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(54) **Title:** METHOD, SYSTEM AND STORAGE MEDIUM FOR SIGNAL SEPARATION

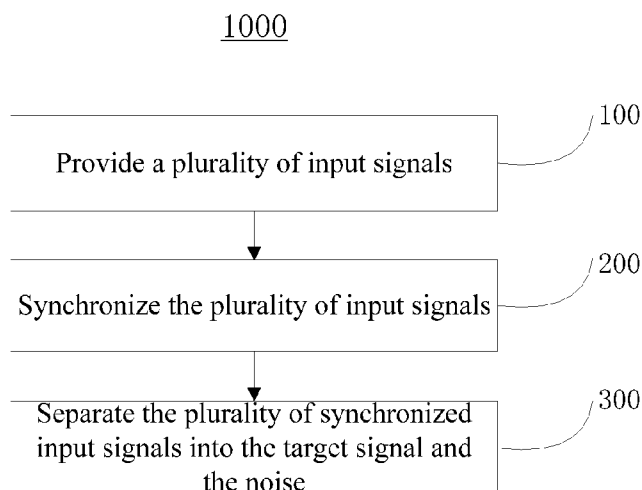


FIG. 1

(57) **Abstract:** Methods, systems and storage medium for separating a target signal from noise are disclosed. A method comprises providing a plurality of input signals, each of the plurality of input signals comprising the target signal; synchronizing the plurality of input signals; and separating the plurality of synchronized input signals into the target signal and the noise.

METHOD, SYSTEM AND STORAGE MEDIUM FOR SIGNAL SEPARATION

Cross-references to Related Applications

This application claims the benefit of U.S. provisional application No. 62/386,136 filed on November 19, 2015, which is incorporated herein by reference in its entirety.

Technical Field

[0001] The present application relates to the field of signal processing technology, and in particular to a method, system and storage medium for separating a target signal from an unwanted signal.

Background

[0002] Noise or unwanted signal interferences are omnipresent. This is a very common problem in applications in audio recordings (e.g., Virtual Reality (VR) 360 audio; hearing aid applications); remote sensing (echo detections; thermal detection; image sensing; radio frequency signature detection); and biomedical applications (e.g., electroencephalography (EEG) signal detections; brain-computer interface; and electromyography (EMG) signals detections) and many others. Noise and target signals can share very similar temporal and frequency characteristics and make the detection of target signals difficult. The separation of the target signals from the noise or unwanted signals will enable selective amplification of the target signals and significantly improve the performance of the sensing systems.

[0003] Currently, sensing devices comprise one or more transducers, A/D converters, digital signal processors, signal actuators, etc. The digital processors generally filter the input signals into different frequency bands. A signal level reduction or gain on each particular frequency band is adjusted to fulfil the individual requirement. Subsequently, algorithms are designed for digital processors to separate and isolate signals, reduce unwanted signals and amplify desired signals.

[0004] Nevertheless, there exist major limitations on current sensing systems and noise reduction algorithms for real time processing. Unwanted signals or noise often share the same frequency characteristics with the target signals. This makes filtering ineffective in removing the noise.

[0005] Usually, target signals and noise come from physically separated sources. Theoretically, when two or more transducers are used to measure these signals, the distances between transducers and sources embedded the necessary information for separating the signal from the noise. However, in practice, inevitable time differences exist when a signal is propagated from a source to different transducers. The propagation delay causes asynchronization in the signals measured by the transducers. As a result, the mixed signals comprising multiple independent signals, with the inevitable propagation delays, cannot be well separated into independent signals. Therefore, the unwanted signals cannot be separated from the target signals. Consequently, the desired signals cannot be selectively amplified.

[0006] Therefore, there exists a need for technologies that can solve the asynchronization effect to effectively separate the noise signal and target signal and thereby improve the perception of target signals through selective amplification.

Summary

[0007] One aspect of the present application discloses a method for separating a target signal from noise, comprising: providing a plurality of input signals, each of the plurality of input signals comprising the target signal; synchronizing the plurality of input signals; and separating the plurality of synchronized input signals into the target signal and the noise.

