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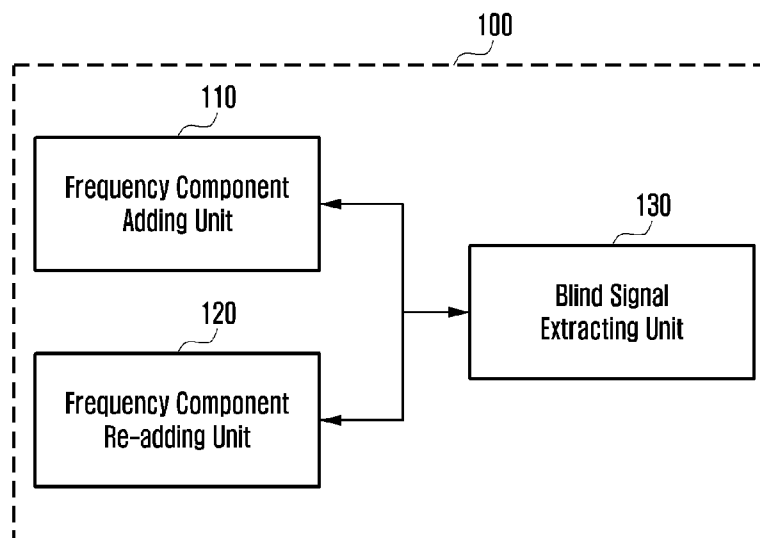
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(54) Title: APPARATUS AND METHOD FOR SOLVING SCALE PROBLEM IN BLIND SIGNAL EXTRACTION OF FREQUENCY DOMAIN



(57) Abstract: Disclosed are an apparatus and a method for solving a scale problem in blind signal extraction of a frequency domain. The apparatus for solving the scale problem in the blind signal extraction includes: a frequency component adding unit for adding a $(2n-1)^{\text{th}}$ frequency component and a $2n^{\text{th}}$ frequency component which are different frequency output signals and adjacent to each other; a frequency component re-adding unit for re-adding a $(2m-1)^{\text{th}}$ frequency component and a $2m^{\text{th}}$ frequency component for the frequency component added by the frequency component adding unit; and a blind signal extracting unit for performing blind signal extraction, based on each of an original output signal, a signal added by the frequency element adding unit, and a signal re-added by the frequency component re-adding unit, wherein the scale problem is solved based on a coefficient enabling a Euclidean distance to be minimum and m and n are natural numbers.



Description

Title of Invention: APPARATUS AND METHOD FOR SOLVING SCALE PROBLEM IN BLIND SIGNAL EXTRACTION OF FREQUENCY DOMAIN

Technical Field

- [1] This application claims the priority under 35 U.S.C. 119(a) to Korean Patent Application Serial No. 10-2013-0019806, which was filed in the Korean Intellectual Property Office on February 25, 2013, the entire content of which is hereby incorporated by reference.
- [2] The present invention relates to an apparatus and a method for solving a scale problem in blind signal extraction, and more particularly to an apparatus and a method for solving a scale problem in blind signal extraction of a frequency domain, which is capable of solving the scale problem occurring when the blind signal extraction of the frequency domain is performed.

Background Art

- [3] With development of a technology of processing a digital signal, various voice services using a voice communication and voice recognition system have been provided. However, improvement of capability of the voice communication and voice recognition system is required to effectively apply the various voice services to the system. Especially, in order to improve sound quality and a voice recognition rate in the voice communication, a technology of separating a desired signal from an undesired signal such as a surrounding noise is essentially required.
- [4] Recently, in application of a sound source separation in a communication system, a biomedical field and a real environment, application and research for a Blind Signal Separation (BSS) in which a sound/signal source has been estimated by using only a mixed signal observed through a multiple-sensor have actively progressed. Here, the BSS is a technology of estimating an original signal source in the mixed signal.
- [5] FIG. 1 is a view illustrating a concept of the BSS.
- [6] As a modeling of the BSS, assuming that N unknown signal sources which are statistically and mutually independent, and of which an average is zero are received via M sensors (microphones) through mixed independent paths respectively, a relation formula expressed by Equation (1) is established between a microphone signal x and an original signals.
- [7]

$$x_j(t) = \sum_{k=1}^N \sum_l h_{jk}(l) s_k(t-l)$$

[8] In Equation 1, $h_{jk}(l)$ means a transfer function from a k^{th} original signal to a j^{th} microphone. Generally, a value of M may be used as N .

[9] The purpose of the BSS is to separate the $h_{jk}(l)$ and an s_k from only a signal x_j which is a mixed signal, in an unknown state, as expressed by Equation (2).

[10] Equation (2) :

$$y_i(t) = \sum_{j=1}^M \sum_{l=0}^{L-1} w_{ij}(l) x_j(t-l)$$

[11] That is, estimation of a value of an unmixing filter or demixing filter $w_{ij}(l)$ is a final aim. The Equations (1) and (2) are formulas for processing data in a time domain, in which L indicates a magnitude of the filter. As the magnitude of the filter increases, an amount of calculation significantly increases. Accordingly, in order to reduce the amount of the calculation, the data in the time domain need to be converted in a signal in a frequency domain. At this time, a frequency domain BSS is performed by using a Short-Time Fourier Transform (STFT), and is expressed by Equation (3).

[12] Equation (3)

[13] :

$$X_j(f, t) = \sum_{\tau = -\frac{L}{2}}^{\frac{L}{2} - 1} x_j(\tau + t) \text{win}(\tau) e^{-j2\pi f \tau}$$

[14]

[15] That is, the STFT is a scheme in which data x_j enough to correspond to a window size with a length of L is loaded and Fourier-transformed, and is repeatedly performed by shifting the data by a little. Through the above-mentioned scheme, a two dimensional data with information on a transverse time frame and a longitudinal frequency bin is made, and thus, in the Equations (1) and (2), convolution in the time domain is transformed into multiplication in the frequency domain. The amount of calculation can be significantly reduced. Therefore, a relation of the microphone signal and an output signal can be expressed by Equation (4).

[16] Equation (4) : $Y(f, t) = W(f)X(f, t)$

[17] In the case of the blind signal extraction, only one signal is extracted differently from the BSS. That is, in the case of the BSS, several signals are separated from each frequency, a permutation problem occurs across different frequency components.

However, in the case of the BSE, since only one signal is extracted from each frequency, there is no permutation problem, but a scale problem still remains.

Disclosure of Invention

Technical Problem

- [18] The present invention has been made to solve the above-mentioned problem in the conventional art, and an aspect of the present invention is to provide an apparatus and a method for solving a scale problem in blind signal extraction of a frequency domain, which are capable of solving the scale problem occurring when the blind signal extraction of the frequency domain is performed.

Solution to Problem

- [19] In accordance with an aspect of the present invention, an apparatus for solving a scale problem in blind signal extraction is provided. The apparatus includes: a frequency component adding unit for adding a $(2n-1)^{\text{th}}$ frequency component and a $2n^{\text{th}}$ frequency component which are different frequency output signals and adjacent to each other; a frequency component re-adding unit for re-adding a $(2m-1)^{\text{th}}$ frequency component and a $2m^{\text{th}}$ frequency component for the frequency component added by the frequency component adding unit; and a blind signal extracting unit for performing blind signal extraction, based on each of an original output signal, a signal added by the frequency element adding unit, and a signal re-added by the frequency component re-adding unit, wherein m and n are natural numbers. In this case, the scale problem is solved based on a coefficient enabling a Euclidean distance to be minimum.
- [20] The blind signal extracting unit may perform the blind signal extraction from two different Short-Time Fourier Transform (STFT) data, based on a lower frequency resolution in which a relative size of the frequency resolution is small.
- [21] The frequency component adding unit repeatedly performs the adding until a signal of the added frequency resolution becomes one.
- [22] The blind signal extraction unit pairs the extracted signals in sequence from the lowest frequency resolution to the highest frequency resolution.
- [23] When any one of the $(2n-1)^{\text{th}}$ frequency component and the $2n^{\text{th}}$ frequency component added by the frequency component adding unit, and the $(2m-1)^{\text{th}}$ frequency component and the $2m^{\text{th}}$ frequency component added by the frequency component re-adding unit is larger than a set scale as compared to the remaining one, it would be better to normalize the two frequency components.
- [24] In the apparatus for solving the scale problem in the blind signal extraction as described above, the values of all frequencies in various frequency resolutions are calculated by using a Euclidean distance and are averaged, and the frequency resolution which has the lowest average is set as an optimal frequency resolution.

