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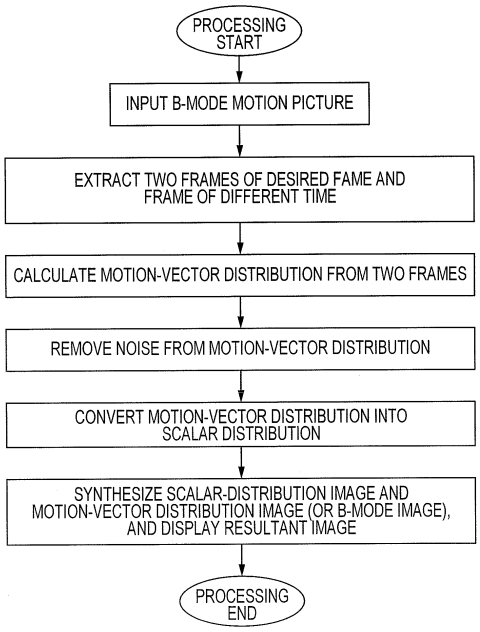
## (54) ULTRASONIC IMAGE PROCESSING METHOD AND DEVICE, AND ULTRASONIC IMAGE PROCESSING PROGRAM

(57) An ultrasonic image processing method and device, and an ultrasonic image processing program which can correspond to analytical methods different depending on a region or the purpose of a diagnosis or treatment. The ultrasonic image processing method comprises an image data creation step which stores a detection result obtained by irradiating a subject with ultrasonic waves by an irradiating section and detecting an ultrasonic signal from the subject by a detecting section and creates at least two-frame image data different in detection timing on the basis of the stored detection result, a motion vector distribution image creation step which creates a motion vector distribution image on the basis of a predetermined motion vector analysis through the use of a plurality frames of the image data, and a conversion step which converts a vector distribution image to a scalar distribution image on the basis of a plurality of established regions of interest (ROI).

*FIG. 2*

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## Description

Technical Field

**[0001]** The present invention is a technology relating to an ultrasonic image processing method and device and an ultrasonic image processing program capable of clearly distinguishing a tissue border at the time of imaging a living body with ultrasonic waves.

Background Art

**[0002]** For an ultrasonic image processing device employed in medical diagnostic imaging, there is disclosed a method in which, as described in, for example, patent literature 1, a modulus-of-elasticity distribution in a tissue is estimated based on a magnitude of a change in a small area in a diagnostic motion picture, and hardness is converted into a color map and then displayed. However, when the tissue border is noted in order to perform modulus-of-elasticity processing, sharpness is found to be degraded. As described in patent literature 2, a technique of producing a scalar distribution image directly from motion vectors of a diagnostic motion picture so as to improve the degree of distinction of the tissue border is available.

**[0003]** In order to remove a noise from a vector distribution, a low-pass filter for uniform smoothing is, as described in, for example, patent literature 3, adopted. In a B-mode image (a scalar distribution of brightness), a similarity filter that retains the sharpness of an edge while removing the noise has been invented in the patent literature 3.

Citation List

Patent Literature

**[0004]**

Patent Literature 1: Japanese Patent Application laid-Open Publication No. 2004-135929
Patent Literature 2: Japanese Patent Application laid-Open Publication No. 2008-079792
Patent Literature 3: Japanese Patent Application laid-Open Publication No. 2004-129773

Summary of Invention

Technical Problem

**[0005]** As a conventional method, for example, the patent Literature 2 describes that an x-direction component or a y-direction component, a vector length, or a vector angle with respect to a reference direction is obtained from each of motion vectors in order to create a scalar value distribution on the basis of the values. Therefore, all pieces of vector information are not contracted, and a vector distribution may or may not be accurately reflected depending on an object image.

**[0006]** In addition, there is an unsolved problem that when a uniformly smoothing type low-pass filter is used to remove an error vector in a motion vector distribution as preprocessing, the sharpness of a border is degraded.

