Blind Source Separation using SIMO-model-based ICA with Self-Generator for Initial Filter

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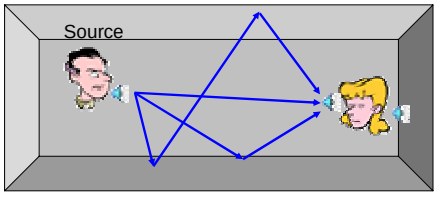
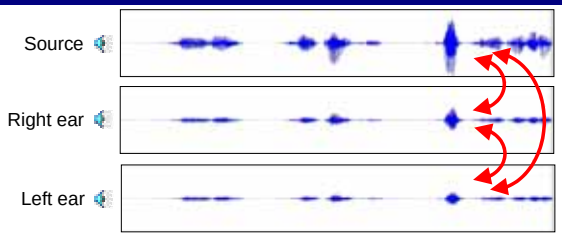
Single-Input Multiple-Output (SIMO)-model-based signals

Generally speaking, human being do not hear the source signal itself. Because the signals we hear involve not only the information about source signal but also the information about spatial qualities.



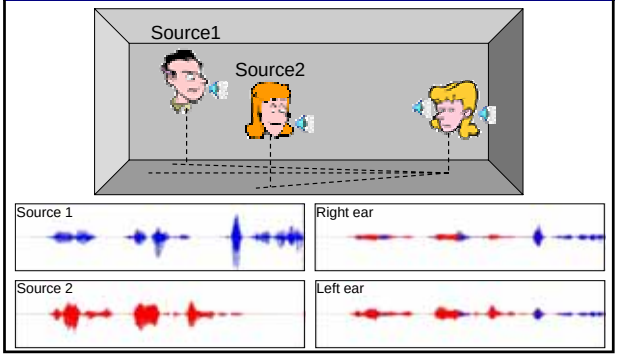
The multiple signals from single source are defined as Single-Input Multiple-Output (SIMO)-model-based signals.

Transmission of acoustic signals

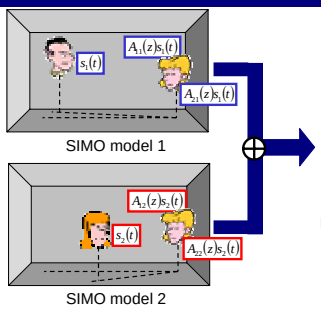


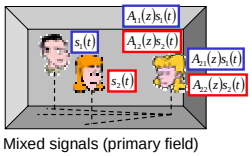
The SIMO-model-based signals in both ears include the information about the directivity, localization, or spatial qualities of each sound source.

Mixing process (1/2)



Mixing process (2/2)



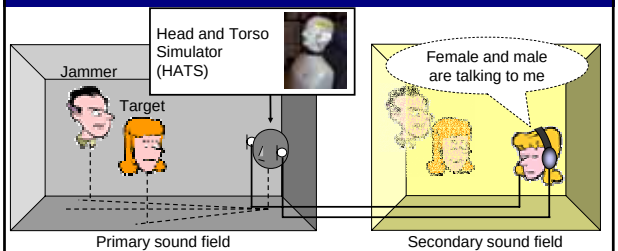


Mixed signals (primary field)

Right ear	$A_{11}(z)s_1(t) + A_{12}(z)s_2(t)$
Left ear	$A_{21}(z)s_1(t) + A_{22}(z)s_2(t)$

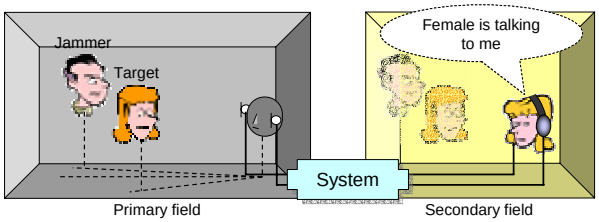
The mixed signals are sum of the SIMO-model-based signals.

Binaural sound reproduction system



Binaural sound reproduction system can copy the primary sound field.
⇒ This system can not reproduce only the target sound.

Research goal



Realization of audio augmented reality system which can enhance and reproduce the target sound

Application

Tele-existence system using vision and audio modality

robot

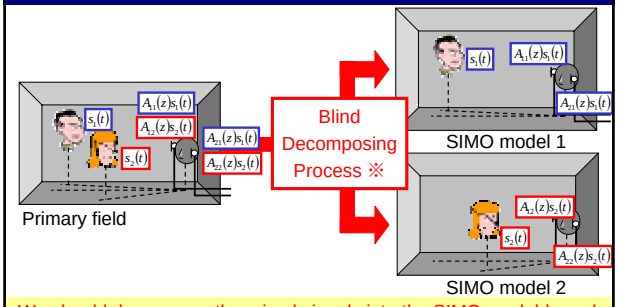
rescue personnel (operator)

In order to represent only target sound to an operator, the followings are required.

