Chapter 7

Conclusion and Future Prospects
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7.1. Conclusion

Active noise control (ANC) is a reasonably good technique to control acoustic noise of low frequency. Therefore, this subject is being researched for last several years. The ANC is an electroacoustic or electromechanical system which cancels an acoustic noise based on the principle of destructive interference. The ANC conventionally employ an adaptive algorithm based on gradient optimization technique. The most famous algorithm in ANC is the FXLMS algorithm. The FXLMS based ANC is associated with number of issues which arises due to complexity and time varying nature of noise processes. Some of these addressed in this thesis are: secondary path, nonlinearity, frequency mismatch in narrowband ANC and computational complexity issues. The thesis contributes by developing and evaluating the performance of four novel algorithms to circumvent four different issues linked with some well known ANC algorithms such as FXLMS algorithm, FSLMS algorithm, frequency synthesis based narrowband ANC and the block ANC algorithm.

The FXLMS algorithm requires secondary path estimate and hence any estimation error leads to performance degradation. Therefore, a PSO based algorithm, which is a non-gradient but simple evolutionary computing type algorithm, is proposed for developing an efficient ANC system. The proposed PSO based ANC algorithm does not require the estimation of secondary path transfer function unlike FXLMS algorithm and hence can be employed for time-varying nature of the secondary path. The conventional PSO based algorithm is shown to be ineffective to regain convergence in case of occurrence of an abrupt change in primary and/or secondary paths. To cope up with the abrupt change in the primary and the secondary paths, the conventional PSO algorithm is modified to introduce a
new conditional reinitialized PSO algorithm. A number of computer simulation experiments are carried out to show the usefulness of the proposed new PSO algorithm. Analytical discussion is made for the effectiveness of the proposed algorithm over the FXLMS and GA based ANC algorithms. The proposed algorithm does not use secondary path identification and hence is independent of any change in secondary path. The algorithm is also simple to implement unlike binary coded GA algorithm based ANC. A new online implementation scheme of the PSO based ANC algorithm is proposed.

Narrowband ANC conventionally uses a waveform synthesis method in which a synchronization signal is essential. In addition to this, to update the parameters of the controller, prior estimation of secondary path is required. Any mismatch in the frequency and secondary path estimate degrades the system performance of the conventional narrowband ANC. A new type of adaptive narrowband ANC algorithm has been presented using PSO based training which neither requires a synchronization signal nor the prior estimation of the secondary path to update the parameters of the controller and hence is free from effect of the change in source frequency and secondary path.. Therefore, the algorithm is free from the effect of the change in the source frequency and the secondary path transfer function. It is shown through exhaustive simulation study that the proposed PSO based adaptive narrowband ANC algorithm is capable of controlling monotone as well the multi-tone noises by accurately estimating the frequencies from the error microphone signal and adjusting the phase and the amplitude of the individual tones. The proposed algorithm can also track the abrupt change in the frequency content of the noise and get adapt to the change in secondary path characteristics. Though this PSO based ANC algorithm converges to very low MSE (order of about $10^{-17}$), it takes relatively higher convergence time (about 30 minutes for three frequencies). To achieve faster convergence, a conditional freezing PSO (CFPSO) algorithm is proposed and is applied to design the ANC algorithm and its performance is also evaluated. It is observed that the CFPSO is converging in about six minutes and hence is faster compared to the normal PSO based ANC algorithm. It is also seen that the CFPSO or the conventional PSO takes more time to converge when number
ANC employs microphones and loudspeakers for its operation. The reference microphone gets saturated when the acoustic noise at the source increases beyond dynamic limits of the microphone. When the controller tries to drive the loudspeaker system beyond its dynamic limits, the saturation nonlinearity is also introduced into the system. The secondary path which is generally estimated with a low level auxiliary noise by a linear transfer function does not model such saturation nonlinearity. Therefore, the FXLMS algorithm fails to perform when the noise level is increased. A nonlinear functional expansion based ANC algorithm is proposed where the PSO algorithm is suitably applied to tune the parameters of a filter bank based FLANN structure, named as nonlinear structure PSO (NLS-PSO). Examining computer simulation results, it is observed that the PSO is capable of updating the parameters of a nonlinear structure and hence capable of reducing the MSE to a lower value under higher grade of saturation nonlinearity both in reference secondary paths. This proposed algorithm is also capable of controlling the noise under nonlinear primary path. The performance of the proposed NLS-PSO algorithm is compared with the FXLMS, FSLMS and GA based ANC algorithms. It is found out that the performance of the proposed NLS-PSO based ANC algorithm is better than the other ANC algorithms under saturation nonlinearity of primary and secondary paths.

In high sampling-frequency operation of active noise control (ANC) system the length of the secondary path estimate and the ANC filter are very long. This increases the computational complexity of the conventional FXLMS algorithm. To reduce the computational complexity of long order ANC system using FXLMS algorithm, frequency domain block ANC algorithms have been proposed in past. These full block frequency domain ANC algorithms have some disadvantages such as large block delay, quantization error due to computation of large size transforms and implementation difficulties in existing low-end DSP hardware. To overcome these shortcomings, the partitioned block ANC algorithm is newly proposed where the long length filters in ANC are divided into a number of equal partitions and
suitably assembled to perform the FXLMS algorithm in the frequency domain. The complexity of this proposed frequency domain partitioned block FXLMS (FPBFXLMS) algorithm is reduced compared to the conventional FXLMS algorithm. It is further decreased by merging one FFT-IFFT combination to derive the reduced structure FPBFXLMS (RFPBFXLMS) algorithm. Computational complexity analysis for different orders of filter and partition size are presented. The choice of the partition size of secondary path equal to the partition size of the ANC filter, has enabled further reduction in computation but at the cost of some performance degradation. For partition size $N/2$ of 64 about 50% saving is achieved whereas about 70% saving is achieved for a partition size of 128. This proposed reduced complexity algorithm can be easily implementable in low cost DSP hardware having 128 or 256 points FFT computing capabilities. In addition, lesser amount of computation leads saving in power consumption and hence, it is better suited for battery operated ANC appliances such as the ANC head sets.

7.2 Future Prospects

The algorithms proposed in this thesis will encourage researches to propose better evolutionary computing algorithms for tuning the ANC controller. The algorithms proposed can also be applied to multi-channel ANC for real practical applications. The PSO based ANC algorithm has the ability for online training and hence has potential to be applied to other online control applications. The speed of the PSO training can be enhanced by developing new strategies. Implementation results of these PSO based ANC algorithms in a duct system will provide better idea about its other application areas. The partitioned block ANC algorithm is computationally efficient and will find more applications in the area of battery operated ANC systems. Embedded systems can also be developed based on the proposed algorithms.