Design of a Coincident Microphone Array for 5.1-Channel Audio Recording Using the Mid-Side Recording Technique

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Abstract. In this paper, a 5.1-channel audio recording method is proposed by applying the mid-side (MS) stereo recording technique to a coincident microphone array. The coincident microphone array consists of a backward-facing cardioid microphone and the MS microphone array which is composed of a pair of forward-facing cardioid and sideways-facing figure-eight microphones. These 3 microphones produce two bi-directional signals and one uni-directional signal through additive and subtractive procedures. Using these signals, the rotated uni-directional signals are produced and synthesized at each angle according to the 5.1-channel speaker array. The performance of the proposed 5.1-channel audio recording method is evaluated using a directional response test and a localization test. It is shown from the tests that the proposed recording method provides a beam pattern well at each direction on the basis of the 5.1-channel speaker configuration and has localization performance within ±8.2 degrees.

Keywords: Multi-channel audio recording, coincident microphone array, mid-side recording

1 Introduction

There has been increased development in video and audio fields. In particular, the technologies related to video systems, such as 3DTV and high definition television (HDTV), have advanced [1]. With these recent developments in video, there has also been an increased demand for even more realistic audio services [2]. In order to enhance the performance of audio fields, multi-channel audio systems should be considered. Although the demand for multi-channel audio systems has increased, there is still a shortage of multi-channel audio content. Instead of recording multi-channel audio contents, an upmixing method that converts mono- or stereo-audio into 5.1 channel audio signals is widely used for providing various content [3][4]. However, such a method degrades the localization performance because of a lack of directional information. As an alternative, some spaced microphone configurations have been primarily used for 5.1-channel recording [5]. However, these configurations need a

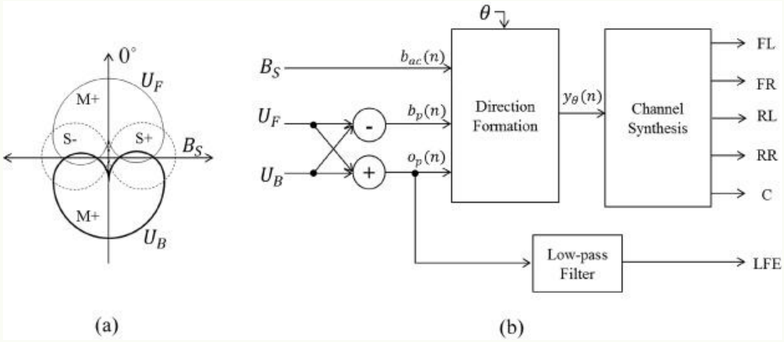

Fig. 1. (a) A microphone array using coincident three microphones and (b) a block diagram of the proposed 5.1-channel audio recording method

large space to allocate five microphones and expensive recording equipments. In this paper, a cost-efficient method of 5.1-channel audio recording is proposed by applying the mid-side (MS) stereo recording technique to a coincident microphone array. By doing this, we can achieve improved localization performance for 5.1-channel audio content.

2 Proposed 5.1-Channel Audio Recording Method

The MS stereo recording technique can generate stereo signals by combining two different microphones such as a coincident-forward-facing cardioid microphone, U_F , which is called as M, and a sideways-facing figure-eight microphone, B_S , which is called S [5]. In other words, right channel signal is made by adding signals from U_F and B_S , while left channel signal is made by subtracting the U_F microphone signal from the B_S microphone signal.