① High-fidelity sound (Sound reproduction)

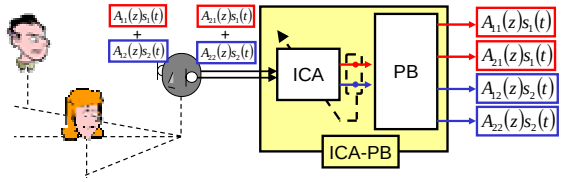
② Noise suppression (Enhancement of the target sound)

Approach



We should decompose the mixed signals into the SIMO-model-based signals without a priori information.

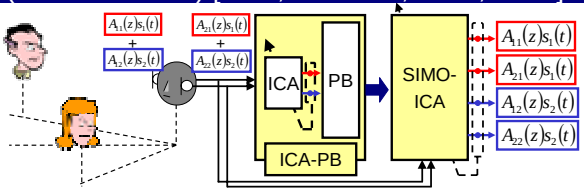
Conventional method 1: Independent Component Analysis (ICA) with Projection Back (ICA-PB) [Murata et al., 1998]



Features:

- Unsupervised algorithm

Conventional method 2: Multi-stage SIMO-model-based ICA (MS-SIMO-ICA) [Ukai, Takatani, et al., 2004]



Features:

- Unsupervised algorithm
- The performance of this method is superior to that of ICA-PB.

Experiment 1

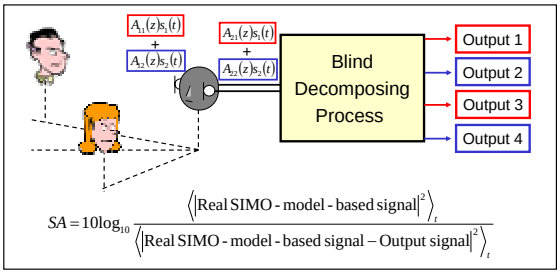
In order to evaluate there effectiveness, the decomposition experiments of the binaural mixed signals are carried out for the different directions of sources.

- Conventional ICA-PB
- Conventional MS-SIMO-ICA

Sound source	2 male and 2 female (12 combination)
Sampling frequency	8000 Hz
Length of filter	1024 [taps]
Initial value of filter	Inverse filter of HRTF whose directions of sources are ±60 [deg]
Evaluation score	SIMO-model Accuracy [dB]

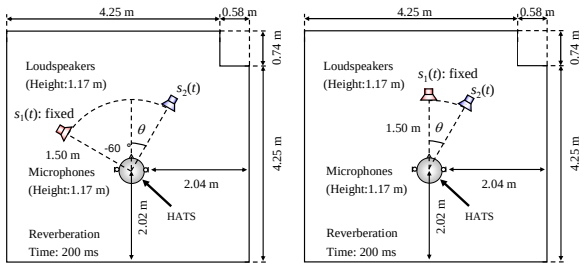
Evaluation Score: SIMO-Model Accuracy (SA)

Similarity between the output signals of the ICA and real SIMO-model-based signals



$$SA = 10\log_{10} \frac{\left\langle \left| \text{Real SIMO - model - based signal} \right|^2 \right\rangle_t}{\left\langle \left| \text{Real SIMO - model - based signal} - \text{Output signal} \right|^2 \right\rangle_t}$$

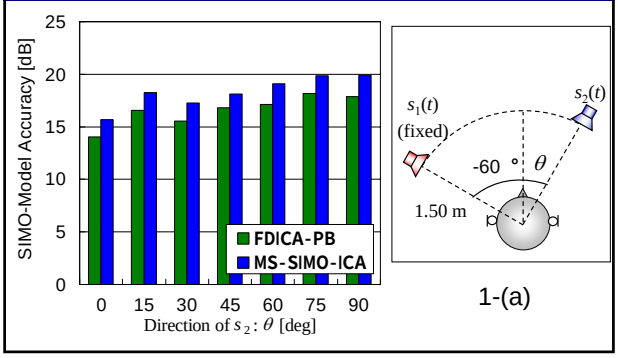
Experimental conditions



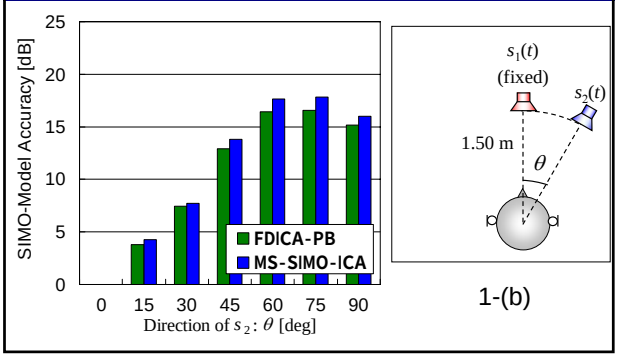
$s_1(t)$: -60 ° (fixed)
$s_2(t)$: 0 ° , 15 ° , 30 ° , 45 ° , 60 ° , 75 ° , 90 °

