Description of Sound Field using Generalized Harmonic Analysis and Cluster Analysis

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Abstract

In this paper, we propose the method for automatically estimating sound source positions using the information on sound signals and generalized harmonic analysis and cluster analysis.

Sound signals, which are measured with closely located four-point microphone method, are analyzed using generalized harmonic analysis and we get the distribution of frequency components and find the frequency component clusters from these results. Finally we can get the movement of sound sources and separated sound source signals. The quality of separated sound was same as that of the original sound.

1. Introduction

Man can accurately perceive the direction and the position of sound sources with his/her two ears. In an attempt to realize an equivalent function using the microphones and computers, closely located four-point microphone method to obtain the position of sound sources with four-point microphone has been proposed by Yamasaki since 1976 [1, 2]. The method can obtain spatial information by four -point microphone that are not located on same plane, and we have used this method to measure the spatial acoustic information of concert halls or equivalent, such as positions and levels of the virtual sources based on correlation function or intensity technique.

In this study we considered that it is possible to separate sound sources on the assumption that the frequency elements of the sound do not correspond with each other. We dealt with the spontaneous signals like the environmental sounds instead of impulse responses whose definite time is known. We used generalized harmonic analysis as a method for frequency analysis. Generalized harmonic analysis was proposed by N. Wiener[3]. The definite merit of generalized harmonic analysis is that it is not restricted on the observation interval and has a very high resolution. This merit is sufficient in detailed observation of the characteristics of sound signals.

First sound signals, which are measured with closely located four-point microphone method, are analyzed using generalized harmonic analysis. Next we get the distribution of frequency components and find the frequency component clusters from these results. Finally we can get the movement of sound sources and separated sound source signals.

2. Generalized harmonic analysis for four-point microphone method

Sound signals, which are measured with closely located four-point microphone, are analyzed using generalized harmonic analysis. In generalized harmonic analysis we can use any frequencies for analysis. We can get the movement of target frequency as follow.

1) The signal measured at o-microphone is analyzed by the use of generalized harmonic analysis.
2) The y, x and z microphone's signals are also analyzed by the use of generalized harmonic analysis with frequency for analysis the result of 1).
3) The results from 1) and 2) do not always have corresponding components like FFT analysis. We calculate the time differences between microphones for the corresponding components. To do this we use the cross correlation between time envelopes and the phase differences for frequency components.
4) We determine the positions of components from the result of 3).

Figure1 shows the time envelopes for each microphone on 357Hz.

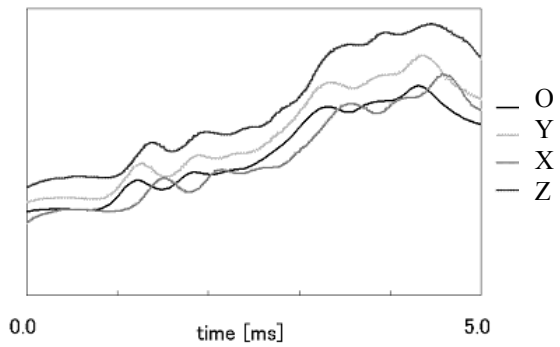

Figure1: Time envelopes for each microphone on 357Hz.

3. Estimation of sound source position

Cluster analysis is a classification method that can divide without external criterion. In this paper, we use K-means method that divides elements to some classes according to the square of Euclidean distance. Methodology is shown below.

1) Set a first cluster and calculate the centers $v_1, \cdots, v_c$.
2) Do the following step 2-1) for every x_k, $k=1, \cdots, n$.

2-1) If $x_k \in G_q$, calculate

$$v_r = \arg\min_{1 \le j \le c} \left\| x_k - v_j \right\|^2 . \quad (1)$$

If $r \neq q$, renew v_r, v_q, G_r, G_q based on

$$v_r = \frac{|G_r|}{|G_r|+1} v_r + \frac{x_k}{|G_r|+1}, \quad (2)$$

$$v_q = \frac{|G_q|}{|G_q|-1} v_q - \frac{x_k}{|G_q|-1}, \quad (3)$$

$$G_r = G_r \cup \{x_k\}, \quad (4)$$

$$G_q = G_q - \{x_k\}. \quad (5)$$

3) repeat 2) until the cluster movement is stopped completely.

