inter•noise 96
25th Anniversary Congress – Liverpool

INCE: 38.2

A MULTI-CHANNEL FUZZY LMS ALGORITHM FOR ACTIVE NOISE CONTROL

H-D Nam (1), K-T Kim (1) & W-S Cheung (2)

(1) Department of Electrical Engineering, Dankook University, Yongsan-gu, Seoul, 140-714, Korea,
(2) Acoustics and Vibration Laboratory, KRISS, Taejon, Korea

1. INTRODUCTION

An active noise control(ANC) technique generally works better than a passive noise control technique at low frequency[1]. In practical situations, the characteristics of the system to be controlled as well as the primary noise characteristics can change with time. In this case, an algorithm with simultaneously performs identification of the secondary path response and control of the primary disturbance must be used[2].

In this paper, active noise control in an enclosure using multi-channel fuzzy LMS(MCFLMS) algorithm is considered.

A new model[3] which has common acoustical poles that correspond to resonance properties of an enclosure, is used to reduce the computational complexity of an active noise control system. A MCFLMS algorithm, where the convergence coefficients of a multi-channel LMS(MCLMS) algorithm is derived using a fuzzy inference engine, is proposed.

Computer simulations and experiments were performed to show the effectiveness of the proposed algorithm in an experimental enclosure.

2. MODELING OF THE SECONDARY PATHS

The secondary paths can be modelled using an all zero model or a pole/zero model. But both models should be remodelled when the positions of control loudspeakers and/or microphones are changed.

In this paper, the common acoustical poles and zero(CAPZ) model[4] is used to reduce the number of model parameters. The background of this model is that the acoustic poles of the secondary path transfer functions are physically common and unchanged even when the positions of loudspeakers and/or microphones are changed.

With the CAPZ model, common acoustic poles can be estimated by least squares method and MA parameters can be estimated recursively using the LMS algorithm.

3. MULTICHANNEL FUZZY LMS ALGORITHM

Consider A multi-channel active control system which has multiple microphones and loudspeakers. The convergence parameter is updated by eq.(1) and μ_N is determined by the fuzzy rule which utilizes an adaptation degree of control filter, ρ_N which is defined by the inverse of the normalized error and the change of adaptation degree, $c\rho_N$.

$$\mu(k) = \frac{2\mu_N}{(L+1)\|x_k\|^2} \quad (0 < \mu_N \le 1) \tag{1}$$

where L is an order of a control filter and x_k is noise signal.

The membership functions of linguistic variables ρ_N^l, $c\rho_N^l$ and μ_N^l for ρ_N, $c\rho_N$ and μ_N are shown in figures 1 and 2.

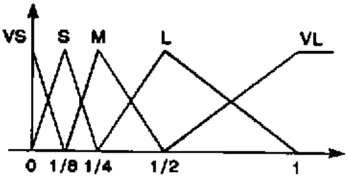

Fig. 1. Membership fn. of ρ_N^l, $c\rho_N^l$

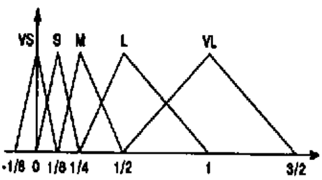

Fig. 2. Membership fn. of μ_N^l

ρ_N^l, $c\rho_N^l$ and μ_N^l for μ_N are partitioned into 5 fuzzy subsets, which are Very Small(VS), Small(S), Medium(M), Large(L) and Very Large(VL), and the fuzzy control rule is shown in table 1.

Table 1. Fuzzy control rule for μ_N^l

		$c\rho_N^l$				
		VS	S	M	L	VL
ρ_N^l	VS	VL	VL	VL	VL	VL
	S	VL	VL	VL	VL	L
	M	VL	VL	VL	L	M
	L	VL	VL	L	M	S
	VL	VL	L	M	S	VS

One example of the rules is as follows.