- [25] In the apparatus for solving the scale problem in the blind signal extraction as described above, a value E1 for an optimal solution calculated in all frequencies for various frequency resolutions may be calculated by using the Euclidean distance, a value E2 for a secondary optimal solution is calculated by using the Euclidean distance, and the frequency resolution having a largest difference of the calculated values (E2-E1) may be set as an optimal value.
- [26] In accordance with another aspect of the present invention, an apparatus for solving a scale problem in blind signal extraction is provided. The apparatus includes: a first frequency component adding unit for adding a $(2n-1)^{\text{th}}$ frequency component and a $2n^{\text{th}}$ frequency component which are different frequency output signals and adjacent to each other; a second frequency component adding unit for adding a $2m^{\text{th}}$ frequency component and a $(2m+1)^{\text{th}}$ frequency component which are different frequency output signals and adjacent to each other; and a blind signal extracting unit for performing blind signal extraction, based on each of an original output signal, a signal added by the first frequency component adding unit, and a signal added by the second frequency component adding unit, wherein m and n are natural numbers. In this case, the scale problem is solved based on a coefficient enabling a Euclidean distance to be minimum.
- [27] The blind signal extracting unit may perform the blind signal extraction from two different Short-Time Fourier Transform (STFT) data, based on a lower frequency resolution in which a relative size of the frequency resolution is small.
- [28] The extracted signals are arranged such that they overlap and intersect with each other.
- [29] When any one of the $(2n-1)^{\text{th}}$ frequency component and the $2n^{\text{th}}$ frequency component added by the first frequency component adding unit, and the $(2m+1)^{\text{th}}$ frequency component and the $2m^{\text{th}}$ frequency component added by the frequency component adding unit is larger than a set scale as compared to the remaining one, the two frequency components are preferably to be normalized.
- [30] In the apparatus for solving the scale problem in the blind signal extraction as described above, the values of all frequencies in various frequency resolutions are calculated by using a Euclidean distance and are averaged, and the frequency resolution which has the lowest average is set as an optimal frequency resolution.
- [31] In the apparatus for solving the scale problem in the blind signal extraction as described above, a value E1 for an optimal solution calculated in all frequencies for various frequency resolutions may be calculated by using the Euclidean distance, a value E2 for a secondary optimal solution is calculated by using the Euclidean distance, and the frequency resolution having a largest difference of the calculated values (E2-E1) may be set as an optimal value.
- [32] In accordance with still another aspect of the present invention, a method of solving a

scale problem in blind signal extraction is provided. The method includes: adding a $(2n-1)^{\text{th}}$ frequency component and a $2n^{\text{th}}$ frequency component which are different frequency output signals and adjacent to each other; re-adding a $(2m-1)^{\text{th}}$ frequency component and a $2m^{\text{th}}$ frequency component for the frequency component added in the adding of the frequency component; performing blind signal extraction, based on each of an original output signal, a signal added by the frequency component adding unit, and a signal re-added by the frequency component re-adding unit; and pairing the extracted signals in sequence from a lowest frequency resolution to a highest frequency resolution, wherein m and n are natural numbers. In this case, the scale problem is solved based on a coefficient enabling a Euclidean distance to be minimum.

- [33] In the performing of the blind signal extraction, the blind signal extraction from two different Short-Time Fourier Transform (STFT) data is performed, based on a lower frequency resolution in which a relative magnitude of the frequency resolution is small.
- [34] The adding of the frequency component is repeatedly performed until a signal of the added frequency resolution becomes one.
- [35] When any one of the $(2n-1)^{\text{th}}$ frequency component and the $2n^{\text{th}}$ frequency component added in the first frequency component adding, and the $(2m+1)^{\text{th}}$ frequency component and the $2m^{\text{th}}$ frequency component added in the second frequency component adding is larger than a set scale as compared to the remaining one, the two frequency components are normalized
- [36] In the method of solving the scale problem in the blind signal extraction as described above, the values of all frequencies in various frequency resolutions are calculated by using a Euclidean distance and are averaged, and the frequency resolution which has the lowest average is set as an optimal frequency resolution.
- [37] In the method of solving the scale problem in the blind signal extraction as described above, a value $E1$ for an optimal solution calculated in all frequencies for various frequency resolutions may be calculated by using the Euclidean distance, a value $E2$ for a secondary optimal solution is calculated by using the Euclidean distance, and the frequency resolution having a largest difference of the calculated values ($E2-E1$) may be set as an optimal value.
- [38] In accordance with still another aspect of the present invention, a method of solving a scale problem in blind signal extraction is provided. The method includes: first-adding a $(2n-1)^{\text{th}}$ frequency component and a $2n^{\text{th}}$ frequency component which are different frequency output signals and adjacent to each other; second-adding a $2m^{\text{th}}$ frequency component and a $(2m+1)^{\text{th}}$ frequency component which are different frequency output signals and adjacent to each other; performing blind signal extraction, based on each of an original output signal, a signal added in the first frequency component adding, and a

signal added in the second frequency component adding, and arranging the extracted signals such that they overlap and intersect with each other, wherein m and n are natural numbers. In this case, the scale problem is solved based on a coefficient enabling a Euclidean distance to be minimum.

- [39] In the performing of the blind signal extraction, the blind signal extraction from two different Short-Time Fourier Transform (STFT) data is performed, based on a lower-frequency resolution in which a relative magnitude of the frequency resolution is small.
- [40] When any one of the $(2n-1)^{\text{th}}$ frequency component and the $2n^{\text{th}}$ frequency component added in the first frequency component adding, and the $(2m+1)^{\text{th}}$ frequency component and the $2m^{\text{th}}$ frequency component added in the second frequency component adding is larger than a set scale as compared to the remaining one, the two frequency components are preferably to be normalized.
- [41] In the method of solving the scale problem in the blind signal extraction as described above, the values of all frequencies in various frequency resolutions are calculated by using a Euclidean distance and are averaged, and the frequency resolution which has the lowest average is set as an optimal frequency resolution.
- [42] In the method of solving the scale problem in the blind signal extraction as described above, a value $E1$ for an optimal solution calculated in all frequencies for various frequency resolutions may be calculated by using the Euclidean distance, a value $E2$ for a secondary optimal solution is calculated by using the Euclidean distance, and the frequency resolution having a largest difference of the calculated values ($E2-E1$) may be set as an optimal value.

Advantageous Effects of Invention

- [43] According to the present invention, when the blind signal extraction of the frequency domain is performed, the scale problem can be solved because only one signal for different frequencies is extracted.

Brief Description of Drawings

- [44] The above and other aspects, features, and advantages of the present invention will be more apparent from the following detailed description taken in conjunction with the accompanying drawings, in which:
- [45] FIG. 1 is a view illustrating a concept of blind signal separation;
- [46] FIG. 2 is a block diagram schematically illustrating a configuration of an apparatus for solving a scale problem in blind signal extraction of a frequency domain according to an embodiment of the present invention;
- [47] FIG. 3 is a view illustrating a relation of data with different resolutions according to the embodiment of the present invention;

- [48] FIG. 4 is a view illustrating a hierarchical approach to solve the scale problem according to the embodiment of the present invention;
- [49] FIG. 5 is a block diagram schematically illustrating a configuration of an apparatus for solving a scale problem in blind signal extraction of a frequency domain according to another embodiment of the present invention;
- [50] FIG. 6 is a view illustrating an example of an alternative approach to solve the scale problem according to the embodiment of the present invention;
- [51] FIG. 7 is a view illustrating another example of the alternative approach to solve the scale problem according to the embodiment of the present invention;
- [52] FIG. 8 is a flowchart illustrating a process of solving the scale problem in the blind signal extraction of the frequency domain according to an embodiment of the present invention; and
- [53] FIG. 9 is a flowchart illustrating a process of solving the scale problem in the blind signal extraction of the frequency domain according to another embodiment of the present invention.

