the method in literature [13]. The output of the fuzzification layer is as follows:

$$OutA_{ij} = \exp(-\frac{(x_i - A_{ij})^2}{B_{ij}^{\ 2}}) \qquad (2)$$

$$i = 1, 2, \cdots, n; \quad j = 1, 2, \cdots, m$$

4.2 Rule layer

There are maybe mn possible rule in the whole. But not all of them make sense. So the first thing is to ascertain the initial rule set. There are p samples set {S1 ,S2 , ..,Sp }. We have the fuzzification layer whose membership degree is ascertained in the training samples input fuzzified, and then pick up the membership degree's maximum as the fuzzy value of the input. Supposing the linguistic value is classified into three values: 1-"small", 2-"medium", 3-"big". It is easy to program to realize the obtaining of the initial rule. Once there inputs a sample, there can gets a rule. In order to choose the rule easily in the later network training, for the repeated rules, we save only one, and for the conflicted rules, we save all. Each

neural cell in the rule layer symbolizes one rule. According to the condition of the rule set, we can ascertain the connection between the rule layer and fuzzification layer. For example, rule:

If x1 is Small and x2 is Big,

Then y is Small.

That is to mean that if x1 is the "small" neural cell and x2 is the "big" neural cell, they connect respectively with the neural cell which symbolizes this rule. According to the course of fuzzy reasoning, the output of the rule layer is:

$$OutB_i = OutA_{i,j_1} \cdot OutA_{i,j_2} \cdots OutA_{n,j_n} \quad (2)$$

i is one number between the 1,2, ,l and j1,j2, ,jn which is decided by the condition of the i rule

4.3 Clearness layer

The clearness adapts the barycenter method. According to the formula of the barycenter method, the output network is:

$$y = OutC_3 = \frac{\sum_{i=1}^{l} OutB_i \cdot W_i}{\sum_{i=1}^{l} OutB_i} \quad (3)$$

Wi is the weight value of the C3 layer.

V. SIMULATING RESEARCH

The article simulates the fire engine colligated parameters detection system. The system gains the temperature, pressure, flux, rotate speed and etc by detection module and output the detecting result and state parameters by fusion calculation in fusion center of computer. The temperature, pressure and flux are detected by multi sensors. Before put into the fusion center, the same type data must be pretreated. After forming each parameter voter, they are fuzzified together with some other parameters such as torque, power, rotate speed and etc, which are used as the input layer of the fuzzy neural network. The structure of fire engine colligated parameters detection system is present by figure 2.

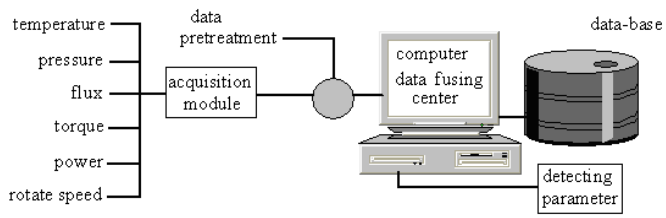

Fig 2. the structure of fire engine synthesis parameter detection system

TABLE 1.DETECTING SAMPLE DATA 1

Working state	Input axletree (℃)	Output axletree (℃)	Motor water (℃)	Middle pressure flux (L/S)
1.low pressure state	54.6	48	74	0
1.low pressure state	60.4	53.4	75	0
1.low pressure state	64.4	57.2	75.6	0
1.low pressure state	67.5	59.7	75.9	0
2.middle pressure state	72.1	63.8	76.1	15.68
2.middle pressure state	72.2	63.3	76.5	15.68
2.middle pressure state	72.8	64.2	76.9	15.68
2.middle pressure state	73.1	65.1	77.1	15.64
2.middle pressure state	74.1	67.1	80.2	15.61
3.mix state	84.2	72.6	78.8	10.48
3.mix state	85.9	73	78.9	10.48
3.mix state	87.2	72.8	79.1	10.45
3.mix state	89.2	73.7	79.2	10.45

Basing on the practical experience in parameters detection of fire engine, we do a pretreatment to the sample data and make out the detection index data according to the results of detection, then give out the corresponding fuzzy rule base which is the training sample of fuzzy neural network.

