한국소음진동공학회 2013년 추계학술대회논문집, pp. 838~839

구형 마이크로폰 어레이를 이용한 최적 빔형성기법
Optimal Beamforming with Spherical Microphone Array

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Abstract

In this paper, optimum beamforming method using spherical microphone array is presented. Beamforming method has been recognized as an important study in localizing sound sources or visualizing acoustic fields in three-dimensional space. Its geometrical arrangement of sensors in space enables to process array signal to analyze the fields of interest by steering array response in three-dimensional.

Meyer and Elko introduced a beamformer based on a spherical harmonic decomposition of the sound field.[1] The beamformer presented has flexible structure whose beampattern does not change in any steering direction. Rafaely introduced conventional beamforming technique using spherical array and applied weighting function on array signal by compensating the delay due to the plane wave assumption.[2] Though the delay-and-sum method has high robustness, it still shows poor spatial resolution in lower frequency contents. Abhayapala and Ward designed beampattern using spherical microphone array based on spherical harmonics decomposition.[3]

Li and Duraiswami described optimal design of spherical microphone array for beamforming to achieve desired beampattern and maximum directivity.[4] They have implemented an adaptive algorithm to calculate beamforming response for the frequency of interest while preserving robustness constraint. Schlesinger and Boone introduced the minimum variance distortionless response (MVDR) beamforming to spherical microphone array to produce optimal filter.[5] Like Meyer and Elko's flexible spherical beamformer which combined phase-mode beamforming and MVDR, Schlesinger and Boone used same beamforming technique while adjustment between directivity and sensitivity are being made. Degree of freedom in optimal beamforming is obtained and computational complexity is lessened. Koretz and Rafaely used Dolph-Chebyshev beampattern to control mainlobe width and maximum sidelobe level.[6]

The spherical harmonics decomposition presented above have based on its symmetrical beampattern. Rafaely has presented a spherical microphone array which incorporates multiple nulls in beampattern design to suppress reflections other than look direction of array.[7] He applied the method in analyzing sound in room in the space domain and the spherical harmonics domain and achieved improved signal-to-noise ratio (SNR) compared to conventional fixed beamforming. Sun, Yan, and Svensson have formulated convex optimization of mainlobe levels, multi-null steering, sidelobe control, and robustness control using spherical harmonics framework.[8] The optimum array weights are computed minimizing the beampower output while maintaining distortionless responses in multiple mainlobe directions and sidelobe levels.

Recently, Hong et al. presented a comparison of beamforming performance based on the spherical microphone array methods with various sensor position.[9] Lee et al. have discussed a method for increasing the difference of side-lobe level in spherical microphone array.[10] It is known that narrow interval between sensors can increase the difference between main lobe and side-lobe of array response which eventually increase the

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source recognition capability. Lee et al. have adapted MEMS sensors into spherical microphone array. Fisher and Rafaely presented the capabilities of near-field spherical array beamforming with radial filtering of sources.[11] The near-field of array is defined in frequency and radial distance. Directional beampattern becomes worse when the source is far from the array. Radial filtering shows improvement in attenuation of far-field and near-field interfering sources relative to a source positioned in the same direction. Alon and Rafaely attempt to resolve the spatial aliasing at high frequencies of array performance.[12] The method presented extends the bandwidth of array through optimal aliasing cancellation.

In this paper, the beamforming based on spherical harmonics decomposition is presented. The array signal processing based on spherical-harmonics is driven in a matrix from and a constrained optimization formulation for the beamformer is discussed. The MVDR beamformer is designed to form nulls in the directions of interference. The optimization is done with classical array processing similar to the optimal beamforming problem. The performance is examined using simulation and experiments in an anechoic chamber. A spherical microphone array with 85 sensors are composed. The radius of the sphere is 12 cm.

A design method for the optimal beamformer widely used in array processing has been developed for spherical arrays, based on a spherical harmonics. Array beampattern coefficients have been analytically presented. we attempt to suppress interference by using the spherical harmonics domain beamforming problem and by formulating a constrained convex optimization problem. The beamformer weights are optimized by minimizing the beampower output while the response in the array look direction is remained distortionless. Performance parameter are such as a maximum sidelobe level and a white noise gain constraint.

Acknowledgement

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MEST) (No. 2010-0014978).

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