Mode for the Invention

- [54] Hereinafter, the embodiments of the present invention will be described in detail with reference to the accompanying drawings. In the following description, the description of a technology which is known to those skilled in the art will be omitted.
- [55] In the description of the structural elements of the present invention, further, a different reference numeral may denote structural elements with the same name in each drawing, and also an identical reference numeral may indicate the same structural element in the drawings. However, this case does not mean that a corresponding structural element has a different function in each embodiment, or that the structural element has the same function in different embodiments. The function of each structural element should be determined based on the description of each structural element.
- [56] Further, in the description of the embodiments of the present invention, a detailed description of known structures or functions incorporated herein will be omitted as it may make the subject matter of the present invention rather unclear.
- [57] Furthermore, in the description of the structural element of the present invention, terms of 'first', 'second', 'A', 'B', '(a)', '(b)' and the like may be used. This term is merely used to distinguish one structural element from other structural elements, and a property, an order, a sequence and the like of a corresponding structural element are not limited by the term. In the case that it is described that any structural element 'is connected to', 'is joined to', or 'contacts' another structural element, it should be understood that the structural element is directly connected to or joined to another

structural element, but a third structural element may be connected to, joined to, or contact them.

- [58] FIG. 2 is a block diagram schematically illustrating a configuration of an apparatus for solving a scale problem in blind signal extraction of a frequency domain according to an embodiment of the present invention.
- [59] Referring to FIG. 2, the apparatus 100 for solving the scale problem in the blind signal extraction according to the embodiment of the present invention includes a frequency component adding unit 110, a frequency component re-adding unit 120, and a blind signal extracting unit 130.
- [60] The frequency component adding unit 110 adds a $(2n-1)^{\text{th}}$ frequency component and a $2n^{\text{th}}$ frequency component which are different frequency output signals and adjacent to each other. The frequency component adding unit 110 repeatedly performs the adding until a resolution signal of the added frequency becomes one (1).
- [61] The frequency component re-adding unit 120 re-adds a $(2m-1)^{\text{th}}$ frequency component and a $2m^{\text{th}}$ frequency component for the frequency component added by the frequency component adding unit 110.
- [62] When any one of the $(2n-1)^{\text{th}}$ frequency component and the $2n^{\text{th}}$ frequency component added by the frequency component adding unit 110, and the $(2m-1)^{\text{th}}$ frequency component and the $2m^{\text{th}}$ frequency component added by the frequency component adding unit 120 is larger than a set scale as compared to the remaining one, the two frequency components can be normalized. However, the equalization of the two frequency components is not limited thereto, and may be unconditionally performed regardless of the scale. Further, the normalization of the two frequency components is not limited with relation to normalization of a specific factor such as power, magnitude, and the like, and may be performed relative to various factors.
- [63] The blind signal extracting unit 130 performs the blind signal extraction based on each of an original output signal, the signal added by the frequency component adding unit 110, and the signal re-added by the frequency component re-adding unit 120. Here, the blind signal extracting unit 130 may perform the blind signal extraction from two different Short-Time Fourier Transform (STFT) data, based on a low frequency resolution in which a relative size of the frequency resolution is small. Further, the blind signal extracting unit 130 pairs the extracted signals in sequence from the lowest frequency resolution to the highest frequency resolution.
- [64] In the case of the blind signal extraction, assuming that only one sequence of the output is present, in Equation (4), $Y(f, t) = Y_1(f, t)$, $X(f, t) = [X_1(f, t) \ X_2(f, t)]^T$, and $W(f) = [W_{11}(f) \ W_{12}(f)]$. That is, only a demixing filter for extracting only one signal and a corresponding extracted signal are present.
- [65] FIG. 3 is a view illustrating a relation of data with different resolutions according to

the embodiment of the present invention. The data with the low frequency resolution is identical to a sum of two neighboring values of data with the high frequency resolution. For example, assuming that $x(i)$ has signal information of 100~200Hz and $x(i+1)$ has signal information of 200~300Hz, $x_bar(i, i+1)$ may be a sum of two signals $x(i)$ and $x(i+1)$ which are data having the signal information of 100~300Hz and the low frequency resolution.

[66] Equations can be expanded as described above. Here, the high frequency resolution and the low frequency resolution are determined by a relative magnitude of the frequency resolution of two different STFT data to be compared.

[67] At this time, the data with the low frequency resolution may be utilized in order to solve the scale problem of the data with the high frequency resolution. That is, in order to solve the scale problem, basically, different frequency data are required as expressed by Equation 5. The Equation 5 is a formula related to the frequency resolution.

[68] Equation (5):

$$\begin{aligned} y^{(i)} &= \mathbf{W}^{(i)} \mathbf{X}^{(i)} \Rightarrow Y^{(i)} = \mathbf{W}^{(i)} \mathbf{X}^{(i)} \quad (i: \text{frequency index}) \\ y^{(i+1)} &= \mathbf{W}^{(i+1)} \mathbf{X}^{(i+1)} \Rightarrow Y^{(i+1)} = \mathbf{W}^{(i+1)} \mathbf{X}^{(i+1)} \end{aligned}$$

[70] In Equation (5), for convenience, a character i denotes a frequency instead of a character f , and information on a time frame is omitted. Further, a signal of a low frequency domain merging two frequency domains can be expressed by Equation (6).

[71] Equation (6) :

$$\bar{y}^{(i, i+1)} = \bar{\mathbf{W}}^{(i, i+1)} \bar{\mathbf{X}}^{(i, i+1)} \quad \text{with} \quad \bar{\mathbf{X}}^{(i, i+1)} = \mathbf{X}^{(i)} + \mathbf{X}^{(i+1)}$$

[73] In Equation (6), the importance is that blind signal separation is performed in order to predict different demixing filters with respect to three data $x(i)$, $x(i+1)$ and $x_bar(i, i+1)$. A thing which should be kept in mind to progress onward is that separated signals y , $y(i+1)$, and $y_bar(i, i+1)$ must be established by $y_bar(i, i+1) = y(i) + y(i+1)$ for an 'identical signal'. In the embodiment of the present invention, since it is already assumed that three signals come from the signal having all in the case of the blind signal extraction, it is applied such that equality is established if a proportional constant is satisfied.

[74] Thus, in the embodiment of the present invention, a distance measure indicated by Equation 7 is proposed.

[75] Equation (7)

[76]

$$E(a, b) = \frac{1}{2} \sum_m \left| a y_m^{(i+1)} + b y_m^{(i)} - \bar{y}_m^{(i, i+1)} \right|^2$$

(m : sample index)

[77]

[78] Here, since the Equation (7) is a quadratic equation, the Equation (7) is differentiated by coefficients a and b so as to obtain values of a and b and values of remaining y are loaded from the data, thereby calculating a value of E corresponding to a , b and y . The Equation (7) can be expressed as Equation (8).

[79] Equation (8) :

[80]

$$E(a, b) = \frac{1}{2} \sum_m \left| a y_m^{(i+1)} + b y_m^{(i)} - \bar{y}_m^{(i, i+1)} \right|^2$$

[81]

In Equation (8), m is a sample index, and i is an index of a frequency component. In the Equation (8), after two neighboring components $y_m^{(i)}$, $y_m^{(i+1)}$ of a high

frequency resolution are multiplied by values of two complex numbers a and b , a Euclidean distance of the obtained value and a component $\bar{y}_m^{(i, i+1)}$ of a low

frequency resolution is expressed by a formula. The Equation (8) can be differentiated for a_n and b_n as indicated by Equation (9), in order to seek a and b so that the Euclidean distance E is minimum.

