A NEW METHOD IN FIRE DETECTION

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ABSTRACT

The detection of fire in its early age is both complex and significant. In this paper the defect of traditional fire detection is being pointed out. A new method for fire detection, that is Artificial Neural Networks(ANN),is been proposed on the base of analyzing the data of fire experiment. ANN has the capability of learning by itself. Therefor, it can come over the weakness of traditional fire detection techniques. The results of computer simulation also show that ANN is an efficient technique in fire detection.

1. INTRODUCTION

With the increasing fire losses, people come to realize the importance of detecting fire in its initial stage. It is the prerequisite condition for making full use of the method of fire extinguishing, decreasing fire loss, keeping life safety and keeping property undamaged. Therefore research workers all over the world all try to study new techniques to realize early detection of fire accurately and quickly.

Fire is a process of combustion that brings disaster. It becomes harmful when fire loses control and spreads about. Both definition and randomization are qualities of fire. The study of auto fire detection is to detect fire in its early stage on the basis of studying of the rules and principals of how fires generate and develop and inform people of the fire status. This is an ideal objective of fire detection. The technique of fire detection was been carried forward step by step just because of the ideal.

Though traditional techniques of fire detection have the function of fire detection, they generally have the problem of frequent occurrence of false alarms and unreliability.

The main fields of the application of artificial neural networks are signal processing and pattern recognition; knowledge processing engine or expert system; and motion process control. The definition of pattern recognition is to realize the analysis, description, judge and recognition of various objects and phenomena. Hence fire detection in general belongs to pattern recognition. And it is reasonable for us to use the technique of artificial neural networks in fire detection.

The second part of this paper we analyze the weakness of traditional fire detection and the feature of fire detection techniques. Then we suggest the way of artificial neural networks to detect fire in its early stage. The brief introduction of fire detection model of artificial neural network is in the third part of this paper. In the forth part, the computer simulating result is been given. In the end the author gives the conclusion.

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2. Fire Detection and Artificial Neural Networks

Fire status decision is a complex process. In the process input data was received, the information was processed based on the knowledge and experience of the person. Actions were taken to obtain additional information, and finally, decisions were made based on all of the available information.

Historically, computer-based detection systems are much more simplistic. They rely on input data from a single sensor type, and make their decision based on limited information about the input signal. In a smoke detection system, for example, particles are electronically or optically sensed, and when a predetermined signal level is reached, an alarm condition is signaled. This requires only a single input signal and a single decision point. This is one of the main reasons why there is relatively large nuisance alarm problem.

Law of fire is both definite and random. During actual process of fire many factors may change unsteady. The process of fire takes place along with many physical phenomena and chemical reactions. The main products of combustion include H_2, CO_2, H_2O, etc. All these are surrounded by complex environment. Data we measured on the spot often might not show the real status of what we observing. How can we discriminate between products of combustion and non-combustion? How can the products of combustion generate by a fire and products of combustion generated by cigarette smoke be discriminated? In short, not only one kind of data but data that shows many aspects of fire must be taken account for the purpose of detect fire quickly and accurately.

There is possible for an object to catch fire in some environment. If another object made of different material is put in the same environment, it may have no possibility of catching fire. Also, the same objects can have different probability to catch fire. Actual fire limit (such as heat velocity, temperature, smoke density and so on) all change along with space and time. Fire experiments show that fire products and fire phenomena are different for different kind of material. For all the reason above, it is quite difficult for us to detect fire by making some regular mathematics models. It will be much complicated even if it can be done. We must look for another way for solution. This is the way of artificial neural networks.

Artificial neural network (ANN) is a nonlinear dynamic system . It simulates the work pattern of human brain. The models of ANN compose of many neurons that are similar in function and structure. These neurons connect forming a net, and adopt parallel processing algorithm. The networks have the ability of modeling the underlying nonlinear map that generates the time series by producing a high dimensional interpolation surface to the actual map. ANN is a system that has the ability of learning by itself and learning is an adaptive process. It can develop knowledge as to surpass the level of designer. Being trained the characteristics of fire are been stored in the weights between ANN neurons. The system can find characteristics and law of the object to solve the problem of fire modeling. In this paper we applied Multilayer Perceptrons (MLP) in solving the problem. We also adopt B-P algorithm in the Perceptron to train the net.

