Intelligent Air Quality Sensor System with Back Propagation Neural Network in Automobile

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Abstract: The Air Quality Sensor (AQS), located near the fresh air inlet, serves to reduce the amount of pollution entering the vehicle cabin through the HVAC (heating, ventilating, and air conditioning) system by sending a signal to close the fresh air inlet door/ventilation flap when the vehicle enters a high pollution area. One chip sensor module which include above two sensing elements, humidity sensor and bad odor sensor was developed for AQS (air quality sensor) in automobile. With this sensor module, PIC microcontroller was designed with back propagation neural network to reduce detecting error when the motor vehicles pass through the dense fog area. The signal from neural network was modified to control the inlet of automobile and display the result or alarm the situation. One chip microcontroller, Atmega128L (ATmega Ltd., USA) was used. For the control and display. And our developed system can intelligently detect the bad odor when the motor vehicles pass through the polluted air zone such as cattle farm.

Keywords: Air quality sensor, automobile sensor, gas sensor, one chip sensor module

1. INTRODUCTION

Every driver on the road is frequently exposed to unhealthy diesel and gasoline exhaust fumes. Especially in population centers with heavy vehicle traffic, high concentrations of these gases penetrate the vehicle interior through the ventilation system. The air quality sensor (AQS), located near the fresh air inlet, serves to reduce the amount of pollution entering the vehicle cabin through the HVAC (heating, ventilating, and air conditioning) system by sending a signal to close the fresh air inlet door/ventilation flap when the vehicle enters a high pollution area. By performing this function, the air quality sensor provides a key health benefit to drivers and occupants of motor vehicles. The AQS single sensor element was fabricated using normally thick-film technology and consisting of SnO2 and some additives coating on a ceramic substrate. The use of a single sensor element to detect the pollutants of interest enhances the sensor's cost effectiveness. In the presence of reducible gases, the resistance of the sensor element increases, starting from a medium range. When detecting oxidizable gases, the resistance is decreased with respect to the sensor element's resistance range in unpolluted air. Normally AQS sensor was composed of two sensing elements for reducible gas and oxidizable gas separately for effectiveness of different sensing gases.

In our study, we developed one chip sensor module which include above two sensing elements, humidity sensor and bad odor sensor. With this sensor module, PIC microcontroller was designed with back propagation neural network to reduce detecting error when the motor vehicles pass through the dense fog area. And our developed system can intelligently detect the bad odor when the motor vehicles pass through the polluted air zone such as cattle farm.

2. INTELLIGENT AQS SYSTEM

2.1 Intelligent AQS system architecture

Typical AQS system in automobile is an integrated system consisting of a sensor element, signal processing by a microprocessor and an interface. The AQS identifies reducible gases (nitrogen oxides NOx) and oxidizable gases (carbon monoxide/gasoline/benzene), which occur in road traffic and are harmful to health. Normal sensor element is dual sensor which is mainly composed of SnO2 and some other additives. One sensing layer of the dual sensor is for reducible gases such as NOx and SOx, and the other sensing layer of that is for oxidizable gases such as CO and other hydrocarbon gases. In addition these sensing layers, a bad odor sensing element, a temperature sensing element and a humidity sensor were added to detect the bad odor also and eliminate the misjudgment by humidity effect. And voice alarm function was added to the LCD monitoring that alarms ‘the passage of tunnel’ or ‘the passage of bad odor area such as cattle farm. Figure 1 shoes typical AQS system in a automobile.

Fig. 1 Typical air quality sensor system in automobile

The AQS sensors the unhealthy gases directly, before they enter the cabin. The AQS quickly closes the fresh air inlet door whenever the vehicle enters a cloud of pollution that means the ‘Fresh mode’ changes to ‘Recirculation mode’ in cabin automatically. In the event of potentially harmful gas peaks in the outside air, it is necessary to activate the recirculation function immediately to activate the recirculation function immediately to achieve the best possible air quality in the car’s interior and optimize passenger health and comfort. The AQS triggers the vehicle’s electronic climate control unit to close the fresh air inlet door allows for automatic closure and opening of the fresh air inlet door, thereby more
comfortably and reliably reducing the levels of harmful gases in the cabin.

3. GAS SENSING PROPERTIES OF THE USED GAS SENSORS

In this AQS system, three commercially available sensor elements were used. A TGS2201 dual sensor (Figaro Gas Sensor Ltd., Japan) which have a reducible gas sensing layer and an oxidizable gas sensing layer on the both sides of same substrate. And a temperature sensor and a humidity sensor were mounted on the sensor module for our AQS system to compensate temperature and humidity effect to SnO\textsubscript{2} based dual sensing elements of TGS2201.

3.1 Gas sensing effects by temperature and humidity

![Fig.2 measuring circuit for gas sensor, temperature sensor and humidity sensor, separately.](image)

Figure 2 shows the measuring circuit for dual type gas sensor, temperature sensor and humidity sensor, separately.

For the AQS system test, firstly the gas sensing properties of dual sensor were surveyed. To simplify the humidity effect and reduce some complicated parameters, humidity was defined as two categories, that is, higher than 70% and lower than 70%. Figure 3 shows the gas sensing properties of dual type gas sensor to CO, CH\textsubscript{4} and NO at 30 °C in both humidity areas.

