A Design of an Adaptive Active Noise Control System in Driver's Cab

Lifei JIANG
Tangshan Teacher's College, Tangshan city Heibei province China
E-mail: jianglifei1977@163.com

Abstract: Based on the analysis of the characteristics of practical noises in a driver's cab, and aiming at the real time signal processing requirements, the high speed digital signal processor is used in the active noise control system. And combined with the nonlinear characteristics of the noise, an adaptive active noise control project based on the radial basis function neural network is proposed, at the same time a filter algorithm is given. The result proves the proposed adaptive active noise control system to be feasible and effective.

Keywords: adaptive active noise control; the high speed digital signal processor; the radial basis function neural network

1 Introduction

With the people's growing awareness of the environmental protection, vehicle noise has become an important vehicle performance. In China's automobile industry development plan, it has been taken into account as one of the major problems to improve vehicle's ride comfort.

Interior noise comes from engine noise, intaking and exhausting gas noise, and chassis noise. These noises pass into the driver's cab through the air and the structure. Among of them 800 Hz or more higher-frequency noise passes through the air, while the 400 Hz or the lower-frequency noise passes through the structure. Experimental studies have shown that a closed vehicle compartment play a larger role to the external noise, so the noise through the air passing has little effect in the driver's cab. Therefore, the lower-frequency noise is primary in the enclosed driver's cab, and its power spectrum shown in Figure 1.

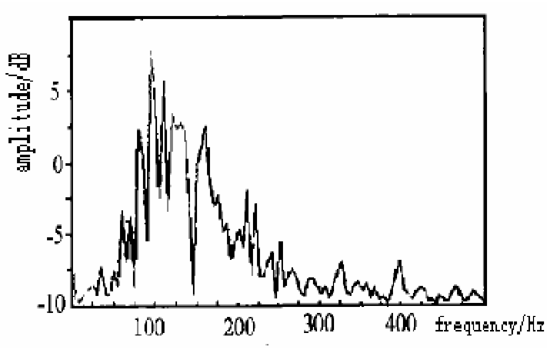

Figure 1. The noise power spectrum in driver's cab.

The traditional noise control methods are passive methods, such as changing the device structure, adding sound absorption or sound insulation materials, and which has good effect of noise cancelling on the high frequency noise, but the effect on the low frequency noise is not satisfactory. The method of active noise control has good results with low frequency noise. Besides this, the characteristics of the sound field with many complex factors are easy to change, which requires noise cancelling system must have a strong tracking capabilities.

To achieve a stable and good noise reduction effect this paper proposed an adaptive active noise control system based on the high speed digital signal processor (DSP) and the radial basis function neural network (RBF) to carry out self-adjusting.

2 The principle of active noise control[1]

Active noise control is based on the theory of elimination and interference or inhibition of two sound wave, by artificially generating a controlling sound source (secondary source), which brings the sound wave equal to the amplitude and opposite to the phase of the original noise source (primary source). When the two sound waves affect each other, the purpose of noise reduction is achieved. Based on this principle a noise reduction model is proposed the diagram shown in Figure 2.

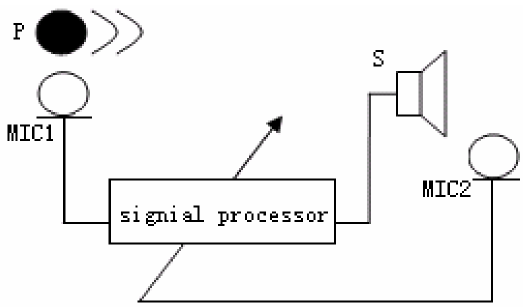

Figure 2. A general model of active noise control

In the model P is the primary sound source, MIC1 as a noise sensor collects the information of the object P, and S is the speaker and the secondary sound source, MIC2 as the error sensors collects the error information. The signal processor, according to the value of the noise and error signals adjusts the control speaker S (secondary source), then a much sound attenuation in a certain region of space is gained.

3 The hardware design of Active Noise control system

Design this system and its hardware block diagram shown in Figure 3.

The sensors MIC1 and MIC2 in Figure 2 pick up the noise signal and error signal, which are amplified by the pre-amplifier and then are transmitted to the anti-folded filter .After these they are converted into digital signals by A/D converter and then directly into the DSP and the host. The controller analysises the datas and then output a control signal. The control signal is converted to analog signal by D/A converter and then passed to the smoothing filter and power amplifier. The amplified signal then drives the speaker S in Figure 2 which superposited with the noise signal to complete the active noise control process.