$R_{2,3}$: IF ρ^{l}_{N} is Small and $c\rho^{l}_{N}$ is Medium THEN μ^{l}_{N} is Very Large

From the rule base in table 1, the inference engine produces fuzzy values of μ^{l}_{N}, and then crisp numerical values of μ_N can be obtained via the defuzzification procedure. The center of gravity (COG) method[5] is used for defuzzification.

4. COMPUTER SIMULATIONS AND EXPERIMENTS

Computer simulations and experiments of a multi-channel active noise control system in an experimental enclosure with 2 louder-speakers and 4 microphones, as shown in figure 3, have been performed to investigate the effectiveness of the proposed algorithm.

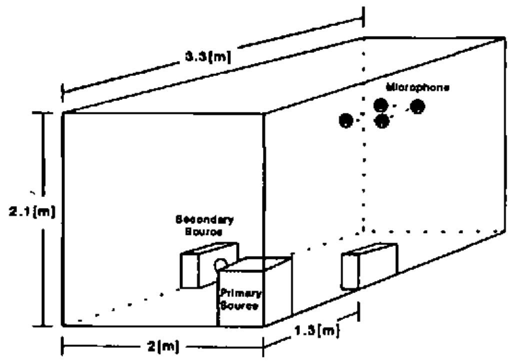

Fig. 3. Experimental enclosure

The conditions in which computer simulations and experiments have been done are as follows.

- Secondary path model: 16 common poles and 12 zeros
- Sampling frequency: 2 [KHz]
- Control filter: FIR filters with 64 parameters
- Adaptive filter algorithms: MCLMS and MCFLMS
- Fuzzy inference engine: Look-up table with 10 quantization levels used
- DSP processor for experiments: TMS320C31 with 40 [MHz] clock
- Data acquisition: 8 channel 16 bit A/D and 4 channel 16 bit D/A converters

- Noise source: 100 [Hz] narrow band noise

The experimental results(controlled errors in Mic.1) are shown in figures 4 and 5, which show the proposed MCFLMS algorithm has better convergence property than a conventional MCLMS algorithm.

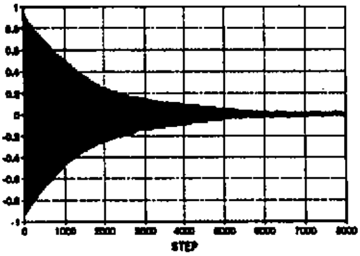

Fig.4. Controlled noise(MCLMS)

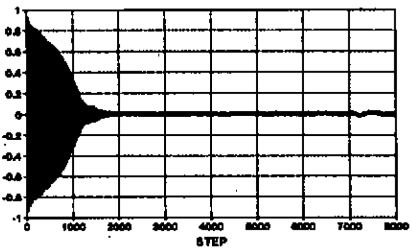

Fig.5. Controlled noise(MCFLMS)

5. CONCLUSIONS

A multi-channel fuzzy LMS algorithm is presented and is applied to active noise control(ANC) in an enclosure.

A Common acoustical pole and zero modeling technique is used to model the secondary path transfer functions to reduce the computational complexity of an active noise control system.

As shown in the results of computer simulations and experiments, the proposed MCFLMS shows better convergence property than conventional MCLMS algorithms. And this algorithm does not require pre-adjustment of convergence parameters, so it could be easily applied to practical ANC systems.

REFERENCES

[1] M. O. Tokhi and R. R. Leitch, Active Noise Control (Oxford Univ. Press, New York, 1992).
[2] H.D. Nam and S.J. Elliott, Mechanical Systems and Signal Processing, 9(5), 555 (1995).
[3] Y. Haneda, S. Makino and Y. Kaneda, IEEE Trans. Speech and Audio Proc., 2(2), 320 (1994).
[4] S. J. Elliott, I. M. Stothers and P. A. Nelson, IEEE Trans. ASSP, ASSP-35(1), 1423 (1987).
[5] W. Pedrycz, Fuzzy Control and Fuzzy Systems (RSP, England, 1989).