[0008] Another aspect of the present application, a system for separating a target signal from noise is provided, which comprising a plurality of input units for inputting a plurality of input signals; a processor; and a memory storing computer readable instructions which when executed by the processor, cause the processor to: synchronize the plurality of input signals; and separate the plurality of synchronized input signals into the target signal and the noise.

[0009] Still another aspect of the present application discloses a non-transitory computer storage medium, storing computer-readable instructions which when executed by a processor, cause the processor to perform a method for separating a target signal from noise, the method comprising: providing a plurality of input signals, each of the plurality of input signals comprising the target signal; synchronizing the plurality of input signals; and separating the plurality of synchronized input signals into the target signal and the noise.

[0010] According to the present application, the asynchronization effect can be reversed or reduced and the noise separation performance can be improved, so that the perception of the target signals can be improved through cancelling the noise.

Brief Description of the Drawings

[0011] Exemplary non-limiting embodiments of the present invention are described below with reference to the attached drawings. The drawings are illustrative and generally not to an exact scale. The same or similar elements on different figures are referenced with the same reference numbers.

[0012] Fig. 1 shows a flow chart of a method for separating a target signal from noise according to an embodiment of the present application;

[0013] Fig. 2 shows a flow chart of operations of synchronizing a plurality of input signals; and

[0014] Fig. 3 shows a structural diagram of a computer system adapted to implement an embodiment of the present application.

Detailed Description

[0015] Hereinafter, the embodiments of the present application will be described in detail with reference to the detailed description as well as the drawings.

[0016] The term “independent component analysis” and its abbreviation “ICA” as used herein are intended to refer to methods for minimizing or maximizing the

mathematical formulation of mutual information in both time and frequency domain based on statistical methods.

[0017] The term “head related transfer function” and its abbreviation “HRTF” as used herein are intended to refer to the difference and / or ratio between an open ear resonance measurement of the user’s ear canal or approximate manmade ear in a dummy head and the resonance measurement taken at the signal source in an anechoic chamber as a function of the angle of incoming signal.

[0018] Fig. 1 shows a flow chart of a method 1000 for separating a target signal from noise according to an embodiment of the present application.

[0019] At step 100, a plurality of input signals are provided. Each of the input signals comprises the target signal. In addition, the input signals may comprise noises that may be different from each other. However, it should be understood that the noises in the input signals may also be the same, and the present application has no limitation in this aspect. For example, in the scenario of an electronic hearing device, the electronic hearing device typically comprises at least two microphones, each of which may receive a mixture of a signal transmitted from a sound source and an ambient noise. Since the microphones are usually placed at different positions, and thus the signal and the noise are received at mutually distanced locations, and the ambient noises received by the microphones may be different in time domain and/or amplitude from each other. For example, in the scenario of a Brain-Computer Interface device, the EEG device typically comprises at least two electrodes, each of which may receive a mixture of a signal transmitted from an EEG source and an ambient noise. Since the electrodes are usually

placed at different positions, and thus the signal and the noise are received at mutually distanced locations, and the ambient noises received by the electrodes may be different in time domain and/or amplitude from each other. Similarly, in the scenario of underwater echo detection, the echo receiving device typically comprises at least two transducers, each of which may receive a mixture of a signal transmitted from a sound source and an ambient noise. Since the transducers are usually placed at different positions, and thus the signal and the noise are received at mutually distanced locations, and the ambient noises received by the transducers may be different in time domain and/or amplitude from each other.

[0020] At step 200, the plurality of input signals are synchronized. Step 200 will be described in details with reference to Fig. 2 as follows.

[0021] As shown in Fig. 2, at step 201, the noise segment in each of the input signals is detected. The noise segment in each of the input signals is detected by performing, for example, pattern recognition. Those skilled in the art should understand that other appropriate technologies may also be employed in this step. According to the present application, the noise detection process of step 201 does not need to be too precise. As long as one time segment containing the onset of the noise from a low level to a high level (i.e., a step function) is detected, this will be sufficient for completing the remaining steps. This approach largely reduces the need for complicated noise detection processes and thus reduces the computational complexity and cost.