[82] Equation (9) :

[83]

$$\frac{\partial E}{\partial a_n} = \frac{1}{2} \sum_m y_{nm}^{(i+1)} \{ a_n y_{nm}^{(i+1)} + b_n y_{nm}^{(i)} - \bar{y}_{nm}^{(i, i+1)} \}^* = 0$$

$$\frac{\partial E}{\partial b_n} = \frac{1}{2} \sum_m y_{nm}^{(i)} \{ a_n y_{nm}^{(i+1)} + b_n y_{nm}^{(i)} - \bar{y}_{nm}^{(i, i+1)} \}^* = 0$$

[84]

In Equation (10), n of a_n and b_n may be ignored because it corresponds to a number of an output signal. a_n and b_n such that the differential equation becomes zero (0) can be obtained by using the Equation (10).

[85]

Equation (10) :

$$[86] \quad \begin{bmatrix} a_n^* \\ b_n^* \end{bmatrix} = \begin{bmatrix} \frac{\sum_m y_{nm}^{(i)} y_{nm}^{(i)*} \sum_m y_{nm}^{(i+D)} y_{nm}^{(i+D)*} - \sum_m y_{nm}^{(i+D)} y_{nm}^{(i)*} \sum_m y_{nm}^{(i)} y_{nm}^{(i+D)*}}{\sum_m y_{nm}^{(i+D)} y_{nm}^{(i+D)*} \sum_m y_{nm}^{(i)} y_{nm}^{(i)*} - \sum_m y_{nm}^{(i+D)} y_{nm}^{(i)*} \sum_m y_{nm}^{(i)} y_{nm}^{(i+D)*}} \\ \frac{\sum_m y_{nm}^{(i)} y_{nm}^{(i+D)*} \sum_m y_{nm}^{(i+D)} y_{nm}^{(i+D)*} - \sum_m y_{nm}^{(i+D)} y_{nm}^{(i+D)*} \sum_m y_{nm}^{(i)} y_{nm}^{(i)*}}{\sum_m y_{nm}^{(i+D)} y_{nm}^{(i+D)*} \sum_m y_{nm}^{(i)} y_{nm}^{(i)*} - \sum_m y_{nm}^{(i+D)} y_{nm}^{(i)*} \sum_m y_{nm}^{(i)} y_{nm}^{(i+D)*}} \end{bmatrix}$$

[87] In Equation (10), * means a complex conjugate. The scale problem between the two components of the high frequency resolution can be solved by using the obtained a_n and b_n . At this time, when y is estimated as a unit variance of a signal S , y may be expressed by Equation (11).

[88] Equation (11):

$$[89] \quad y^i = \frac{S^i}{\sigma^i}$$

$$y^{i+1} = \frac{S^{i+1}}{\sigma^{i+1}}$$

$$\bar{y}^{(i,i+1)} = \frac{S^i + S^{i+1}}{\sigma^{(i,i+1)}} = \frac{y^i \sigma^i + y^{i+1} \sigma^{i+1}}{\sigma^{(i,i+1)}} = \frac{\sigma^{i+1}}{\sigma^{(i,i+1)}} y^{i+1} + \frac{\sigma^i}{\sigma^{(i,i+1)}} y^i$$

[90] Further, since it is predicted that following Equation (12) can be derived from Equation (8),

$$[91] \quad \text{Equation (12):} \quad a_n y_{nm}^{(i+1)} + b_n y_{nm}^{(i)} = \bar{y}_{nm}^{(i,i+1)}$$

[92]

[93] a_n and b_n can be calculated by Equation (13) from these relative Equations, and the scale problem can be solved by appropriately using a_n and b_n .

$$[94] \quad \text{Equation (13):} \quad a_n = \frac{\sigma^{i+1}}{\sigma^{(i,i+1)'}} \quad b_n = \frac{\sigma^i}{\sigma^{(i,i+1)'}}$$

[95] The scale problem for two different frequency output signals in the high frequency resolution signal can be solved. The terminal aim of the present invention is to solve the scale problem for all frequencies, and the solution of the scale problem may be generally achieved in two manners. The first manner is a hierarchical approach, and the other is an alternative approach.

[96] In the hierarchical approach, as shown in FIG. 4, a signal of a lower frequency resolution is structurally and continuously generated and an identical work is repeatedly performed. For example, in order to solve the scale problem in a signal with five hundred twelve frequency resolutions (high frequency resolution), the signal must be compared to a signal with two hundred fifty six frequency resolutions (low frequency resolution). However, in the circumstance, the scale problems of (1, 2), (3, 4), (511, 512) can be solved, but the scale problems in (1, 2) and (3, 4), (3, 4) and (5, 6), (509, 510) and (511, 512) cannot be solved. Therefore, the scale problem is solved

by generating data having a lower structure. That is, the scale problem is solved by generating one hundred twenty eight frequency resolution (low frequency resolution) for two hundred fifty six frequency resolution (high frequency resolution which a signal has at this time), in which this is repeatedly performed until one signal of the low frequency resolution remains.

[97] FIG. 5 is a block diagram schematically illustrating a configuration of an apparatus for solving a scale problem in blind signal extraction of a frequency domain according to another embodiment of the present invention.

[98] Referring to FIG. 5, the apparatus 200 for solving the scale problem in the blind signal extraction according to another embodiment of the present invention includes a first frequency component adding unit 210, a second frequency component adding unit 220, and a blind signal extracting unit 230.

[99] The first frequency component adding unit 210 adds $(2n-1)^{\text{th}}$ frequency component and $2n^{\text{th}}$ frequency component which are different frequency output signals and adjacent to each other.

[100] The second frequency component adding unit 220 adds $2m^{\text{th}}$ frequency component and $(2m+1)^{\text{th}}$ frequency component which are different frequency output signals and adjacent to each other.

[101] When any one of the $(2n-1)^{\text{th}}$ frequency component and the $2n^{\text{th}}$ frequency component added by the frequency component adding unit 210, and the $(2m+1)^{\text{th}}$ frequency component and the $2m^{\text{th}}$ frequency component added by the second frequency component 220 is larger than a set scale as compared to the remaining one, the two frequency components can be preferably to be normalized. However, the equalization of the two frequency components is not limited thereto, and may be unconditionally performed regardless of the scale. Further, the equalization of the two frequency components is not limited with relation to equalization of a specific factor such as power, magnitude, and the like, and may be performed relative to various factors.

[102] The blind signal extracting unit 230 performs the blind signal extraction based on each of an original output signal, the signal added by the first frequency component adding unit 210, and the signal re-added by the second frequency component re-adding unit 220. Here, the blind signal extracting unit 230 may perform the blind signal extraction from two different Short-Time Fourier Transform (STFT) data, based on a lower frequency resolution in which a relative size of the frequency resolution is small. Further, the blind signal extracting unit 230 can arrange extracted signals such that they overlap and intersect with each other.

[103] The alternative approach can solve the scale problem if two sorts of frequency resolutions are present, as shown in FIGS. 6 and 7. That is, it means that only two

hundred fifty six frequency resolution signals are necessary when the scale problem is solved in five hundred twelve frequency resolution signals. In this case, when the scale problem is solved in the five hundred twelve frequency resolution signals, the frequency component is duplicated in a manner of (1, 2), (2, 3), (3, 4), (4, 5), , (510, 511), and (511, 512), thereby solving the scale problem.

- [104] FIG. 8 is a flowchart illustrating a process of solving the scale problem in the blind signal extraction according to an embodiment of the present invention.
- [105] Referring FIG. 8, the frequency component adding unit 110 adds $(2n-1)^{\text{th}}$ frequency component and $2n^{\text{th}}$ frequency component which are different frequency output signals and adjacent to each other. In step S110, the frequency component adding unit 110 repeatedly performs the adding until one signal of the added frequency resolution remains.
- [106] In step S120, the frequency component re-adding unit 120 re-adds a $(2n-1)^{\text{th}}$ frequency component and a $2n^{\text{th}}$ frequency component for the frequency component added by the frequency component adding unit 110.
- [107] When any one of the $(2n-1)^{\text{th}}$ frequency component and the $2n^{\text{th}}$ frequency component added by the frequency component adding unit 110, and the $(2m-1)^{\text{th}}$ frequency component and the $2m^{\text{th}}$ frequency component added by the frequency component re-adding unit 120 is larger than a set scale as compared to the remaining one, the two frequency components can be took an average. However, the equalization of the two frequency components is not limited thereto, and may be unconditionally performed regardless of the scale.
- [108] In step S130, the blind signal extracting unit 130 performs the blind signal extraction based on each of an original output signal, the signal added by the frequency component adding unit 110, and the signal re-added by the frequency component re-adding unit 120. Here, the blind signal extracting unit 130 may perform the blind signal extraction from two different Short-Time Fourier Transform (STFT) data, based on a low frequency resolution in which a relative size of the frequency resolution is small. Further, the blind signal extraction unit 130 pairs the extracted signals in sequence from the lowest frequency resolution to the highest frequency resolution.
- [109] FIG. 9 is a flowchart illustrating a process of solving the scale problem in the blind signal extraction of the frequency domain according to another embodiment of the present invention.
- [110] Referring to FIG. 9, in step S210, the first frequency component adding unit 210 adds $(2n-1)^{\text{th}}$ frequency component and $2n^{\text{th}}$ frequency component which are different frequency output signals and adjacent to each other.
- [111] The second frequency component adding unit 220 adds $2m^{\text{th}}$ frequency component and $(2m+1)^{\text{th}}$ frequency component which are different frequency output signals and

adjacent to each other.