**[0007]** In addition, since an analysis technique is not selected according to a region or a purpose of diagnosis or treatment, the method is not compatible with the analysis technique that varies depending on the region or the purpose of diagnosis or treatment.

**[0008]** An object of the present invention is to provide an ultrasonic image processing method and device and an ultrasonic image processing program which are compatible with an analysis technique that varies depending on a region or a purpose of diagnosis or treatment.

Solution to Problem

**[0009]** The present invention includes means for converting motion vectors into a scalar distribution on the basis of a selected method.

**[0010]** In the present invention, the motion-vector distribution image is converted into a scalar-distribution image on the basis of plural set regions of interest (ROIs).

**[0011]** In the present invention, a motion vector distribution is converted into a complex matrix and then subjected to eigenvalue expansion. Thus, a coexistent change pattern is decomposed into eigenvalues, and extracted in consideration of amplitudes and phases of vectors. Therefore, appropriate border distinction can be achieved. In addition, a scalar distribution is constructed for each set of components of motion vectors, and a similarity filter capable of achieving both noise removal and edge preservation is applied to each of scalar distributions. A vector distribution is constructed from a result of the application. Thus, the noise removal can be achieved without degradation of the sharpness of a border.

Advantageous Effects of Invention

**[0012]** According to the present invention, an ultrasonic image processing method and device and an ultrasonic image processing program which are compatible with an analysis technique that varies depending on a region or a purpose of diagnosis or treatment can be provided.

Brief Description of Drawings

**[0013]**

Fig. 1 is a diagram showing an example of a system configuration for an ultrasonic image processing method of the present invention.
Fig. 2 is a diagram showing a processing procedure for an ultrasonic border detection method of the present invention.

Fig. 3 is a diagram showing an example of a motion vector distribution in the present invention.
Fig. 4 is a diagram showing a processing procedure for eigenvalue expansion of the present invention.
Fig. 5 includes diagrams showing an example of motion vector extraction for an invasive tumor in the present invention.
Fig. 6 includes diagrams showing an effect of ultrasonic border detection through eigenvalue expansion of the present invention.
Fig. 7 includes diagrams showing an example of motion vector extraction for the biceps muscle of arm in the present invention.
Fig. 8 includes diagrams showing an effect of ultrasonic border detection through divergence and rotation of the present invention.
Fig. 9 is a diagram showing an effect of a motion vector similarity filter of the present invention.
Fig. 10 is a diagram showing a processing procedure for the motion vector similarity filter of the present invention.
Fig. 11 is a diagram showing an example of a weighting function for the motion vector similarity filter of the present invention.
Fig. 12 includes diagrams showing processing procedures for a synthetic display method of the present invention.
Fig. 13 is a diagram showing an example of display by the synthetic display method of the present invention; and
Fig. 14 is a diagram describing a chemical formula and others.

Description of Embodiments

**[0014]** Fig. 1 shows an example of a system configuration for an ultrasonic border detection method of the present invention. An ultrasonic probe 1 having ultrasonic elements arrayed one-dimensionally transmits an ultrasonic beam (ultrasonic pulses) to a living body, and receives an echo signal (receiving signal) reflected from the living body. Under the control of a control system 4, a transmission signal having a delay time matched with a transmission focus is outputted from a transmission beam former 3, and sent to the ultrasonic prove 1 via a transmitting/receiving selection switch 5. An ultrasonic beam reflected or scattered inside the living body and returned to the ultrasonic probe 1 is converted into an electric signal by the ultrasonic probe 1, and sent as a receiving signal to a receiving beam former 6 via the transmitting/receiving selection switch 5. The receiving beam former 6 is a complex beam former that mixes two receiving signals that are 90° out of phase. The receiving beam former 6 performs dynamic focus in which the delay time is adjusted according to the receiving timing under the control of the control system 4, and outputs a radiofrequency (RF) signal of a real part and an imaginary part. The RF signal is detected by an envelope detection unit 7, converted into a video signal, inputted to a scan converter 8, and then converted into image data (B-mode image data). The foregoing configuration is identical to that of a known ultrasonic imaging system.

