GENETIC ALGORITHM FOR ACTIVE NOISE CONTROL

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ABSTRACT

This paper presents a genetic algorithm for an active noise control (ANC) system. The acoustic noise in aircraft cabins is not only harmful to the human ear but also will impede oral communication in such environments. The methods for suppressing acoustic noise using passive sound absorbers are effective for high frequency noise. However, at low frequencies it is not so as the acoustic wavelengths become large compared to the thickness of a typical acoustic absorber. For these reasons, a number of practically important acoustic noise problems are dominated by low frequency contributions. Hence generally these problems cannot be solved using passive methods as they are very expensive in terms of weight and bulk. This has necessitated the exploration of alternative methods of noise control. Active Noise Control (ANC) is one such alternative.
The conventional ANC system often implements the filtered-x least mean square (FXLMS) algorithm to update the coefficients of FIR filters because of its simplicity but it requires identifying secondary path which increases the computational complexity while implementing multichannel ANC system and also it converges to local minima. In this paper, the FXLMS algorithm is replaced with genetic algorithm because it does not require identifying secondary path for ANC system and also it prevents local minima problem.

I. INTRODUCTION

To cancel out the noise in a system, active noise control is used. It generates an anti-noise signal with the same magnitude and opposite phase shift to the undesired noise to disrupt it. ANC systems are generally efficient in reducing low frequency noise. The conventional ANC system uses FXLMS algorithm because of its simplicity. Despite of its effectiveness in attenuating low-frequency noise, FXLMS has several limitations. FXLMS algorithm requires identifying secondary path before adaptation and it may converge to local minima during the adaptive process. To overcome such limitations, a genetic algorithm is used in this paper.

Genetic algorithm may be applied to active noise control (ANC) systems in two quite different ways. First, it may be used to adapt the weights of the digital filters which generate the signals to drive the control sources that cancel the noise. Second, it may be used to optimise the locations of the control sources. In this paper, the genetic algorithm is used to adapt the weights of the FIR filter.

The rest of the paper is organized as follows. Section-II introduces a conventional ANC system. Section-III describes the genetic algorithm (GA) based ANC system, along with the description of how to update the coefficients of the filter using GA. Simulation results are finally given in Section-IV, along with recommendations for future research.

II. CONVENTIONAL ANC SYSTEM

The conventional ANC system often implements the filtered-x least mean square (FXLMS) algorithm to update the coefficients of FIR filters because of its simplicity. Assume that $x(n)$ denotes the unwanted noise interference, $d(n)$ denotes the measured noise by the microphone, $y(n)$ denotes the output signal of ANC and presents the output of the speaker to cancel the undesired noise. Additionally, *P(z)* refers to the primary path and $S(z)$ refers to the secondary path,which runs from speaker to the microphone. The ANC,which is an FIR filter, is denoted as $W(z)$.The FXLMS algorithm is used to update the coefficients of ANC for cancelling out the undesired noise.

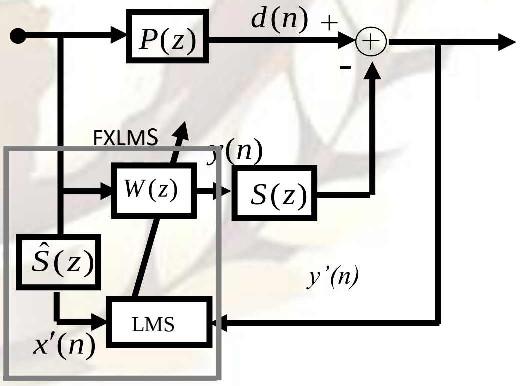


Fig.1: ANC using FXLMS algorithm

III.GENETIC ALGORITHM BASED ANC SYSTEM

The genetic algorithms are based on genetic mechanisms of natural selection as in biological evolution. The evolution of GA from generation to the next generation involves fitness evaluation, selection, crossover, mutation and reproduction. Here in the GA based ANC, the FXLMS algorithm is replaced with the genetic algorithm to update the coefficients of ANC for cancelling out the undesired noise.