- [112] When any one of the $(2n-1)^{\text{th}}$ frequency component and the $2n^{\text{th}}$ frequency component added by the frequency component adding unit 210, and the $(2m+1)^{\text{th}}$ frequency component and the $2m^{\text{th}}$ frequency component added by the second frequency component 220 is larger than a set scale as compared to the remaining one, the two frequency components can be preferably normalized. However, the equalization of the two frequency components is not limited thereto, and may be unconditionally performed regardless of the scale.
- [113] In step S230, the blind signal extracting unit 230 performs the blind signal extraction based on each of an original output signal, the signal added by the first frequency component adding unit 210, and the signal re-added by the second frequency component re-adding unit 220. Here, the blind signal extracting unit 230 may perform the blind signal extraction from two different Short-Time Fourier Transform (STFT) data, based on a low frequency resolution in which a relative size of the frequency resolution is small. Further, the blind signal extracting unit 230 can arrange extracted signals such that overlap and intersect with each other.
- [114] According to the apparatus and the method for solving the scale problem in the above-mentioned blind signal extraction, an optimal frequency resolution value is changed by a little depending on an environment, and thus the frequency resolution value is not limited to a specific value. At this time, the optimal frequency resolution may be determined with reference to a value of E determined by Equation (8). The value of E means a value obtained by calculating a difference between the frequency signal of the low frequency resolution and the high frequency resolution in the scale and permutation by using the Euclidean distance after the scale and permutation of a signal of two neighboring frequency bins of the high frequency resolution are regulated. Accordingly, if the permutation and the scale problem are accurately solved, the value of E becomes zero (0). In the meantime, if they are inaccurate, the value of E increases.
- [115] Two methods may be proposed considering this point. In the first method, an average of values of E for all frequencies of the various frequency resolutions is calculated, and the frequency resolution having the lowest average value of E is regarded as an optimal frequency resolution. In the second method, not only a value E1 of E for the optimal solution (in which the permutation and the scale are solved) but also a value E2 of E for a secondary optimal solution in each frequency of the various frequency resolutions are calculated, and then a difference of two values (E2-E1) is observed. The more the difference of the values (E2-E1) increases, the more clear a distinction for two solutions is, so that reliability for the value of E1 is more improved. Meanwhile, the less the difference of the values (E2-E1) decreases, the more unclear the distinction for

two solutions is, so that the reliability for the value of E1 is degraded. That is, the frequency resolution having the largest difference of the values (E2-E1) may be set as the optimal value.

[116] After the optimal frequency resolution is obtained, an area of the frequency resolution in which a signal is desired to be essentially processed is calculated by using a principle of the above-mentioned hierarchical approach. For example, an aim is to calculate NFFT=2048 in order to currently process a voice. Assuming that an optimal frequency resolution for solving the scale problem in the proposed manner is NFFT=512, the scale problem for NFFT=512 and NFFT=1024 is solved by a reference of NFFT=512, and then the scale problem for NFFT=104 and NFFT=2048 is solved again, thereby solving the scale problem step by step for NFFT=2048 which is the frequency resolution to be essentially solved.

[117] Although it is described that all structural elements constituting the embodiment of the present invention are integrated with one piece, or integrally operated, it is noted that the present invention is not limited to the embodiment necessarily. At least two elements of all structural elements may be selectively joined and operate without departing from the scope of the present invention. Further, all structural elements may be implemented in independent hardware respectively, but some or all of the structural elements may be selectively combined and implemented in computer programs which have a program module performing functions of some elements or all elements which are combined in one or more pieces of hardware. Furthermore, such a computer program may be stored in a computer readable medium such as a USB memory, a CD, a flash memory and the like, and read and executed by a computer so as to implement the embodiment of the present invention. A storage medium for the computer program may include a magnetic recording medium, an optical recording medium, a carrier wave medium and the like.

[118] Further, all terminologies including technical or scientific terms have the same meanings as those generally understood by persons skilled in the art to which the present invention belongs, respectively, unless they are differently defined in the detailed description. It should be interpreted that general terms including the predefined terms are identical to meanings in a context of the related technology. Also, the terms should not be ideally or excessively interpreted as formal meanings unless they are not clearly defined in the present invention.

[119] Although the technical spirit of the present invention is simply and exemplary described in the above-mentioned description, it will be appreciated by those skilled in the art to which the present invention pertains that various changes and modifications may be implemented without departing from the natural scope of the present invention. Further, the embodiments of the present invention disclosed in the description are to

not limit but describe the technical spirits of the present invention, and of course the technical scope and spirits of the present invention is not limited by these embodiments. Thus, the scope of the present invention should be interpreted through the claims appended to the description, and it should be understood that all technical spirits within equivalents thereto pertain to the scope of the present invention.

Claims

- [Claim 1] An apparatus for solving a scale problem in blind signal extraction of a frequency domain, the apparatus comprising:
a frequency component adding unit for adding a $(2n-1)^{\text{th}}$ frequency component and a $2n^{\text{th}}$ frequency component which are different frequency output signals and adjacent to each other;
a frequency component re-adding unit for re-adding a $(2m-1)^{\text{th}}$ frequency component and a $2m^{\text{th}}$ frequency component for the frequency component added by the frequency component adding unit;
and
a blind signal extracting unit for performing blind signal extraction, based on each of an original output signal, a signal added by the frequency element adding unit, and a signal re-added by the frequency component re-adding unit,
wherein the scale problem is solved based on a coefficient enabling a Euclidean distance to be minimum and m and n are natural numbers.
- [Claim 2] The apparatus as claimed in claim 1, wherein the blind signal extracting unit performs the blind signal extraction from two different Short-Time Fourier Transform (STFT) data, based on a lower frequency resolution in which a relative magnitude of the frequency resolution is small.
- [Claim 3] The apparatus as claimed in claim 1, wherein the frequency component adding unit repeatedly performs the adding until one signal of the added frequency resolution remains.
- [Claim 4] The apparatus as claimed in claim 3, wherein the blind signal extracting unit pairs the extracted signals in sequence from a lowest frequency resolution to a highest frequency resolution.
- [Claim 5] The apparatus as claimed in claim 1, wherein when any one of the $(2n-1)^{\text{th}}$ frequency component and the $2n^{\text{th}}$ frequency component added by the frequency component adding unit, and the $(2m-1)^{\text{th}}$ frequency component and the $2m^{\text{th}}$ frequency component re-added by the frequency element re-adding unit is larger than a set scale as compared to the remaining one, the two frequency components are normalized.
- [Claim 6] The apparatus as claimed in claim 1, wherein the values of all frequencies in various frequency resolutions are calculated by using a Euclidean distance and are averaged, and the frequency resolution which has the lowest average is set as an optimal frequency resolution.
- [Claim 7] The apparatus as claimed in claim 6, wherein a value $E1$ for an optimal

solution calculated in all frequencies in various frequency resolutions is calculated by using the Euclidean distance, a value E2 for a secondary optimal solution is calculated by using the Euclidean distance, and the frequency resolution having a largest difference of the calculated values (E2-E1) is set as an optimal value.