**[0015]** In a device of the present invention, a processing unit 10 produces a motion vector distribution on the basis of image data items of two or more frames outputted from the scan converter 8. Thereafter, the produced motion vector distribution is converted into a scalar distribution. After the original image data items and the associated motion vector distribution or scalar distribution are synthesized by a synthesis unit 12, the resultant data is displayed on a display unit 13.

**[0016]** A parameter setting unit 11 is used to set parameters for signal processing to be performed by the processing unit 10 or select a display image to be provided by the synthesis unit 12. The parameters are entered through a user interface 2 by an operator (a diagnostic machine operator). A motion-picture display method is, for example, such that an original image and a vector distribution image (or a scalar image) are synthesized into one image and the image is displayed on the display, or two or more motion pictures are displayed side by side.

**[0017]** Fig. 2 shows an example of processing of an ultrasonic image processing method to be performed by the processing unit 10 and synthesis unit 12 of the present invention. First, a B-mode motion picture is inputted. Thereafter, two frames of a desired frame and a frame at a different time are extracted. A motion vector distribution is calculated from the two frames. A motion vector distribution calculation method is implemented based on, for example, a block matching method described in the patent literature 2. A calculated motion vector distribution is subjected to noise removal processing, and a noise-removed motion vector distribution is converted into a scalar distribution. A scalar distribution image and a motion vector distribution image or the B-mode image are synthesized and displayed. Thus, processing of one image is completed. When the desired frame is changed time-sequentially in order to continuously display synthetic images, a synthesized motion picture can be displayed. Herein, in the block matching processing of calculating the motion vector distribution, if a calculated matching error is equal to or larger than a pre-set threshold, the motion picture is not updated. This makes it possible not to display an image of low reliability but to suppress a motion-picture variance. Otherwise, when an index associated with the matching error is displayed together with an image, a diagnostic-machine operator can decide on the reliability of a display image.

**[0018]** Fig. 3 shows an example of a motion vector distribution in the present invention. As a region of interest (ROI), a range of vectors that number, for example, mxn is set. In the present invention, an x-direction component of each of vectors in the vector distribution and a y-direction component thereof are permuted with a real part and an imaginary part respectively, whereby the

range of vectors is converted into a complex matrix having m rows and n columns and subjected to processing.

**[0019]** As a processing method for converting the converted complex matrix of m rows and n columns into scalar values, a method based on eigenvalue expansion will be described first. Fig. 4 shows a processing procedure based on the eigenvalue expansion. To begin with, a two-dimensional vector distribution is converted into a complex matrix expressed by mathematics 1. For the mathematics 1, refer to Fig. 14. The eigenvalue expansion expressed by mathematics 2 is performed on the converted complex matrix of m rows and n columns on the basis of numerical calculation, whereby an eigenvalue matrix of m rows and one column is obtained. Scalar values are determined from the eigenvalue matrix.

**[0020]** As for a scalar value determination method, a maximum value of absolute values of eigenvalues or a sum of the absolute values is used so that a large change within a ROI can be reflected as a scalar value.

**[0021]** Fig. 5 shows an example of motion vector extraction in accordance with the present invention for a case of a vx2 tumor of a rat. Fig. 5(a) shows a B-mode image, and Fig. 5(b) shows a motion vector distribution produced through block matching using the B-mode image shown in Fig. 5(a) and an image of one immediately succeeding frame.

**[0022]** For the motion vector distribution, eigenvalue expansion is implemented in each ROI having a ROI size of 3x3 in order to calculate an eigenvalue matrix. Fig. 6 (b) shows a result of calculation of a distribution of maximum values of absolute values out of the eigenvalue matrices. Fig. 6(a) shows a result of application of a method of converting vector lengths to a scalar distribution, which is described in the patent literature 2, to the same frame. When both the results are compared with each other, although a border of a tumorous region that occupies almost the upper half is equally detected, a change in an ambient tissue in the lower half is seen to be more clearly displayed in Fig. 6(b). The case of a tumor is presented herein. The present invention can be applied to various objects. For example, the present invention can be applied to the usage of monitoring the position of a treatment needlepoint inserted into a body. A 3x3 square matrix is used as a ROI shape to perform eigenvalue expansion. For example, when a non-square ROI of 3x5 is used, the eigenvalue expansion cannot be adapted. Therefore, equivalent singular value decomposition compatible with the non-square ROI is implemented, and singular values are substituted for eigenvalues.