3. Fire Detection Model and Calculation

The fire detection model is showed in Fig 1

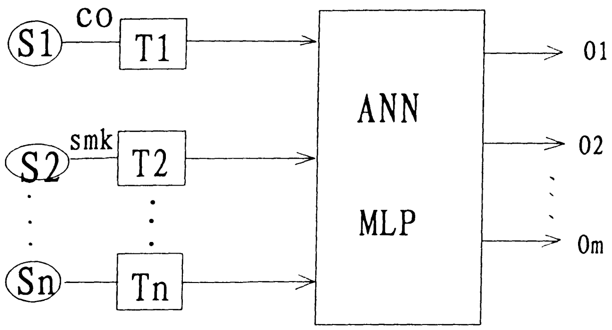

Fig 1 Model of fire detection

The s1,s2,...sn are sensors that detect fire data such as CO, smoke and so on. These are been sent to artificial neural networks MLP after being pretreated. T1, T_2,...Tn are the pretreators. The ANN is being trained by the selected data. After being trained ANN automatically can find law between fire data and fire patterns, and it remembers the law in their weights. The system outputs are O1, O2,... Om.

There are many neural network models that can be adopted in fire detection. We just study the application of multilayer perceptron (MLP) in this paper. Others will be shown in the following papers. MLP forms an error-minimizing mapping between two related spaces on the basis of training data. It consists of several hidden layers of neurons that are capable of performing complex nonlinear mapping between the input and output layer. In general, all neurons in a layer are fully interconnected to neurons in adjacent layers, but there is no connection within a layer. Data information is recorded into the hidden layers and the output is generated by combination operations on the hidden layer.

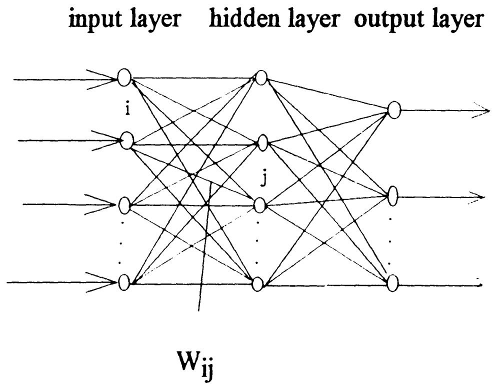

Figure 2. Architecture of MLP

The BP learning algorithm is used to train the network and establish the interconnection weights. The basic element of the multilayer perceptron is the neuron, which is depicted in Figure 2. Each neuron has primarily local connections and is characterized by a set of real weights applied to the previous layer to which it is connected and a real threshold level θ_j.The j^{th} neuron in m^{th} layer accepts inputs $v^{(m-1)} \in R^N$ from $(m-1)^{th}$ layer and returns a scalar $v_j^{(m)} \in R$ which is given by

$$v_j^{(m)} = f_j \left(\sum_i w_{ij}^{(m)} v_i^{(m-1)} + \theta_j \right) \tag{1}$$

The output value $v_j^{(m)}$ serves as input to the $(m+1)^{th}$ layer to which the neuron is connected. The neurons store knowledge or information in the weights, and the weights are modified through experience or training.

The output value is compare with the desired output, resulting in an error signal. The increments used in updating of the weights, Δw_{ij} and threshold levels $\Delta\theta_j$ of the m^{th} layer can be accomplished by the following rules

$$\Delta w_{ij}^{(m)} = \varepsilon d_j^{(m)} v_j^{(m-1)} + \Delta w_{ij}^{(m)} \tag{2}$$

and

$$\Delta \theta_j^{(m)} = \beta \, d_j^{(m)} \tag{3}$$

Where ε is the learning gain; β is the threshold level adaptation gain. The error signals $d^{(m)}$ for layer m is calculated starting from the output layer M

$$d_j^{(M)} = v_j^{(M)} \left(v_j - v_j^{(M)} \right) \left(1 - v_j^{(M)} \right) \tag{4}$$

and recursively back-propagating the error signal to lower layers

$$d_j^{(m)} = v_j^{(m)} \left(1 - v_j^{(m)} \right) \sum_l d_l^{(m+1)} w_{lj}^{(m+1)} \tag{5}$$

And the criterion (reiteration) rule is to make the square mean of error function the smallest.

4. Simulation and Analysis

The experiment data adopted in this paper is from the fire test performed at the Loss Prevention Council building at Fire Research Station in Borehamwood UK according to BS5445 part 9 1986[1]. In the test ,seventy dried beech wood sticks (1cm × 2cm × 25cm) arranged as defined in BS5445 were ignited using 5cm3 of methylate spirits. This initially produces a slow burning fire generating small amounts of visible smoke. Towards the end of the test, the fire becomes more vigorous and larger quantities of smoke are produced. Figure 3(a) shows the values of the standard parameters obtained during the fire, along with the percentage of fuel consumed. In this figure O-W represents original weight, T represents temperature . Smoke density(optical) and smoke density(ionisation) are represented by M and Y ,respectively. In this particular test, the category boundaries we defined by the output from the standard ionization smoke detector, with the class A-B boundary at 6.9min,B-C at 8.8 min, and C-N at 11.2 min . Figure 3(b) shows the concentration of hydrogen, carbon monoxide, oxygen and humidity during the fire.