- [Claim 8] An apparatus for solving a scale problem in blind signal extraction, the apparatus comprising:
a first frequency component adding unit for adding a $(2n-1)^{\text{th}}$ frequency component and a $2n^{\text{th}}$ frequency component which are different frequency output signals and adjacent to each other;
a second frequency component adding unit for adding a $2m^{\text{th}}$ frequency component and a $(2m+1)^{\text{th}}$ frequency component which are different frequency output signals and adjacent to each other; and
a blind signal extracting unit for performing blind signal extraction, based on each of an original output signal, a signal added by the first frequency component adding unit, and a signal added by the second frequency component adding unit,
wherein the scale problem is solved based on a coefficient enabling a Euclidean distance to be minimum, and m and n are natural numbers.
- [Claim 9] The apparatus as claimed in claim 8, wherein the blind signal extracting unit performs the blind signal extraction from two different Short-Time Fourier Transform (STFT) data, based on a lower frequency resolution in which a relative magnitude of the frequency resolution is small.
- [Claim 10] The apparatus as claimed in claim 9, wherein the extracted signals are arranged such that they overlap and intersect with each other.
- [Claim 11] The apparatus as claimed in claim 8, wherein when any one of the $(2n-1)^{\text{th}}$ frequency component and the $2n^{\text{th}}$ frequency component added by the first frequency component adding unit, and the $(2m+1)^{\text{th}}$ frequency component and the $2m^{\text{th}}$ frequency component added by the frequency component adding unit is larger than a set scale as compared to the remaining one, the two frequency components are normalized.
- [Claim 12] The apparatus as claimed in claim 8, wherein the values of all frequencies in various frequency resolutions are calculated by using a Euclidean distance and are averaged, and the frequency resolution which has the lowest average is set as an optimal frequency resolution.
- [Claim 13] The apparatus as claimed in claim 12, wherein a value E1 for a calculated optimal solution in all frequencies of various frequency resolutions is calculated by using the Euclidean distance, a value E2 for a

secondary optimal solution is calculated by using the Euclidean distance, and the frequency resolution having a largest difference of the calculated values ($E2-E1$) is set as an optimal value.

[Claim 14]

A method of solving a scale problem in blind signal extraction, the method comprising:

adding a $(2n-1)^{\text{th}}$ frequency component and a $2n^{\text{th}}$ frequency component which are different frequency output signals and adjacent to each other; re-adding a $(2m-1)^{\text{th}}$ frequency component and a $2m^{\text{th}}$ frequency component for the frequency component added in the frequency component adding;

performing blind signal extraction, based on each of an original output signal, a signal added by a frequency component adding unit, and a signal re-added by a frequency component re-adding unit; and

pairing the extracted signals in sequence from a lowest frequency resolution to a highest frequency resolution,

wherein the scale problem is solved based on a coefficient enabling a Euclidean distance to be minimum, and m and n are natural numbers.

[Claim 15]

The method as claimed in claim 14, wherein in the performing of the blind signal extraction, the blind signal extraction from two different Short-Time Fourier Transform (STFT) data is performed, based on a lower frequency resolution in which a relative magnitude of the frequency resolution is small.

[Claim 16]

The method as claimed in claim 14, wherein the adding of the frequency component is repeatedly performed until a signal of the added frequency resolution becomes one.

[Claim 17]

The method as claimed in claim 14, wherein when any one of the $(2n-1)^{\text{th}}$ frequency component and the $2n^{\text{th}}$ frequency component added in the first frequency component adding, and the $(2m+1)^{\text{th}}$ frequency component and the $2m^{\text{th}}$ frequency component added in the second frequency component adding is larger than a set scale as compared to the remaining one, the two frequency components are normalized.

[Claim 18]

The method as claimed in claim 14, wherein the values of all frequencies for various frequency resolutions are calculated by using a Euclidean distance and are averaged, and the frequency resolution having the lowest average is set as an optimal frequency resolution.

[Claim 19]

The method as claimed in claim 18, wherein a value $E1$ for an optimal solution calculated in all frequencies in various frequency resolutions is calculated by using the Euclidean distance, a value $E2$ for a secondary

optimal solution is calculated by using the Euclidean distance, and the frequency resolution having a largest difference of the calculated values ($E2-E1$) is set as an optimal value.

[Claim 20]

A method of solving a scale problem in blind signal extraction, the method comprising:

first-adding a $(2n-1)^{\text{th}}$ frequency component and a $2n^{\text{th}}$ frequency component which are different frequency output signals and adjacent to each other;

second-adding a $2m^{\text{th}}$ frequency component and a $(2m+1)^{\text{th}}$ frequency component which are different frequency output signals and adjacent to each other;

performing blind signal extraction, based on each of an original output signal, a signal added in the first frequency component adding, and a signal added in the second frequency component adding, and arranging the extracted signals such that they overlap and intersect with each other,

wherein the scale problem is solved based on a coefficient enabling a Euclidean distance to be minimum, and m and n are natural numbers.

[Claim 21]

The method as claimed in claim 20, wherein in the performing of the blind signal extraction, the blind signal extraction from two different Short-Time Fourier Transform (STFT) data is performed, based on a low frequency resolution in which a relative magnitude of the frequency resolution is small.

[Claim 22]

The method as claimed in claim 20, wherein when any one of the $(2n-1)^{\text{th}}$ frequency component and the $2n^{\text{th}}$ frequency component added in the first frequency component adding, and the $(2m+1)^{\text{th}}$ frequency component and the $2m^{\text{th}}$ frequency component added in the second frequency component adding is larger than a set scale as compared to the remaining one, the two frequency components are normalized.

[Claim 23]

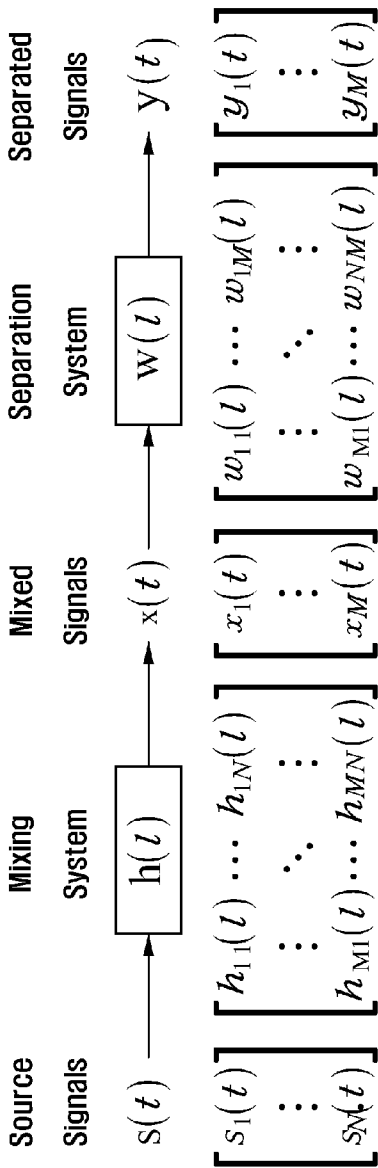
The method as claimed in claim 20, wherein the values of all frequencies for various frequency resolutions are calculated by using a Euclidean distance and are averaged, and the frequency resolution having the lowest average is set as an optimal frequency resolution.

[Claim 24]

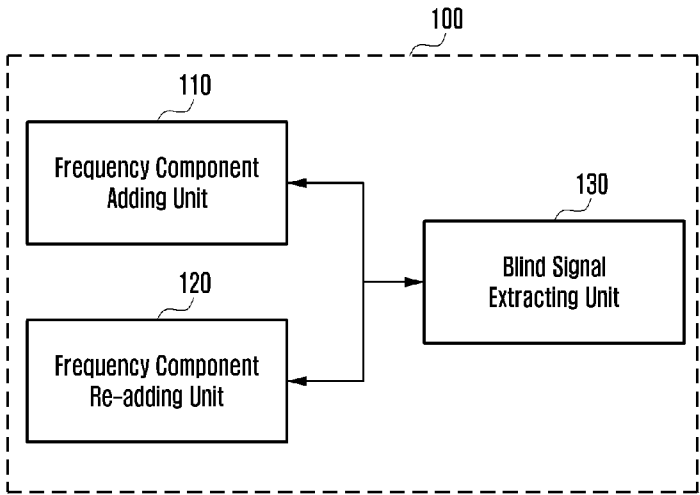
The method as claimed in claim 23, wherein a value $E1$ for an optimal solution calculated in all frequencies for various frequency resolutions is calculated by using the Euclidean distance, a value $E2$ for a secondary optimal solution is calculated by using the Euclidean distance, and the frequency resolution having a largest difference of the

calculated values (E2-E1) is set as an optimal value.