**[0023]** Aside from eigenvalue expansion, several methods are available in calculating scalar values. Fig. 7 shows motion vectors of the biceps muscle of arm as another example for the purpose of presenting the advantages of the methods. Fig. 7(a) shows a B-mode image, and Fig. 7(b) shows a motion vector distribution produced through, for example, block matching using the B-mode image shown in Fig. 7(a) and an image of an immediately succeeding frame. In the case of the invasive tumor shown in Fig. 5, a difference in hardness between a normal tissue and the tumor is reflected on the motion vectors. In the case of the biceps muscle of arm, the motion vectors represent slippages among different muscular tissues (shown as areas A, B, and C in the drawing).

**[0024]** As one of methods for obtaining scalars, divergence expressed by mathematics 3 can be applied. The divergence can be interpreted as reflection of a divergent quantity of vectors in a unit area. As for a calculation method, partial differential in an x direction is performed on an x component Ax of each vector, and partial differential in a y direction is performed on a y component Ay thereof. The sum of the results is then obtained. As for a measurement error in an ultrasonic image, since precision in the x direction (azimuthal direction) is higher than that in the y direction (beam direction) because of a system configuration. By adopting weighting divergence in which a larger weight (for example, 0.7) is applied to the partial derivative of Ay and a smaller weight (for example, 0.3) is applied to the partial derivative of Ax, the higher precision can be achieved. As a concrete method of calculating a partial derivative, a first-order spatial differential filter (for example, the Sobel filter employed generally in image processing) is applied to each ROI. The Sobel filter to be applied to the y direction for a ROI size 3x3 is expressed by mathematics 4.

**[0025]** Fig. 8(a) shows a result of application of divergence. A border between the area A and area B and a border between the area B and area C are seen to be displayed clearly. Herein, an effect on slippages in the biceps muscle of arm has been described. Since divergence copes with a divergent quantity, the divergence proves effective especially in a usage of monitoring control for measuring a degree of thermal expansion of a subject tissue during a high-intensity focused ultrasound (HIFU) treatment, a usage of checking a tissular degeneration after completion of the treatment, or a usage of monitoring in real time a stretching or contracting motion of the heart using a trans-esophageal probe, which indwells in the esophagus, during surgery.

**[0026]** As another method of obtaining scalars, rotation expressed by mathematics 5 can be applied. The rotation reflects a rotational quantity of a vector in a unit area. A concrete calculation method is such that a first-order spatial derivative in an x direction is calculated for a y component, a first-order spatial derivative in a y direction is calculated for an x component, and a difference between the first-order spatial derivatives is obtained. The obtained value is called a tensor. Fig. 8(b) shows a result of application of rotation processing. In the display, absolute values of tensors are employed. The drawing demonstrates a property that a border position can be more sharply extracted than it can through divergence.

**[0027]** A scalar calculation method is not limited to the foregoing one. A method of applying a strain tensor (provided by an equation (6)) that reflects a change between two points, or a method of applying an inner product or outer product of vectors can be adopted. An operating

panel is provided with a selection switch so that any of the methods can be selected according to a feature a diagnostic machine operator wants to note.

**[0028]** An extracted motion vector distribution contains an error vector that is likely to derive from, for example, block matching processing applied to an area of a low signal-to-noise ratio. In order to remove the error, normally, a low-pass filter is adapted for smoothing. However, this poses a problem in that the sharpness of a border is degraded by low-pass filter processing. Accordingly, in the present invention, a similarity filter capable of preserving border information while removing an error is applied.