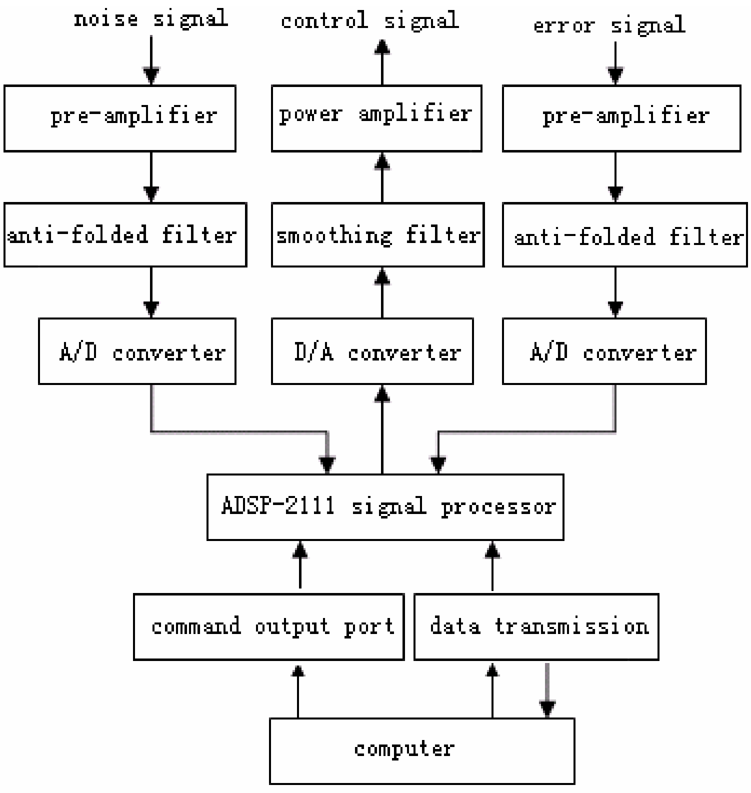

Figure 3. A block of the hardware of the active noise control

In the system the digital signal processor is AD's 16-bit fixed-point ADSP-2111 chip.The chip use the Harvard architecture, and has six buses (one program bus, two data buses, two address buses and one DMA bus). This separated program bus and data bus allows to obtain instruction word (from the program memory) and operands (from the data memory) at the same time with no interfering with each other.Therefore it is much faster than the common microcontroller, which is very fit for the real-time noise control [2].

4 The model of the adaptive active noise control based on RBF network

Now the design of the adaptive controller is more based on linear control theory, but the sound system more manifests the nonlinear features and so the nonlinear controller research is necessary. In the following an adaptive active noise control system based on RBF network is to be given.

4.1 The structure of the RBF neural network [6]

RBF network is a single hidden layer feedforward network based on the knowledge of local regulation and overlap acceptance of bio-regions .The network structure shown in Figure 4.

The input layer nodes only pass the input signal to the hidden layer. The hidden layer nodes work as the Gaussian function and the output layer nodes are usually a simple linear function. It is a fully connected network, and it is of simple structure, fast training and can approximate any nonlinear function, so it has been widely used.

4.2 The model of the active noise control based on RBF network

Block diagram for the model of the active noise control based on RBF network see Figure 5.

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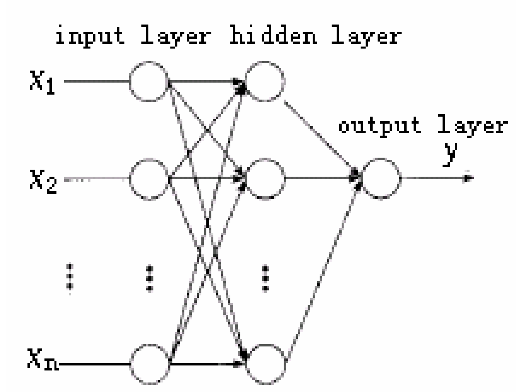

Figure 4. The mode of RBF network

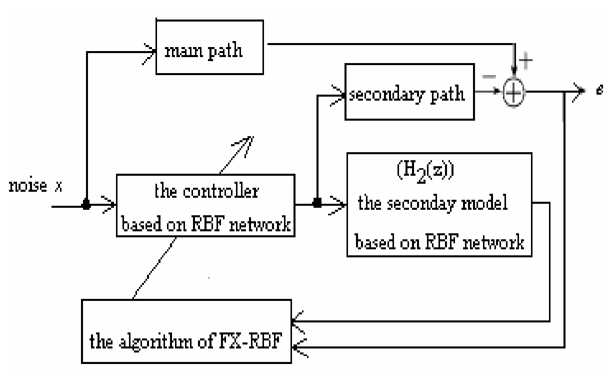

Figure 5. The model of the active noise control based on RBF network

The active noise control (ANC) system consists of the main path and the secondary path. Take the measured signal from noise resource as the main path input and at the same time deliver it to the controller. After the delay the self-adapting controller's output will get superposition with the main path output, then the error signal e is gained. According to making it approaching zero, self-adapting controller adjust its weights to gain the active noise control.

4.3 The training algorithm of RBF neural network

To realize the self-adapting active noise control, the transfer function $H_2(z)$ of the secondary path is needed. The off-line training method is taken when training the model of $H_2(z)$. For the more details, please see [3].