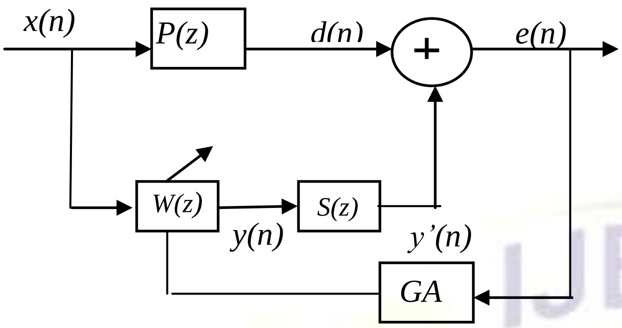
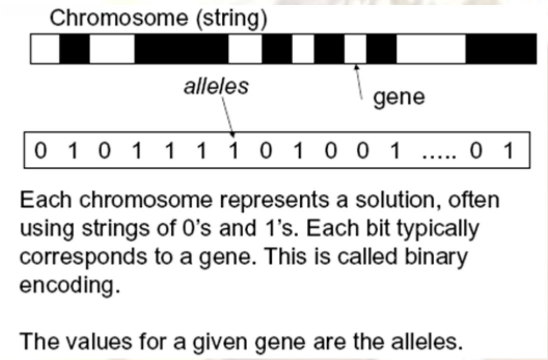


Fig.2: GA based ANC

The block diagram of genetic algorithm based ANC is as shown in figure2. The generations of the basic genetic algorithm will be explained below.



The operation of crossover and mutation is as shown below figures3 & 4.

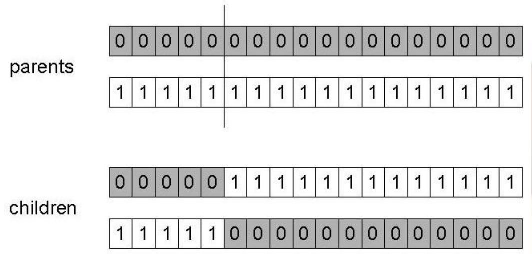


Fig.3: Crossover operation

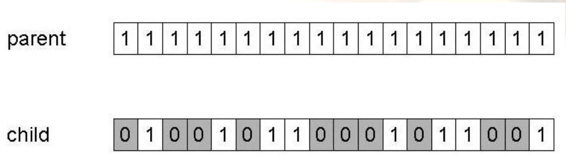


Fig.4: Mutation operation

First, the current population is evaluated using the fitness evaluation function and then ranked based on their fitness values. Second, GA selects "parents" from the current population using Roulette Wheel Selection based on their fitness values. Third, the GA reproduces "children" from selected "parents" using crossover and mutation operations. This cycle of evaluation, selection, and reproduction is terminated when either an acceptable solution is obtained or required number of generations is reached.

The genetic algorithm based ANC system consists of following stepsand also the flowchart isas shown in figure5:

Step1:*Set the parameters*. The population size is set to *p*, and the order of the FIR filters is
L-1.

Step2:*Undertake the filtering of noise*. In the FIR filter, *p* groups of the anti-noise signal yj(n) can be generated after decoding the *p* groups of population into real coefficients Wj(n)=[wj(0,n),wj(1,n),,wj(L-1,n)],j=1,…*p*

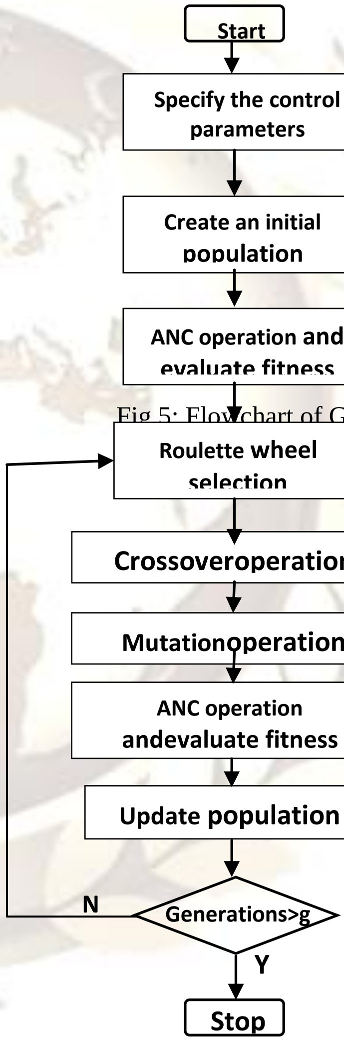


Fig.5: Flowchart of GA

Step3:*Perform the fitness function.*The residual noise function is given as

$$e_j(n) = d(n) - y_j'(n), \qquad j = 1,..,p$$

and

$$O(n) = \max\left(e_j(n), e_j(n-1) \ldots.., e_j(n-L+1)\right)$$

The residual noise of the ANC system can be minimized by defining the fitness functions of *p* populations as

$$f_j = \frac{1}{O_j}, \qquad j = 1, \dots, p.$$

Thus, the performance of each individual in *p* populations can be evaluated using the fitness function.

Step4:*Reproduce the population.*Using roulette wheel selection involves the following procedures.