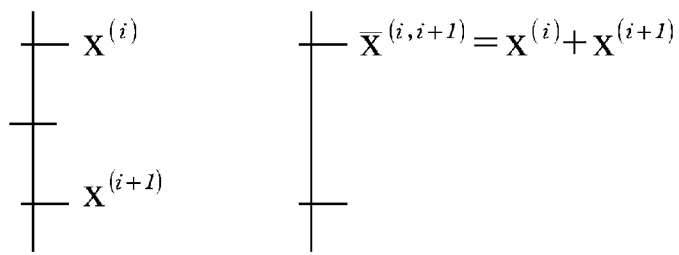
[Fig. 1]



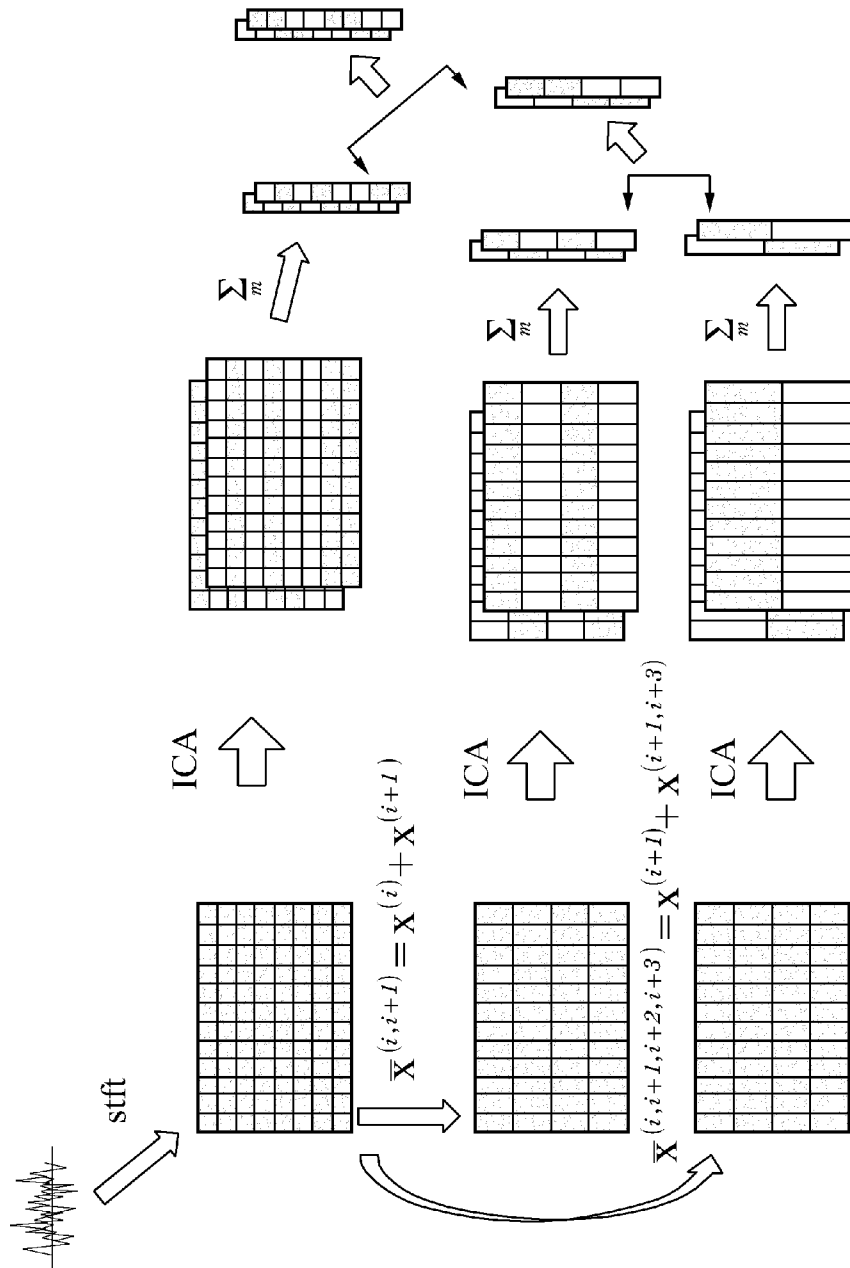
[Fig. 2]



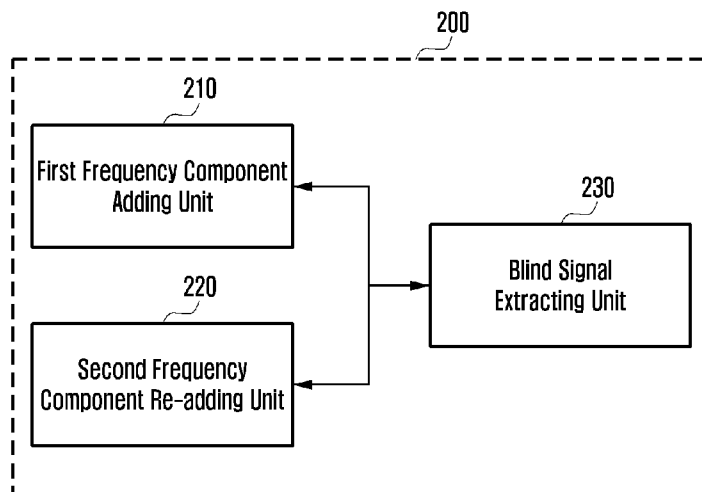
[Fig. 3]



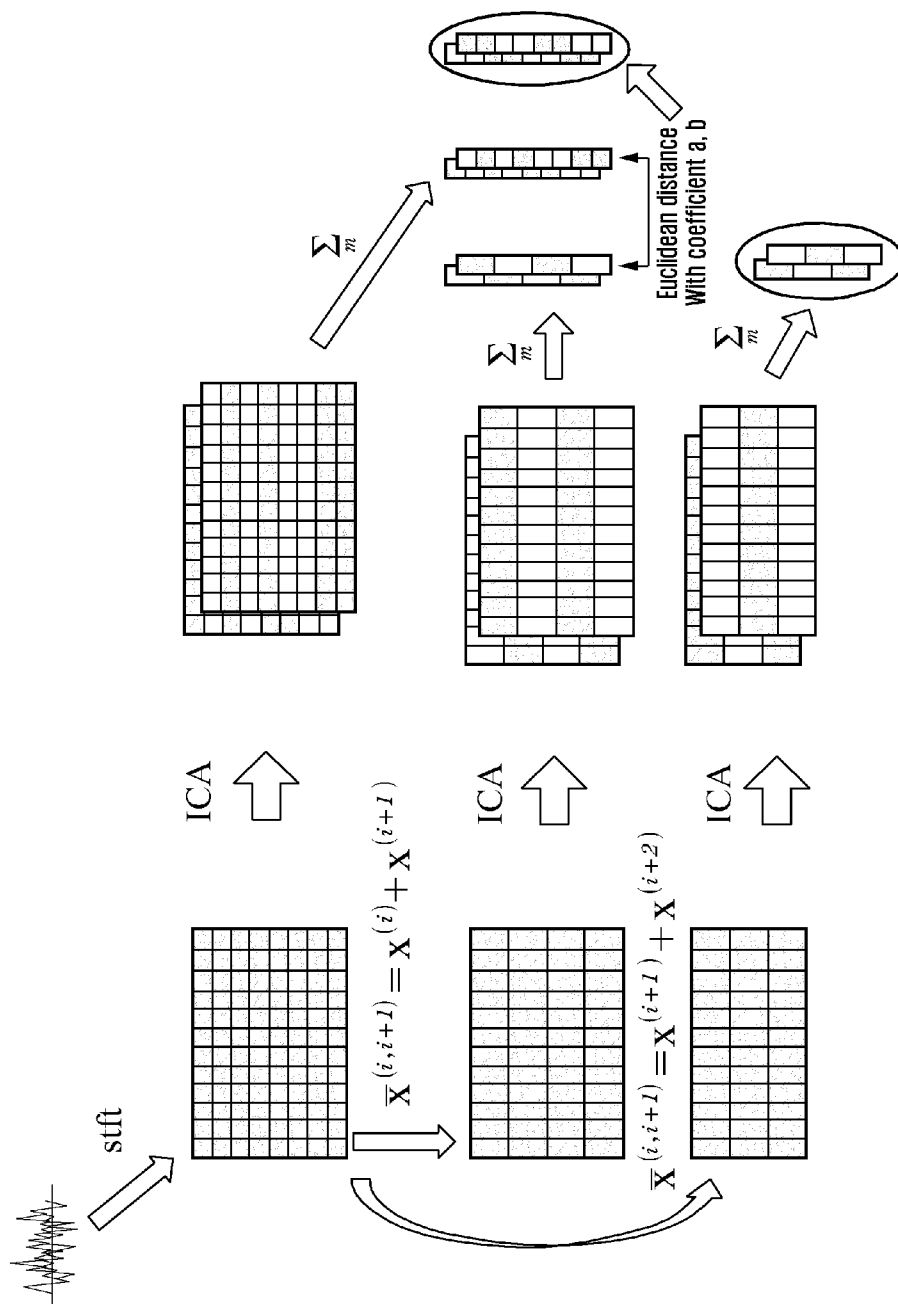
[Fig. 4]



