Active noise control algorithm and implementation on overcoming the practical issue

SHI DONGYUAN (G1500076L)

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1 Abstract

Noise control attracts more and more attention, as the rapid advance of human's urbanization. Compared to traditional passive noise control approach, the active noise control (ANC) technique only utilizes the sensor to acquire the information of the noise and synthesizes the anti-noise driving the actuator to cancel the noise. Therefore, the ANC technique shows the apparent advantages of the cost, size, and easy deployment. With these advantages, ANC is widely used in active control headphone, duct noise control fields and so on. However, the ANC technique still meets many practical challenges, such as the output nonlinearity of the secondary path, no place to settle the error sensor, and the soaring computations as the increasing scale of the multichannel active noise control (MCANC) system. For effectively solving these practical issues, the paper reviews several techniques and proposes many innovative algorithms and methods. The distortion coming from the saturation audio amplifier plays a central role in the output nonlinearity on the secondary path. The distortion seriously influences the noise reduction performance and even results in the divergence of the adaptive ANC algorithm. One of the most effective ways is to constrain the power of the output signal so that the audio amplifier can work under the linear model and avoids the saturation. For guaranteeing the ANC system to achieve the optimal noise reduction performance under output constraint, the paper proposes two-gradient direction FxLMS algorithm The algorithm will automatically

change the gradient direction to reduce the power gain of the control filter when the ANC system exceeds the constraint of the output power. The alternative method is to utilize the leaky FxLMS algorithm adaptively restraining the magnitude of the control filter. With the assistance of the optimal leak factor suggested in this paper, the leaky FxLMS algorithm can also gain optimal control under output constraint. The performances of these two algorithms are verified by the numerical simulation and the experiment in the paper.

In some ANC applications, its impractical to place the error sensor in the desired location. Hence, the paper revisits the virtual sensing ANC technique that is capable to project the quiet zoom to the desired position from the location of the physical microphone. Furthermore, the paper extends the single channel version sensing ANC to multichannel version sensing ANC (MVANC). The frequency domain and time domain prove the MVANC can achieve the same noise reduction performance as the MCANC, which places the real error sensors in desired positions. The analysis of the sensor-actuator configuration exhibits the physical limitation of the MVANC. A four-channel MVANC is implemented in a small noise chamber, and its experimental results validate these analyses. Selective active noise control (SANC) approach proposed in the paper obtains a series of filters and stores into a database in the preliminary stage. When dealing with a specific type of primary noise, the SANC algorithm will select out a suitable pre-trained filter from the database based on the frequency-band-match method. The paper proves that the selected filter chosen by the frequency-band-match method can obtain a satisfying noise reduction performance. Without the adaptive update progress, SANC saves a considerable amount of computation and has higher robustness.

Finally, the paper summaries a series of approaches, which can optimize the structure of the digital processing algorithm implemented on FPGA. By using these methods, the paper proposes the systolic FxLMS, which significantly increase the sampling rate and throughput rate of the ANC system. For realizing a large scale MCANC on FPGA, the paper introduces a Multiple-parallel-branch with folding structure. This architecture is used to implement a 24-channel MCANC and successfully balances the computation resource consummation and the maximum running speed. This 24-channel MCANC is deployed in an open window whose noise reduction performance sufficiently validates the effectiveness of the proposed architecture.

2 Publication

I have published two journal papers [1, 2], four ICASSP papers [3–6], two APSIPA papers [7, 8], one ICA paper [9], other papers [10–16].

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