- Normalized fitness functions Rj, j=1,2,..*p,* are estimated
  The accumulated of normalized fitness functions should be obviously be 1

$$\sum_{j=1}^{p} Rj = 1, \qquad j = 1, \dots . p.$$

- The *p* random number r_j, j=1,….,*p*, is generated between 0 and 1.
- The selected individual is determined by random number r_j, $0 \le r_j \le 1$, j=1,…,*p*.

If the selected number r_1 is smaller than R_1 ($r_1 < R_1$), then the individual W_1 is produced, if the number r_2 satisfies $R_1 < r_2 < R_1 + R_2$, then the individual W_2 is reproduced. Thus the new populations after reproduction procedures are obtained.

Step5: *Perform crossover operations.*Thecrossover operations are normally divided into two classes: "one-point" and "two-point" type crossovers. The "two-point" type crossover is used in this paper. The two crossover points are randomly generated for two chromosomes, and then, the contents of two points are swapped to form the offspring. The crossover rate is important in genetic algorithm.

Step6:*Implement the mutation operation:* This step presents the mutation processing in GA. The mutation rate is also an important factor in genetic algorithm. The inverting mutation operation is used in this paper.

Step7: *Conduct new population:* After the new population is generated, the new chromosomes that new chromosomes that represent the *p* group of the new filter coefficients.

Step8:*Perform filtering operations***:** After the new coefficients of the filter are used, the following signal is obtained for the FIR filter:

Step9: *Perform the new fitness function:* After *p* populations of anti-noise signal $y'_{newj}(n)$, j=1,..*p*, are generated, the new fitness function is evaluated to decide the optimum one, similar to that in step3.

Step10:*Perform replacement operations:* The population of the GA is updated by applying the generational-replacement method. The new fitness function replicates two best fitness functions of chromosomes from the old population to replace two worst fitness functions of chromosomes in the offspring.

Step11:*Perform iterative operations:* Following the replacement in step10, steps 4-10 are repeated to locate the largest fitness function and realize the anti-noise signal to cancel out the unwanted noise.

IV. SIMULATION RESULTS

The coefficient length of a FIR filter is W=128.The initial population size *p*is 3, and the number of generations is 600.The GA based ANC is implemented using MATLAB. The crossover rate,p_c and the mutation rate,p_m used in this paper are 0.8 and 0.01.The input signal, main path, secondary path and error convergence of GA based ANC is as shown in figures7,8,9 and10 below.

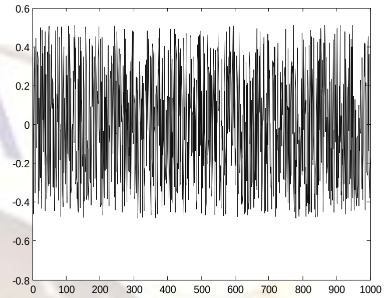


Fig.7: Input signal

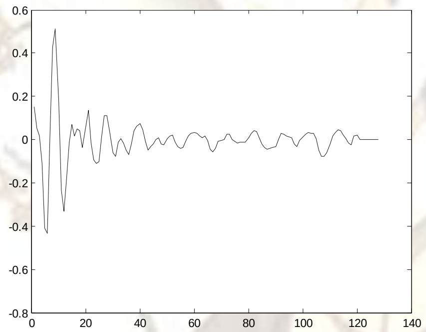


Fig.8: Main path

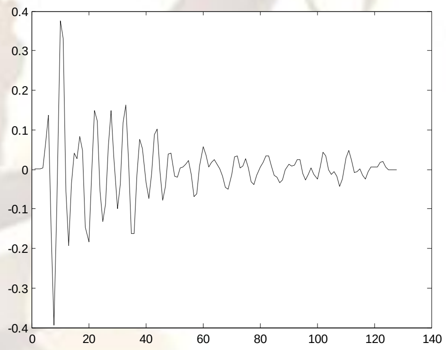


Fig.9: Secondary path

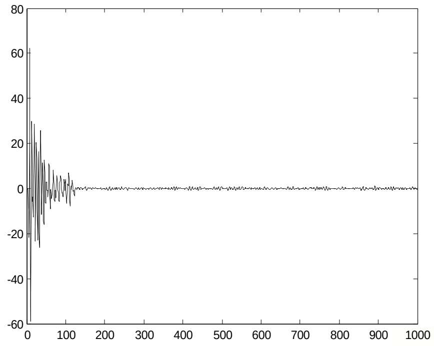


Fig.10: error convergence

V. CONCLUSION

This paper has presented GA-based method for ANC systems. This method does not require evaluating the secondary path when implementing the multichannel ANC systems. The global searching property of GA also facilitates efforts to prevent local minima.

VI. REFERENCES

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