Gas Sensing Array Design using ANN and Implementation through MEMS Structure

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ABSTRACT

In present article we delve on the concept of design, development, and implementation of an intelligent system of gas detector for detecting concentration of different gas components like Ammonia (NH_3), Carbon Dioxide (CO_2), Carbon Monoxide (CO), Hydrogen Sulfide (H_2S), Methane (CH_4), and Nitrogen Oxide (NO_x). Present confined space like manhole boilers, pits. For the detection purpose a gas sensor array is used Instead of single sensor here we have implemented a gas sensor array which is used for recognition of multiple gases simultaneously. Detection of multiple gas sensors in the presence of the mixture of multiple toxic gases at those instant results in cross-sensitivity. So we have used specific gas sensor for each gas component in the gas sensor array incorporated with multilayer feed forward neural network trained by back propagation algorithm model of ANN to resolve the multiple gas detection and cross-sensitivity issue quite effectively and finally implemented through MEMS structure.

Keywords: Back propagation, MEMS (Micro-electromechanical systems), Cross-sensitivity, Mean Square Error (MSE).

1. INTRODUCTION

Of late, due to pollution and health hazards, the environmental awareness and precautions are primary concern. House hold garbage and industrial waste are thrown or drained to manhole. After decomposition, toxic gases, sewer gas mainly Ammonia (NH_3), Carbon Dioxide (CO_2), Carbon Monoxide (CO), Hydrogen Sulfide (H_2S), Methane (CH_4), and Nitrogen Oxide (NO_x) are formed in the manhole [1]. At the time of maintenance and cleaning of the drainage, this gases effects adversely on human health and death if they are not dealt with properly. Its health effects can vary depending on the level & repeated exposure can result in health. So, as a manhole is mixture of different gasses the continuous monitoring is required.

The concept of neural network is implemented in the sensory system for detecting the undesirable gasses intelligently. Neural network is built with the sensors and main processing is done in the network to indicate the presence of toxic gases. The key feature of neural network is training or learning, and here it is done through back propagation which is systematic method of training multi-layer artificial neural network. An array of MEMS sensors are used to detect the concentration of those gasses in the manhole and results some sensed values which includes cross sensitivity. When there are no good theories available to make reasonable predictions about cross sensitivity [2], in such situations the Back Prop network provides some answer.

2. CONCEPT OF BACK PROPAGATION

In a back-propagation [3] neural network, the learning process has two main parts. First, a training input pattern is fed to the network input layer. The network propagates the input pattern from layer to layer until the output pattern is generated by the output layer. If the generated pattern defers from the expected output, an error is calculated and then propagated backwards through the network from the output layer to the input layer. The weights are modified as the error is propagated. The figure of three-layer back-propagation neural network [3] is shown here.

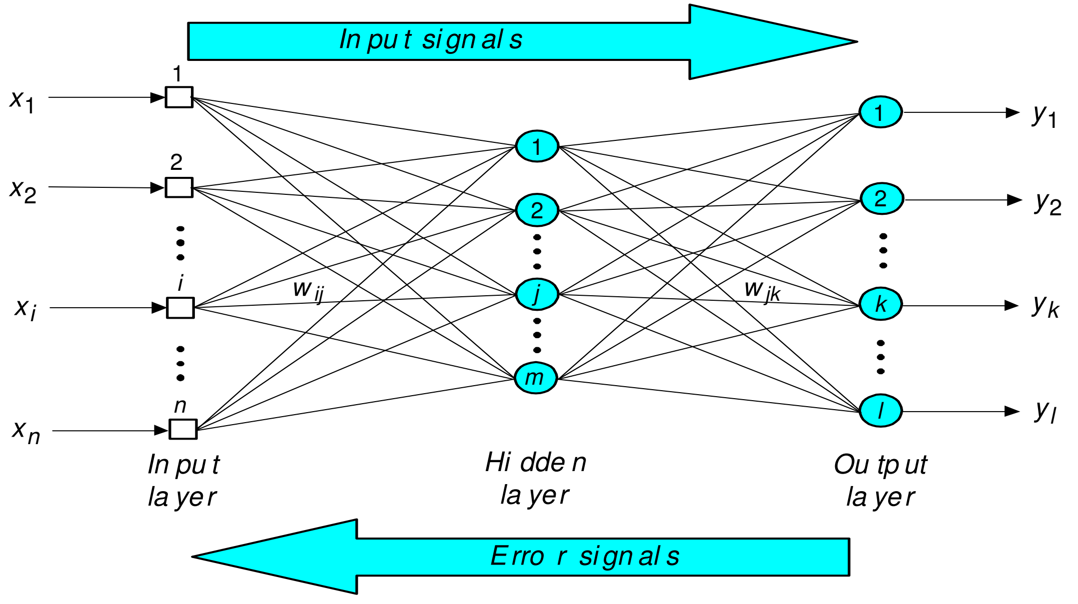


Figure 1: Three-layer back-propagation neural network [3]

3. MEMS

Micro-electromechanical systems (MEMS) are a process technology used to create tiny integrated devices or systems that combine mechanical and electrical components. They are fabricated using integrated circuit (IC) batch processing techniques and can range in size from a few micrometers to millimetres. These devices (or systems) have the ability to sense, control and actuate on the micro scale, and generate effects on the macro scale.[4]

Operation of the overall system

The mems based sensors sense the gases and generates responses and it is fed to the pre-processing block and then applied to the neural network. In neural network training is mainly concerned with back propagation. The training algorithm [5], in which weights are moved to the negative gradient is discussed step wise.