4. Conclusions

The results of the experiments is as following. Figure2 shows the distribution of frequency components for two sound sources and Fig.4 shows the distribution for three sound sources.

By the method introduced previously we can get the frequency components cluster. By Synthesizing all frequency components in each cluster we also can get some sound signal. Figure 3 and 5 show the synthesized sound for two sources and three sources, respectively. The quality of separated sound was same as that of the original sound.

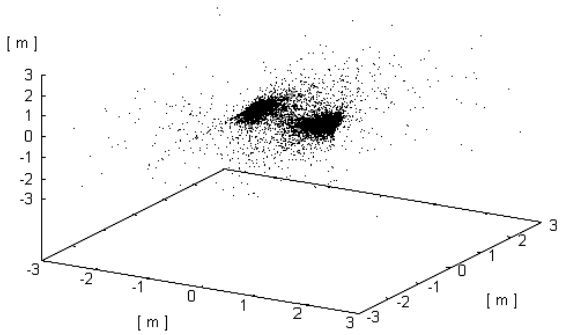

Figure2: Distribution of frequency components for two sound sources.

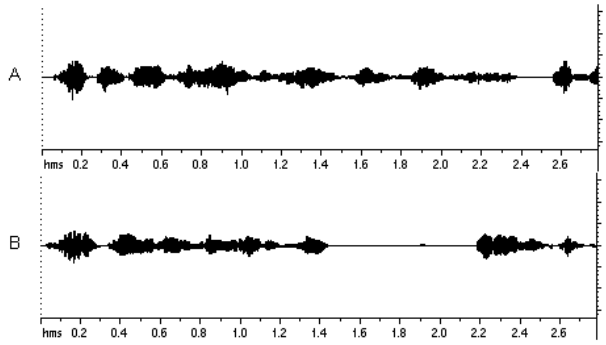

Figure3: separated sounds.

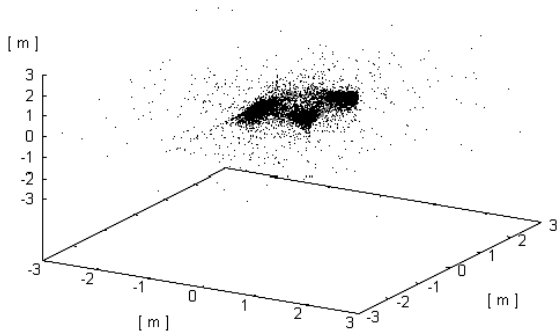

Figure4: Distribution of frequency components for three sound sources.

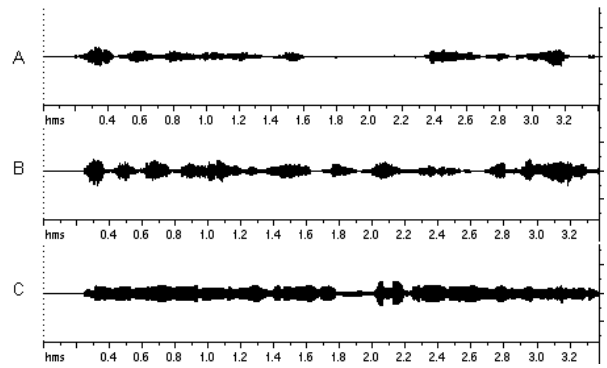

Figure5: three separated sounds.

5. References

[1] Y. Yamasaki and T. Itow, "Measurment of spatial information in sound fields by closely located four point microphone method," *J. Acoust. Soc. Jpn (E)* 10, pp.101-110, 1989.

[2] K. Endo, T. Horikoshi, Y. Yamasaki and T. Itow, "Grasp and estimation of spatial information in a room by closely located four-point microphone method," *Proc. ICASSP 86*, pp.909-919, 1986.

[3] N. Wiener, *The Fourier Integral and Certain of Its Applications*, Dover Publication Inc, 1933.