Besides the secondary path, the other model is the controller model, which is the core of the adaptive active noise control. The controller model see figure 6. *x(n)* is the input noise signal, *Xo(n)* is the controller output and z^{-1} is the delay links.

The control signal will directly decide the effectiveness of the noise cancelling. Because the noise feature is always changing, and the isolated output and input data can't have a real reflection of the object's feature, so we need to train the model on-line and get the variable structure based on RBF neural network.

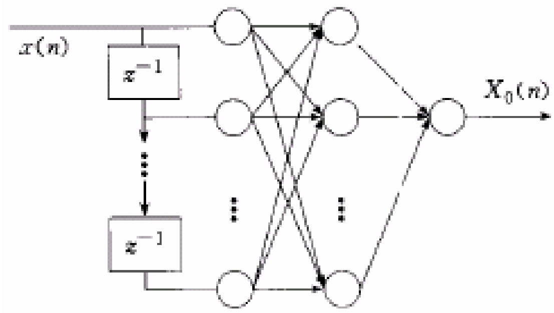

Figure 6. The controller of the active noise control based on RBF network

In the training the variable structure controller based on RBF neural network need amend three parameters: the radial basis function center, width, and the linear output layer weights. Aiming at intuitive adjustment the width of RBF, the width value δ is 0.08326, for more detail information, please see [4]. The vector

$$X(n) = \{x(n), x(n-1), ..., x(n-k+1)\}$$

is k rank input signal, the vector C_J (k dimension) ($J = 1,2,...,L_1$) is the radial basis function center, The vector $W = \{w_1, w_2, ...w_{L1}\}$ is the output layer weighs. The value d_{bar} is the threshold value of the input samples, and the value e_{bar} is the threshold value of the system error. The controller's training algorithm as follows[6], (training the RBF network which include one neuron in the hidden layer, $L_1 = 1$)

Step 1, calculate the interval between the input vector $X(n)$ and the radial basis function center C_J $d_{\min}(n) = \min\{\| X(n) - C_J(n-1) \|\}$ ($1 \le J \le L_1$), if $d_{\min}(n) < d_{bar}$, take the $d_{\min}(n)$ value's neuron as the winning neuron, then go to step 2. If $d_{\min}(n) = d_{bar}$ and the system error $e \ge e_{bar}$, the trained network should include one new neuron in the hidden layer. Its initialization is:

$L_1 = L_1 + 1, C_{L1}(n) = X(n)$, $w_{L1}(n) = e(n)$, then go to step 3. If $d_{\min}(n) \ge d_{bar}$ and the system error $e < e_{bar}$, the system error e can be compensated by other neurons in neural network, and it is not necessary to include a new neuron, and directly go to step 3.

Step 2, amend the winning neuron $C_{win}(n) = C_{win}(n-1) + \alpha(n)[X(n) - C_{win}(n-1)]$, ($\alpha(n)$ is a decreasing function, and the initialized value approaches to one, then trends to zero).

Step 3, calculate the output of the controller, $X_0(n) = W(n) X_1(n)$, then it drive the secondary speaker. At the same time amend the linear output weight W.

$$W(n) = W(n-1) + \beta H_2(n) X_1(n) e$$

($X_1(n)$ is the controller's output vector of the hidden layer, $0 \le \beta \le 1$), then go to step 1 until satisfy the control request.

5 The simulation on the system [5]

In order to compare the FX-RBF algorithm based on the RBF network and the linear FX-RBF algorithm, the simulation test the noise from 100Hz to 500Hz, the effect of noise cancelling shown in Figure 7. The results showed that the average effect of canceling noise is about 30 dB in the controlling based on RBF networks, however the max of the noise cancelling is not up to 30 dB in the linear controlling, or it is bad in some frequency.

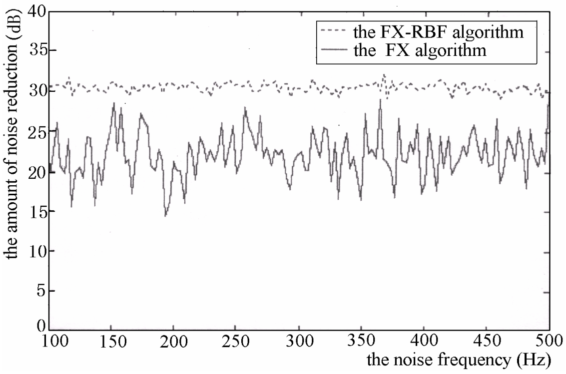

Figure 7. The simulation of the active noise control based on RBF network

6 Conclusions

Based on the analysis of the characteristics of practical noises in a driver's cab, and aiming at the real time signal processing requirements, the adaptive active noise control system based on the high speed digital signal processor and the radial basis function neural network is feasible and effective, and the result of simulation is good.

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