[0022] At step 202, cross-correlation is calculated between two of the detected noise segments to obtain a time delay between the detected noise segments.

[0023] At step 203, the input signals are synchronized based on the obtained time delay(s). For example, if the time delay between the detected noise segment in a first input signal $f_1(t)$ and the detected noise segment in a second input signal $f_2(t)$ is determined to be δ , the first input signal $f_1(t)$ is synchronized to be $f_1(t-\delta)$. For another example, if the time delay between the detected noise segment in the first input signal $f_1(t)$ and the detected noise segment in the second input signal $f_2(t)$ is determined to be $-\delta$, the first input signal $f_1(t)$ is synchronized to be $f_1(t+\delta)$. Since the input signals are synchronized, the asynchronization effect caused by the propagation difference can be reduced or reversed.

[0024] Referring to Fig. 1 again, at step 300, the synchronized input signals are separated into the target signal and the noise. In the present embodiment, an independent component analysis (ICA) is performed to separate the synchronized input signals into the target signal and the noise. However, those skilled in the art should understand that other appropriate technologies may be used to separate the input signals into the target signal and the noise, and the present application has no limitation in this aspect.

[0025] Once the target signal and the noise are appropriately separated, subsequent processing can be performed on the separated target signal and the noise. For example, the target signal may be selectively amplified and the noise or unwanted signals may be selectively reduced to improve the perception of the target signal.

[0026] The signals in the art could be referred to audio signals, image signals, electro-magnetic signals, EEG signals, EMG signals, radio wave signals or other forms

of signals that could be picked up by transducers and the present application has no limitation in this aspect.

[0027] Particularly, for the specific application to hearing aid application, in order to further narrow down the selectivity of the target audio signal and reduce the noise, the target audio signal should be further selected using its incoming direction to the transducers. Accordingly, the method according to the present embodiment may further comprise: extracting directional information from the separated target signal and noise; and selecting the target signal based on the extracted directional information. In the scenario that the input signals are audio signals, a head-related transfer function (HRTF) may be adopted to extract directional information from the separated target signal and noise. The HRTF is the Fourier Transform of a head related impulse response (HRIR) which is the impulse response between the sound source and the eardrum. The HRTF may contain all physical characteristic values relating to the sound transmission to the ears of a listener or mannequin, including the angle of sound incidence from the sources to the listener's or mannequin's ears. Based on the extracted directional information, the target signals can be further selected by, for example, a series of bandstop / bandpass filters that are tuned to a particular source direction (front: 10.3kHz to 14.9kHz; back: 680 to 2kHz).

[0028] According to the present application, the perception of the target signals can be improved while reducing the computational cost. In addition, the input signals are synchronized in time domain and thus the method according to the present application will not introduce any frequency distortion.

[0029] Now referring to Fig. 3, a structural schematic diagram of a computer system 800 adapted to implement an embodiment of the present application is shown.

[0030] As shown in Fig. 3, the computer system 300 includes a central processing unit (CPU) 301, which may execute various appropriate actions and processes in accordance with a program stored in a read-only memory (ROM) 302 or a program loaded into a random access memory (RAM) 303 from a storage section 308. The RAM 303 also stores various programs and data required by operations of the system 300. The CPU 301, the ROM 302 and the RAM 303 are connected to each other through a bus 304. An input/output (I/O) interface 305 is also connected to the bus 304.

[0031] The following components may be connected to the I/O interface 305: an input section 306 comprising a keyboard, a mouse, etc.; an output section 307 comprising a liquid crystal display device (LCD) and a speaker etc.; a storage section 308 comprising a hard disk, etc.; and a communication section 309 comprising a network interface card, such as a LAN card and a wireless Near-field communication unit. The communication section 309 performs communication processes via a cloud network, such as the Internet. A driver 310 is also connected to the I/O interface 305 as required. A removable medium 311, such as a magnetic disk, an optical disk, a magneto-optical disk, a semiconductor memory, may be installed on the driver 310, to facilitate the retrieval of a computer program from the removable medium 311, and the installation into the storage section 308 as needed.