Step 1: The weights and biases are adjusted initialized with small values.

Step 2: One set of input and output are needed for the training.

Step 3: Inputs to the hidden layers are computed by multiplying corresponding weights.

Step 4: Errors are measured from the networks output and target output.

Step 5: To successive errors are compared and weights and biases are iteratively adjusted to minimize the error.

$$W_{k+1} = W_k + \square\, G_k$$

Step 6: For each iteration mse is compared and finally minimum error is obtained after several nos. of iteration.

Neural System

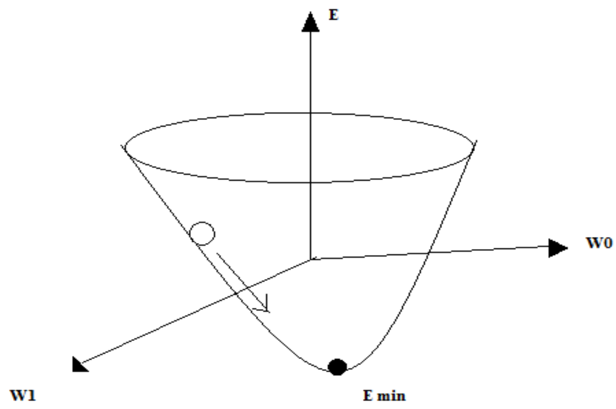
Presently, neural networks using a massively parallel dispersion structure have causes interest because the back-propagation neural network [6]. Accordingly, here also, a Back prop algorithm was employed for gas recognition. Figure 2 shows a block diagram of the designed neural network. Any learning to take place we need stimulation. There are set of stimulations we are taking from the environment. After that we some changes in free parameters according to the stimulations. It takes some iteration and once it is learned it responds to environment in a changed or new way. The response of the sensor array to gases uses the input of the neural network. Sensor array was composited sensors. The variation of the output voltage is represented the variation of resistance when the sensors react to gases.

Error computation

The instantaneous error [7] is calculated for the network at the output layer for a single input pattern.

$$E = \Sigma\ E^p = \tfrac{1}{2}\ \Sigma\ (t^p - y^p)$$

Where, t^p and y^p are the target output and fitted output for the neu ral networks respectively.



In the time of training and measuring performance (i.e MSE vs. Epochs) the MSE is taken as MSE is the most suitable function for minimizing the value of error for an asymptotically large number of different training data patterns [8].

Here for detecting five gasses it is observed during simulation it is observed that at learning rate of all neural networks 0.1 and in the 5-6-5 NN configuration the minimum error is obtained and from the gathered data 75% data were fed for training and 25% for testing. After simulation by using standard software fabrication is also done. It is seen in figure 3 that there are two main parts like heater and electrode. Heater part is used to activate the sensing layer and electrode is used to collect the sensor response.

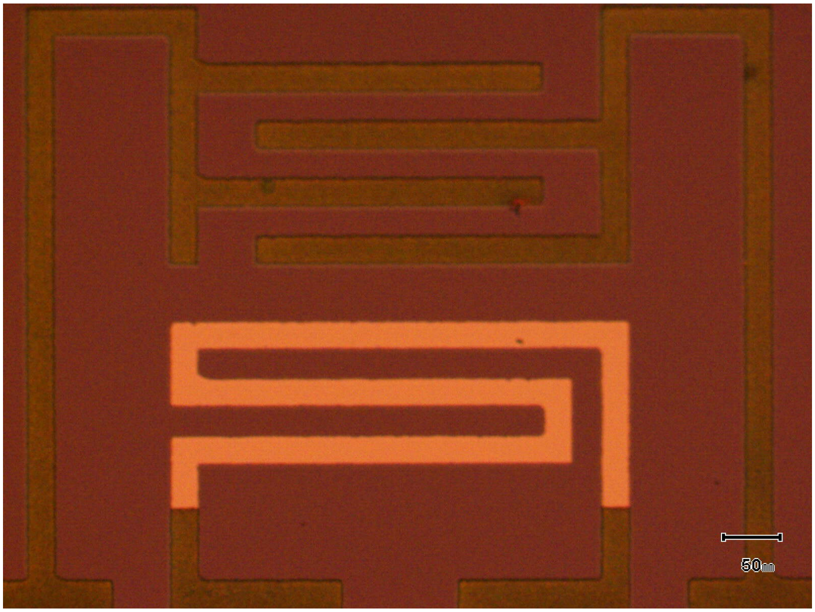


Fig. 3. Fabricated MEMS based gas sensor

4. CONCLUSION

In this study the main part is gas sensor performance. With respect to different toxic gases the parasitic parameter of sensor will change. All the performances are optimized by ANN technique and after that if any type of gas is taken and measure the resistance with respect to particular gas concentration then from the model using ANN it can be identify the types of gas. In this paper the simple gas sensor using MEMS structure is designed and fabricated.

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