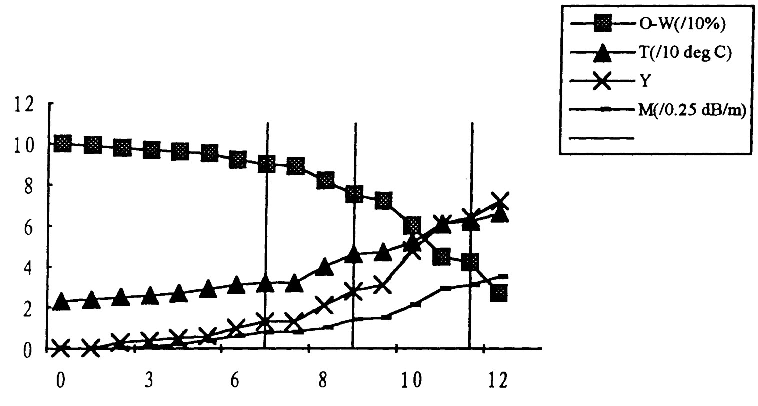

Fig. 3 (a) open cellulosic fire (wood); standard parameters.

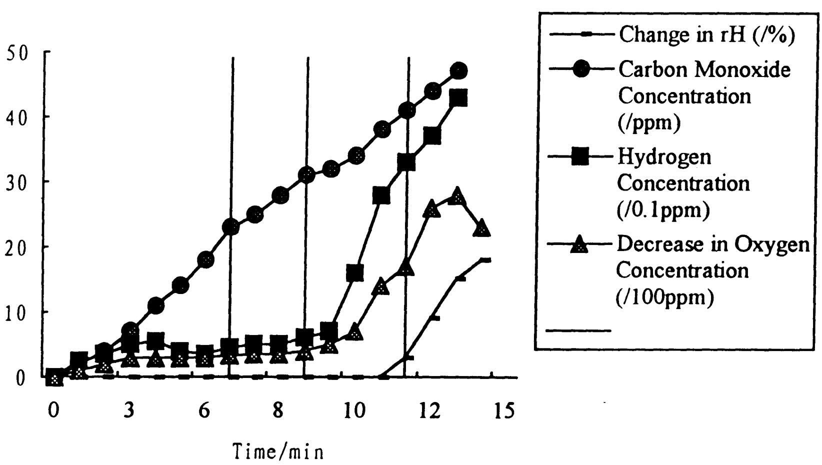

Fig. 3 (b) variation of test gases.

In this simulation test, a three-layer preceptron neuron net is adopted. There are five inputs for the net, each present a kind of sensor data. The output layer has three neurons. The ANN models 'learn' non-linear function mappings from examples. The relationship between input and output data is stored concealing in the net weights. Six groups of data were selected to train the neural net. After being trained the neural net can be used in fire pattern recognition.

The recognition results are shown in table 1. In the table, S presents the results of experiment and M presents the simulating results.

Table 1

T	Smk	CO	H_2	O_2	A-B		B-C		C-N	
					S	M	S	M	S	M
25	0	5.0	0.4	200	0.7	0.8	0.1	0.17	0.1	0.01
31	0.5	17.5	0.4	300	0.9	0.77	0.3	0.22	0.1	0.1
40	1	27.5	0.5	300	0.1	0.1	0.9	0.89	0.1	0.08
42	1.6	30	0.65	400	0.1	0.08	0.5	0.51	0.5	0.51
51	2	34	1.5	800	0.1	0.11	0.1	0.1	0.9	0.88
62	3	40	3.2	1500	0.1	0.1	0.1	0.09	0.5	0.5

From the table we can see that the recognition has a high accuracy when applied with artificial neural net and the effect is satisfying. It shows that artificial neural networks have quality of adaptations and robustness and that this technique has excellent prospects in fire detection. It's a good way to reduce the number of false alarms and determine the status of fire quickly and accurately.

5. Conclusion

In this paper we applied techniques of artificial neural networks in fire detection. Artificial nelural network distributed store knowledge and process it parallels. Thus, the system can not only process information for training but can process new knowledge. The simulation results are satisfying, and show the bright future of ANN technique in the field of fire detection. It is believed that the new techniques will be applied in actual with further study of the technique.

It also can be seen that the system has some limitation in the data for training. Different training data will cause the results with different accuracy. All these should be studied further.

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