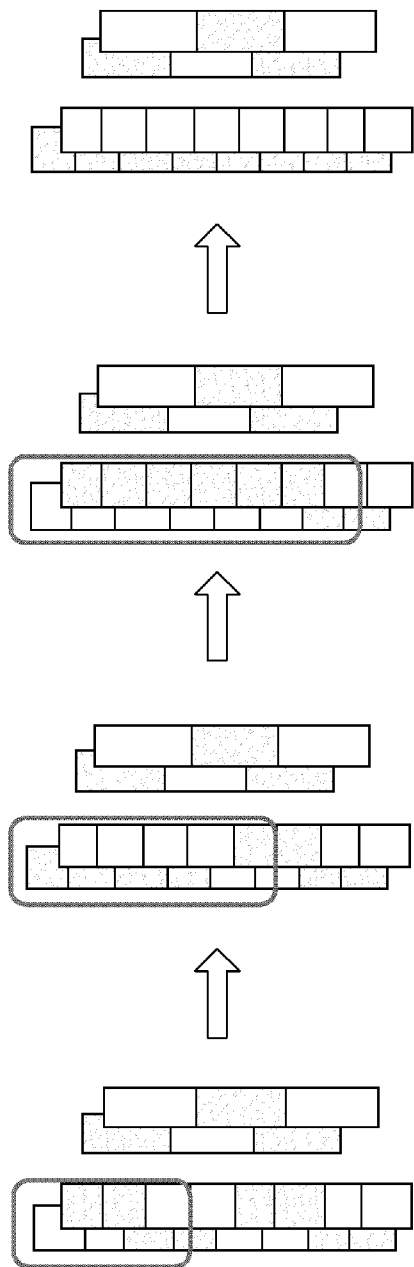
[Fig. 5]



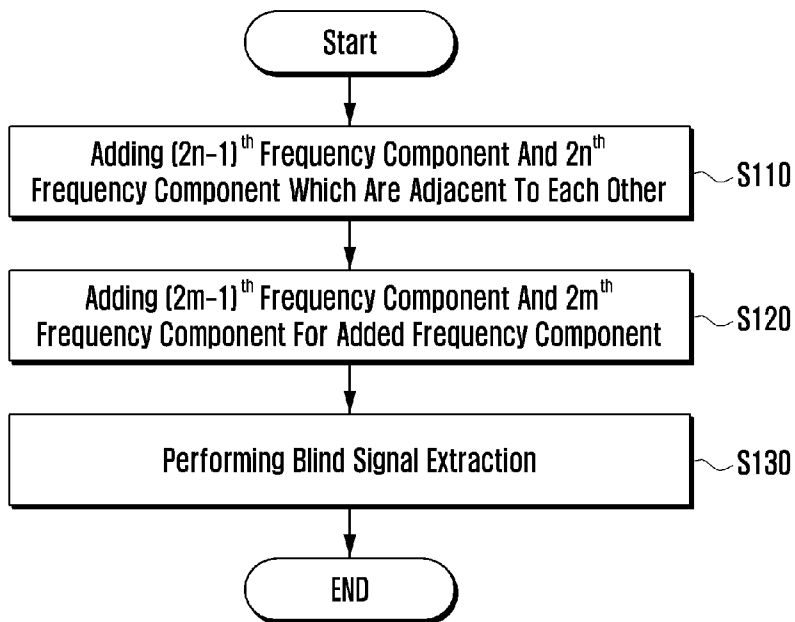
[Fig. 6]



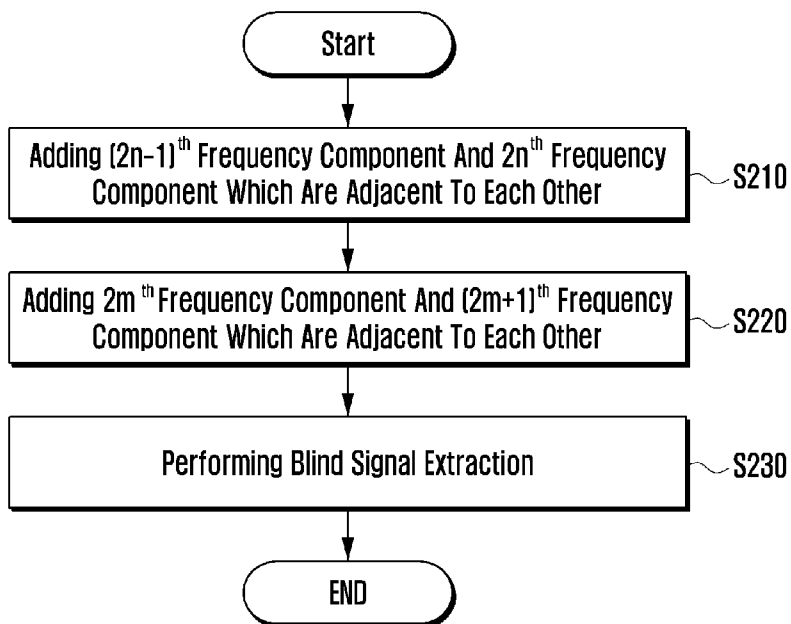
[Fig. 7]



[Fig. 8]



[Fig. 9]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2014/001536**A. CLASSIFICATION OF SUBJECT MATTER****G10L 21/0272(2013.01)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)

G10L 21/0272; G06F 17/10; G10L 21/02; G06F 17/00; H04L 12/28

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: scale, problem, blind, extraction.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR 10-2011-0121955 A (KOREA ADVANCED INSTITUTE OF SCIENCE AND TECHNOLOGY) 09 November 2011 See abstract, claim 1 and fig. 2.	1-24
A	US 2013-0031152 A1 (XUEJING SUN) 31 January 2013 See abstract, claim 1, and figs. 1, 4.	1-24
A	KR 10-2011-0070764 A (ELECTRONICS AND TELECOMMUNICATIONS RESEARCH INSTITUTE et al.) 24 June 2011 See abstract, fig. 1.	1-24

☐ 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

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"&" document member of the same patent family

Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/KR2014/001536

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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US 2013-0031152 A1	31/01/2013	CN102903368 A EP 2551850 A1	30/01/2013 30/01/2013
KR 10-2011-0070764 A	24/06/2011	US 2011-0149719 A1 US 8521477 B2	23/06/2011 27/08/2013