$s_1(t)$: 0 ° (fixed)
$s_2(t)$: 0 ° , 15 ° , 30 ° , 45 ° , 60 ° , 75 ° , 90 °

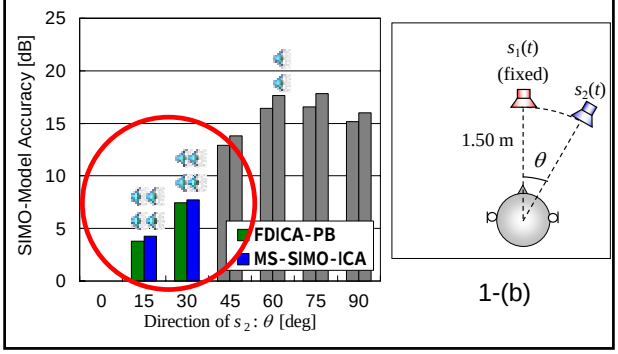
Experimental results 1-(a)



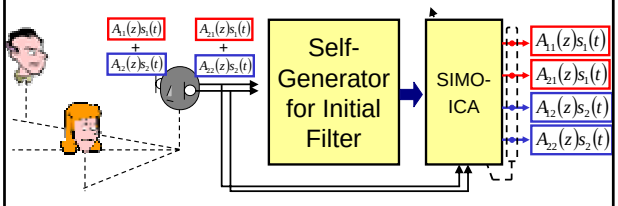
Experimental results 1-(b)



Experimental results 1-(b)



Proposed method: SIMO-ICA with Self-Generator for Initial Filter



Features:

- Unsupervised algorithm
- Self-Generator consists of ICA-PB, single talk detection , and DOA estimation.

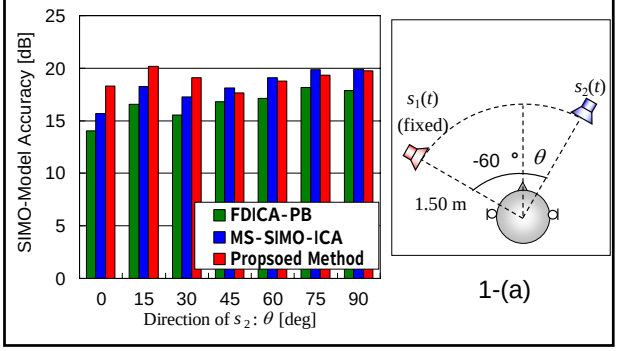
Experiment 2

In order to evaluate its effectiveness, the decomposition experiments of the binaural mixed signals are carried out for the different directions of sources.

- Conventional ICA-PB
- Conventional MS-SIMO-ICA
- Proposed SIMO-ICA with Self-Generator for Initial Filter

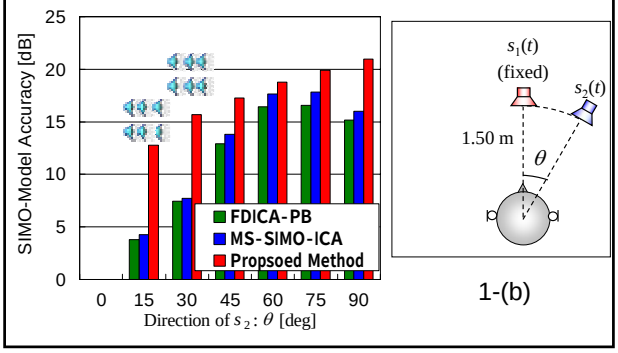
Sound source	2 male and 2 female (12 combination)
Sampling frequency	8000 Hz
Length of filter	1024 [taps]
Initial value of filter	Inverse filter of HRTF whose directions of sources are ±60 [deg]
Evaluation score	SIMO-model Accuracy [dB]

Experimental results 2-(a)



1-(a)

Experimental results 2-(b)



1-(b)

Conclusion

- We propose a new blind decomposition using single-input multiple-output-model-based independent component analysis (SIMO-ICA) with Self-Generator for Initial Filter.
  - The self-generator consists of ICA-PB, single talk detection, and DOA estimation.
  - Using the estimated DOA of sources, the self-generator generate the valid initial filter automatically.
- In order to evaluate its effectiveness, decomposition experiments are carried out.
  - The experimental results reveal that the performance of the proposed method is superior to those of conventional methods.