In order to record 5.1 channels, a backward-facing cardioid microphone, U_B , is added to the MS configuration. As shown in Fig. 1(a), the bold solid line indicates a beam pattern of U_B . Fig. 1(b) shows a block diagram of the proposed 5.1-channel audio recording method using this microphone array. A bi-directional signal with a directional axis of 0°, $b_p(n)$, is first obtained by subtracting signals from U_F and U_B . In addition, an omni-directional signal, $o_p(n)$ is obtained by adding the U_F microphone signal from U_B . These two signals, $b_p(n)$ and $o_p(n)$, are processed with a bi-directional signal, $b_{ac}(n)$, in the direction formation module. In fact, since three microphones are placed very closely, the phase and time difference between three signals are indistinguishable. Instead, there are the amplitude differences of three microphone signals depending on the direction of audio source. Therefore, for a

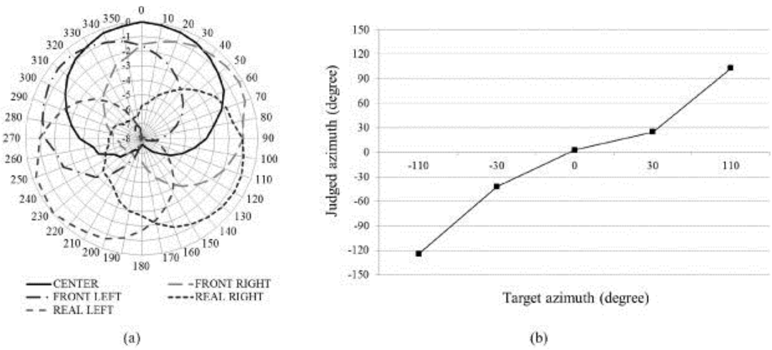

Fig. 2. Results of (a) the directional response test and (b) sound localization test.

given direction, $b_p(n)$ and $b_{ac}(n)$ are panned using the amplitude panning law [6]. Next, the panned signal is added by $o_p(n)$ to generate a uni-directional signal, $y_\theta(n)$. That is, $y_\theta(n)$ is represented as [7]

$$y_\theta(n) = (o_p(n) + b_p(n)\cos(\theta) + b_{ac}(n)\sin(\theta))/2 \quad (1)$$

where θ is an arbitrary direction.

In the channel synthesis, 5.1-channel signals are obtained by changing θ on the basis of a speaker configuration defined by the ITU-R Recommendation BS.775-1 [8]. In other words, five signals for center (C), front left (FL), front right (FR), rear left (RL), and rear right (RR) are obtained using Eq. (1) by setting θ to 0°, 30° , - 30° , 110°, and -110°, respectively. Finally, a signal for the low-frequency enhancement (LFE) channel is generated by applying a low-pass filter (LPF) to the omnidirectional signal $o_p(n)$. In this paper, the cut-off frequency of the LPF is set to 120 Hz since the LFE channel is used for improving bass quality without any directional information.

3 Performance Evaluation

In order to demonstrate the performance of the proposed recording method, we performed two different tests such as a directional response test and a sound localization test. For the first test, a white noise signal was prepared to analyze all frequency bands. The coincidence microphone set as mentioned in Section 2 was positioned at the center, and a mono-speaker was arranged at 0° in the horizontal plane. The coincident microphone set was rotated from 0° to 360° at a step of 10° in a nonreverberant audio booth. For the second test, three audio files including speech, music, and white noise were also prepared and played using the 5.1-channel speaker configuration defined by the ITU-R BS.775-1. Next, we recorded these audio files by the coincidence microphone set and measured the perceived source directions of the recorded audio files.

Fig. 2(a) shows the directional response of each channel. As shown in the figure, the proposed recording method formed a beam pattern well at each direction. In addition, Fig. 2(b) shows the sound localization test result. It was shown from the figure that the proposed recording method could localize audio within an average of ±8.2 degrees.

4 Conclusion

In this paper, we proposed a 5.1-channel audio recording method using a coincident microphone array that was composed of a backward-facing cardioid microphone and an MS microphone array. First of all, we constructed a relationship between three signals from the coincident microphone array. After that, five channel signals were synthesized by differently setting the relationship according to an angle corresponding to a 5.1-channel speaker configuration defined by the ITU-R BS.775-1. It was shown from a directional response test and a sound localization test that the proposed recording method provided a well-formed beam pattern and had a localization performance within an average of ±8.2 degrees.

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