[0032] According to an embodiment of the present disclosure, the process described above with reference to the flow chart may also be implemented as an

embedded computer system similar to the computer system 300 but without keyboard, mouse, and hard disk. Update of programs will be facilitated via a wireless communication or cabled communication (309).

[0033] In particular, according to an embodiment of the present disclosure, the process described above with reference to the flow chart may be implemented as a computer software program. For example, an embodiment of the present disclosure comprises a computer program product, which comprises a computer program that is tangibly embodied in a machine-readable medium. The computer program comprises program codes for executing the method as shown in the flow charts. In such an embodiment, the computer program may be downloaded and installed from a network via the communication section 309, and/or may be installed from the removable media 311.

[0034] The flow charts and block diagrams in the figures illustrate architectures, functions and operations that may be implemented according to the system, the method and the computer program product of the various embodiments of the present invention. In this regard, each of the blocks in the flow charts and block diagrams may represent a module, a program segment, or a code portion. The module, the program segment, or the code portion comprises one or more executable instructions for implementing the specified logical function. It should be noted that, in some alternative implementations, the functions denoted by the blocks may occur in a different sequence from that the sequence as shown in the figures. For example, in practice, two blocks in succession may be executed substantially in parallel, or in a reverse order, depending on the

functionalities involved. It should also be noted that, each block in the block diagrams and/or the flow charts and/or a combination of the blocks may be implemented by a dedicated hardware-based system executing specific functions or operations, or by a combination of a dedicated hardware and computer instructions.

[0035] The units or modules involved in the embodiments of the present application may be implemented by way of software or hardware. The described units or modules may also be provided in a processor. The names of these units or modules are not considered as a limitation to the units or modules.

[0036] In another aspect, the present application also provides a computer readable storage medium. The computer readable storage medium may be the computer readable storage medium included in the apparatus in the above embodiments, and it may also be a separate computer readable storage medium which has not been assembled into the apparatus. The computer readable storage medium stores one or more programs, which are used by one or more processors to execute the method for separating a target signal from noise described in the present application.

[0037] The forgoing is only a description of the preferred embodiments of the present application and the applied technical principles. It should be understood by those skilled in the art that the invention scope of the present application is not limited to technical solutions formed by the particular combinations of the above technical features. It should also cover other technical solutions formed by any combinations of the above technical features or equivalent features thereof without departing from the concept of the invention. For example, a technical solution formed by replacing the

features disclosed above by technical features with similar functions is also within the scope of the present invention.

What is claimed is:

1. A method for separating a target signal from noise, comprising:
providing a plurality of input signals, each of the plurality of input signals comprising the target signal;
synchronizing the plurality of input signals; and
separating the plurality of synchronized input signals into the target signal and the noise.
2. The method of claim 1, wherein the synchronizing the plurality of input signals comprises:
detecting a noise segment in each of the plurality of input signals;
calculating cross-correlation between two of the detected noise segments to obtain a time delay between the detected noise segments; and
synchronizing the plurality of input signals based on the obtained time delay.
3. The method of claim 1, wherein the plurality of input signals are obtained at a plurality of mutually distanced locations.
4. The method of claim 1, the separating the plurality of input signals into the target signal and the noise comprising: separating the plurality of synchronized input signals into the target signal and the noise by an independent component analysis.

5. The method of claim 2, the detecting the noise segment in each of the plurality of input signals comprising: detecting the noise segment in each of the plurality of input signals by performing a pattern recognition.

6. The method of claim 1, further comprising:
extracting directional information from the separated target signal and noise; and
selecting the target signal based on the extracted directional information.