The detecting data are pretreated in order to lower the complexity of input sample. We decrease the input sample nodes, which makes for improving the training speed of neural network. Aiming at the detecting data of fire engine, basing on the practical experience, we dispose the detecting data into input node sample data according to the following rule:

X1=input axletree temperature(degree)-output axletree temperature(degree)

X2=100-motor water temperature(degree)

X3=vacuum level (KPa)

X4=low pressure(MPa)+middle pressure(MPa)

X5=low pressure flux(L/S)+middle pressure flux(L/S)

X6=rotate speed(r/min)

TABLE 1.DETECTING SAMPLE DATA 2

Working state	Vacuum level (KPa)	Low pressure (MPa)	Middle pressure (MPa)	Low pressure flux (L/S)	speed (r/min)
1.low pressure	28.2	0.019	1.017	30.14	3094
1.low pressure	28.5	0.019	1.016	30.14	3093
1.low pressure	28.6	0.019	1.014	30.01	3090
1.low pressure	28.4	0.018	1.012	30.14	3087
2.middle pressure	15.2	2.028	1.135	0	3163
2.middle pressure	15.1	2.024	1.135	0	3162
2.middle pressure	15.1	2.031	1.134	0	3161
2.middle pressure	14.8	2.029	1.132	0	3159
2.middle pressure	14.7	2.031	1.132	0	3161
3.mix state	30.5	2.044	1.032	20.38	3120
3.mix state	30.3	2.041	1.029	20.38	3121
3.mix state	30.3	2.043	1.029	20.38	3120
3.mix state	30.3	2.045	1.028	20.38	3118

Y1=1.low pressure working state
Y2=2.middle pressure working state
Y3=3.mix pressure working state

TABLE 3 CORRESPONDING RELATIONSHIP BETWEEN PRETREAMENT DATA AND DETECTING RESULT

Working state	X1	X2	X3	X4	X5	X6	**Y1**	**Y2**	**Y3**
1.low pressure state	7	25	28.2	1.03	30.1	3093	1.001	0.001	0.001
2. high pressure state	8.9	24	15.2	3.36	157	3162	0.001	1.001	0.001
3. mix pressure state	15.5	20.9	30.3	3.08	30.9	3120	0.001	0.001	1.001

We adopt BP neural network to study and train the fuzzified training sample set. We ascertain that BP network has three layers: the input layer has six nodes corresponding to night detection indexes; the output layer has three nodes corresponding to three detecting state results; the number of neural cell network in the hidden layer is thirteen by the requirement of network's astringency, simulation speed and precision. The quick BP algorithm is used to train the neural network. We set that the index of training aim error square sum is 0.001, the maximum circle time is 6000, the initial study speed is 0.01 and the momentum constant is 0.95. Because the weight value of fuzzy logic is between 0 and 1, the activation function of each kind of neural cell adopt Log-Sigmoid function which can make the input range mapped from $(-\infty,+\infty)$ to (0,1)so as to contact with fuzzy logic well. The training result of fuzzy neural network is expressed by table 2. We compare not-sample input with sample input, and then make a comparison between detecting result and output result. It can be seen that the fuzzy neural network can complete the fire engine synthesis parameter detection well, the detecting result is exact, the tolerant capability is powerful and it has a certain practicability.

TABLE4 DETECTING RESULT

Working state	**Y1**	**Y2**	**Y3**
1.low pressure working state	1.0001	0.0001	0.0001
2. high pressure working state	0.0001	1.0000	0.0001
3. mix pressure working state	0.0001	0.0001	1.0000

VI. CONCLUSION

The paper builds a new multi sensor data fusion system based on fuzzy neural network, and puts forward the improved BP rule algorithm according to the character of system's structure. The algorithm has good generalization ability and can map nonlinear function well. The fuzzy logic reasoning neural network ascertains the initial rule based on the samples and corrects continually in the network training. Finally we get the predigested rule set with importance degree and reliability. We try to ascertain the initial weight value of the fuzzification layer by golden partition method and decide the initial weight value of clearness layer according to the conclusion of the initial rule. The try has rather good practice sense to multi sensor fusion method in the condition of building uncertain weight value of the membership function.

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