**[0029]** Fig. 9 shows an example of an effect of a motion-vector similarity filter. On the assumption that a ROI size is 3x3, a situation is supposedly such that four vectors oriented in the same right-hand upward direction and four vectors oriented in different right-hand downward directions are associated with a noted vector Io. When a smoothing filter is adopted as a low-pass filter, since the number of right-hand upward vectors other than the noted vector is identical to the number of right-hand downward vectors, the noted vector having undergone smoothing processing is oriented intermediately rightward.

**[0030]** A similarity filter described in the patent literature 3 is introduced as a scheme for achieving both noise removal from a two-dimensional brightness image and edge preservation thereof by assigning a larger weight to a pixel in a ROI, which exhibits a brightness closer to the brightness exhibited by a noted pixel, so as to thus calculate a weighted mean. In the present invention, a two-dimensional vector distribution is decomposed into an x-component (azimuthal direction) distribution and a y-component (beam direction) distribution, and the similarity filter is applied to each of the distributions, and a smoothed vector image is constructed based on the resultant x-component distribution and y-component distribution. Herein, when the x component is regarded as a real-number component and the y component is regarded as an imaginary-number component, the vector is expressed as a complex number according to an equation (7). An x component $A_{xij}$ of a vector $I_{ij}$ that ranks the i-th in a beam-axis direction within a ROI and ranks the j-th in an azimuthal direction orthogonal to the beam-axis direction is associated with a real-number component, and a y component $A_{yij}$ thereof is associated with an imaginary-number component, whereby the vector $I_{ij}$ can be expressed by mathematics 7. Processing of the similarity filter is, as expressed by mathematics 8, such that a sum of weighted products of $I_{ij}$ by weights $W_{ij}$ which are associated with differences from a noted vector Io is calculated, and normalized by a sum total of weighted values in order to obtain a smoothed noted vector Io'. Through the processing, deterioration of edge information of the noted vector Io can be, as shown in Fig. 9, avoided.

**[0031]** The similarity filter of the present invention can be extended to three-dimensional measurement. An approach to the three-dimensional measurement is such that, for example, an array transducer of a two-dimensional array type is used to acquire at a high speed plural tomographic image data items in a slice direction orthogonal to the beam direction and azimuthal direction, and a three-dimensional parallelepiped structure is reconstructed. Assuming that $A_{zijk}$ denotes a vector component in the slice direction of three-dimensional data, a noted vector $I_{ijk}$ is expressed by mathematics 9. In this case, an updating equation by the similarity filter is represented by mathematics 10 using weights $W_{ijk}$ of a three-dimensional distribution.

**[0032]** After a three-dimensional vector distribution is determined, the vector distribution is converted into a scalar distribution using a technique of eigenvalue expansion or the like in the same manner as a two-dimensional vector distribution is. The scalar distribution is divided into, for example, plural two-dimensional sections, and then subjected to display processing.

**[0033]** Fig. 10 shows a processing procedure of a motion-vector similarity filter of the present invention for a ROI. To begin with, a vector distribution is inputted. A ROI size and a half-value width of a weight distribution are set as processing parameters. As the weight distribution, a one-sided distribution of a Gaussian distribution shown, for example, in Fig. 11 is adopted. The axis of abscissas indicates an absolute value of a difference between a noted vector Io and another vector $I_{ij}$ within the ROI. The larger the difference is, the smaller a weight is. The distribution shape varies depending on the half-value width. After the parameters are set, each two-dimensional vector is converted into a complex number. New vectors are calculated according to the equation (8), and the processing is terminated. If a noise component in the vector distribution is subjected to filter removal processing in advance, after the vector distribution is converted into the scalar distribution, precision can be improved.

**[0034]** In the patent literature 2, a B-mode motion picture and an elastographic motion picture are displayed side by side. Since an error deriving from a nonlinear factor of the elastographic picture is not contained in motion-vector distribution information, an accurate behavior is shown. However, when a vector distribution image alone is used, association with a tissue position cannot be achieved. Therefore, if the vector distribution image is superposed on the B-mode image, thus synthesized with the B-mode image, and displayed, a highly discernible diagnostic image can be provided. Fig. 12(a) presents the processing procedure. First, a B-mode original image is inputted. Thereafter, a vector distribution is calculated, and the original image and the associated vector distribution are synthesized and displayed.