7. The method of claim 6, the extracting the directional information from the separated target signal and noise comprising: extracting the directional information from the separated target signal and noise by a head-related transfer function.

8. The method of claim 1, wherein the input signal is a signal picked up by a transducer.

9. The method of claim 8, wherein the input signal is one of:
an audio signal;
an EEG signal;
an EMG signal;
an image signal; and
a radio frequency signal.

10. A system for separating a target signal from noise, comprising:
- a plurality of input units for inputting a plurality of input signals;
 - a processor; and
 - a memory storing computer readable instructions which when executed by the processor, cause the processor to:
- synchronize the plurality of input signals; and
 - separate the plurality of synchronized input signals into the target signal and the noise.
11. The system of claim 10, wherein the synchronizing the plurality of input signals comprises:
- detecting a noise segment in each of the plurality of input signals;
 - calculating cross-correlation between two of the detected noise segments to obtain a time delay between the detected noise segments; and
 - synchronizing the plurality of input signals based on the obtained time delay.
12. The system of claim 10, wherein the plurality of input signals are obtained at a plurality of mutually distanced locations.
13. The system of claim 10, the separating the plurality of input signals into the target signal and the noise comprising: separating the plurality of synchronized input signals into the target signal and the noise by an independent component analysis.

14. The system of claim 11, the detecting the noise segment in each of the plurality of input signals comprising: detecting the noise segment in each of the plurality of input signals by performing a pattern recognition.

15. The system of claim 10, further comprising:
extracting directional information from the separated target signal and noise; and
selecting the target signal based on the extracted directional information.

16. The system of claim 15, the extracting the directional information from the separated target signal and noise comprising: extracting the directional information from the separated target signal and noise by a head-related transfer function.

17. The system of claim 10, wherein the input signal is a signal picked up by a transducer.

18. The system of claim 17, wherein the input signal is one of:
an audio signal;
an EEG signal;
an EMG signal;
an image signal; and
a radio frequency signal.

19. A non-transitory computer-readable storage medium, storing instructions which when executed by a processor, perform a method for separating a target signal from noise, the method comprising:

providing a plurality of input signals, each of the plurality of input signals comprising the target signal;

synchronizing the plurality of input signals; and

separating the plurality of synchronized input signals into the target signal and the noise.