3.2 Gas sensing parameter extraction from gas sensor, temperature sensor and humidity sensor

![Fig.3 Responses of gas sensor to CO, CH\textsubscript{4} and NO with different humidity level.](image)

Fig. 3 Responses of gas sensor to CO, CH\textsubscript{4} and NO with different humidity level.

4. NEURON NETWORK FOR INTELLIGENT DECISION

4.1 Error back-propagation

The key features of AQS include dynamic adaptation to various driving environments such as city, rural, traffic jams, tunnels and humid weather. The sensor’s sensitivity should be controlled by software to continuously adapt to ambient pollution levels. The AQS’s software structure allows the microcontroller to use different parameter settings based on the driving environment. During vehicle operation, the AQS adapts to the environment and uses algorithms to provide optimized performance for particular driving situations. An error back propagation neural network was used to reduce the malfunction of the gas sensor by environmental parameters such as humidity, temperature and bad odor.

Figure 4 shows 3 layers architecture of back propagation neural network. This network was composed of input layer to accept input signal form each sensors, hidden layer to enhance the performance of learning effect and output layer to discriminate the gas kinds. The statistic and the neural network techniques are usually used for gas pattern recognition. Recently back propagation neural network algorithm having nonlinear discriminating ability appeared as a powerful recognizer in the pattern recognition using parallel distribution process.

![Fig. 4 a schematic diagrams of 3 layer error back-propagation Neural network.](image)

Neuron network with biology remember by experience or knowledge leaning new information with weight value on synapse. In this paper, Error back-propagation algorithm is used.

4.2 Gas sensing effects by temperature and humidity

In this study, 4 sensors were used as a input of the neural network. The nodes in input layer and output layer are already determined by the number of sensors and results to be determined, respectively. Learning rate, which affects learning speed and accuracy, are set properly in a range of 0.1–0.5 in
this study. Figure 5 shows the neural network architecture of this study. The gas sensor signal was converted to digital signal through A/D converter, and the digital signal introduced in input layer. Using the synaptic weights learned by the back-propagation neural network and input signals, the objective output node in output layer is selected and the determination is displayed on the LCD or a monitor.

Firstly, synaptic weight was investigated by the computer simulation using the extracted parameters of Fig. 3. The synaptic weights are listed following the error rate in shown in Fig. 6.

![Fig. 5. Neural network architecture for intelligent AQS system](image)

**Fig. 5. Neural network architecture for intelligent AQS system**

<table>
<thead>
<tr>
<th>Error Range</th>
<th>1 Layer Weight Update Value</th>
<th>1 Layer Weight Update Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.40069701</td>
<td>+2.398 0.448 3.718 8.877</td>
<td>+2.398 0.448 3.718 8.877</td>
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<tr>
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<td>+4.659 0.516 3.207 1.374</td>
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<td>-2.398 0.448 3.718 8.877</td>
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<tr>
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<td>-2.465 0.816 0.016 8.816</td>
<td>-2.465 0.816 0.016 8.816</td>
</tr>
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**Fig. 6. Synaptic weight value for minimum Error range**

**5. INTELLIGENT AQS CONTROLLER BOARD**

The signal from neural network was modified to control the inlet of automobile and display the result or alarm the situation.

![Fig. 7 Block diagram of AQS Controller board](image)

**Fig. 7 Block diagram of AQS Controller board.**

One chip microcontroller, ATMega128L (ATmega Ltd., USA) was used for the control and display.

In our study, automatic and manual buttons was designed for the driver can choose the manual opening the air inlet or automatically opening by the signal from AQS. Figure 8 shows the designed intelligent AQS microcontroller PCB layout and the photograph of fabricated intelligent AQS main board. The microcontroller alarm using recorded human voice and displayed the opening or closing status of the air inlets. The voice recordable chip (ISDI420, Voice chip Co.) was used for this system.

Figure 9 shows test apparatus for AQS controller and heat unit.

![Fig. 8 Intelligent AQS microcontroller board. (a) Intelligent AQS main board layout (b) Photograph of fabricated microcontroller board.](image)

**Fig. 8 Intelligent AQS microcontroller board.**

(a) Intelligent AQS main board layout

(b) Photograph of fabricated microcontroller board.

![Fig. 9 Test apparatus for AQS controller and heat unit.](image)

**Fig. 9 Test apparatus for AQS controller and heat unit.**
6. CONCLUSIONS

One chip sensor module which include above two sensing elements, humidity sensor and bad odor sensor was developed for AQS (air quality sensor) in automobile. With this sensor module, PIC microcontroller was designed with back propagation neural network to reduce detecting error when the motor vehicles pass through the dense fog area. Using the sensitivity signals from a sensor array as multi-dimensional input patterns, a gas pattern recognizer using a multi-layer neural network with an error-back-propagation learning algorithm was then implemented. And our developed system can intelligently detect the bad odor when the motor vehicles pass through the polluted air zone such as cattle farm.

REFERENCES


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