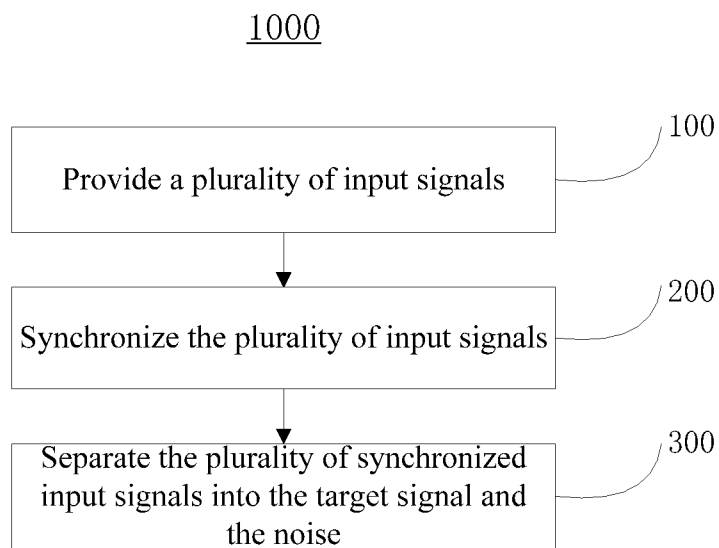


FIG. 1

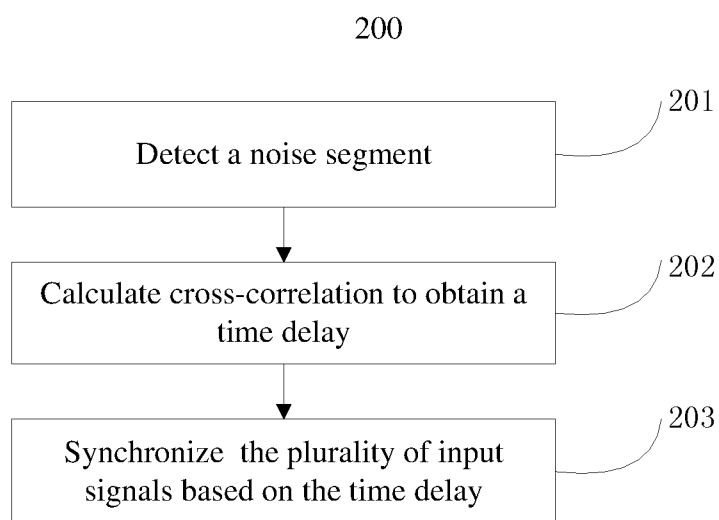


FIG. 2

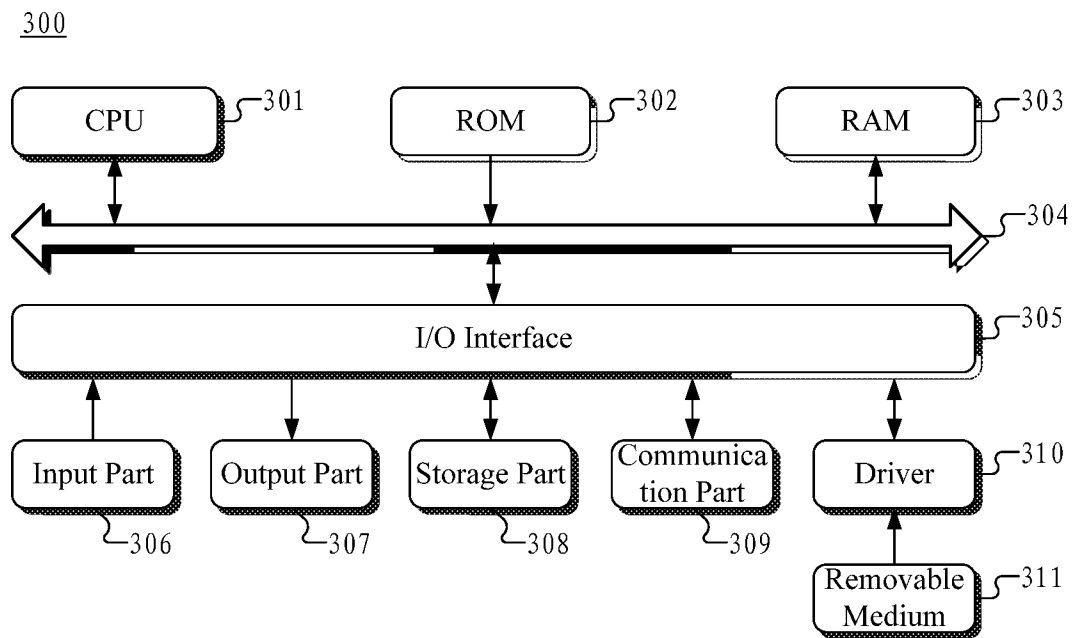


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2016/095283

A. CLASSIFICATION OF SUBJECT MATTER

H04R 3/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNABS;CNTXT;CNKI;VEN:delay,separat+,target signal,noise, +synchron+, unwanted signal?,corss w correlati+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 102509552 A (UNIV. ZHEJIANG) 20 June 2012 (2012-06-20) description paragraphs [0007], [0008], [0011], [0012], [0016]-[0018]	1-19
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A	EP 0786172 B1 (PHIG KONINK PHILIPS ELECTRONICS NV ET AL.) 27 November 2002 (2002-11-27) the whole document	1-19
A	JP 2002199359 A (MATSUSHITA ELECTRIC IND CO., LTD) 12 July 2002 (2002-07-12) the whole document	1-19

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

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“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

26 October 2016

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Name and mailing address of the ISA/CN

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2016/095283

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