**[0035]** Fig. 13 shows an example of a synthetic image (a tumorous case). By superposing a vector distribution, a magnitude of a change and a direction thereof can be readily grasped. As a method for improving discernment, a B-mode image and a scalar distribution image may be synthesized and displayed. Fig. 12(b) presents the

processing procedure. A difference from Fig. 12(a) lies in a point that after a vector distribution is calculated, the vector distribution is converted into a scalar distribution, and an original image and the scalar distribution are synthesized and displayed. By synthesizing the original image with the scalar distribution image, similarly to a colored elastographic image presented in the patent literature 1, a tissue border can be readily identified and a contour can be clearly seen. Referring to Fig. 12, cases where image synthesis is performed have been described. Instead of synthesizing images into one image and displaying the image, the two images may be simultaneously displayed side by side. Further, if an elastographic image and a motion-vector image are synthesized and displayed or are displayed side by side, or if three images of the elastographic image, B-mode image, and motion-vector image are displayed side by side, it would prove effective.

**[0036]** As for the foregoing various display methods, a system configuration permitting a system operator to select any of the methods using a selection switch included in a system panel is feasible. As an easy-to-see display form of a default at the time of powering up, a form in which, for example, two screen images of a screen image having a B-mode image and a vector distribution synthesized and a screen image of a scalar distribution alone are displayed side by side is conceivable. As a method for producing the scalar distribution image, such a method is feasible that: a proper production processing method (rotation processing, divergence processing, eigenvalue processing, or the like) is pre-set according to a purpose of diagnosis (discrimination of a tumor or therapeutic monitoring) or an object case; selection switches associated with items are included; and a system operator selects each item. Otherwise, as an image of a scalar distribution, three kinds of images, that is, a rotation-processing image, a divergence-processing image, and an eigenvalue processing image may all be displayed. A form in which four screen images including the three kinds of images as well as a synthetic image (B-mode image and vector distribution) are displayed side by side is valid.

Industrial Applicability

**[0037]** The present invention can be applied to, aside from a diagnostic or therapeutic ultrasound system for medicine, any system that measures a strain or a slippage using ultrasonic waves.

Reference Signs List

**[0038]** 1: ultrasonic probe, 2: user interface, 3: transmission beam former, 4: control system, 5: transmitting/receiving selection switch, 6: receiving beam former, 7: envelope detection unit, 8: scan converter, 10: processing unit, 11: parameter setting unit, 12: synthesis unit, 13: display unit

**Claims**

1. An ultrasonic image processing method **characterized in that**:

   an image data production step of storing a result of detection, which is performed by a detection unit in order to detect an ultrasonic signal of a subject to which ultrasonic waves are irradiated by an irradiation unit, and producing at least two frame image data items, detection timings of which are different from each other, from the stored result of detection;
   a motion-vector distribution image production step of producing a motion-vector distribution image using a plurality of frames out of the image data items through predetermined motion-vector analysis processing; and
   a conversion step of converting the motion-vector distribution image into a scalar-distribution image according to a selected method on the basis of ROIs, that is, a plurality of set regions of interest.

2. The ultrasonic image processing method as set forth in Claim 1, **characterized in that**:

   the conversion step includes
   a first processing step of setting a small region ROI to be noted within the motion vector distribution, permuting beam-direction components and azimuthal-direction components within the ROI with real-number components and imaginary-number components respectively, and thus converting the motion vector distribution within the ROI into a complex matrix,
   a second processing step of performing eigenvalue expansion processing on the complex matrix so as to obtain an eigenvalue matrix, and
   a third processing step of determining one scalar value by obtaining a maximum value of absolute values of eigenvalues out of the eigenvalue matrix or obtaining a sum total of the absolute values of the eigenvalues; and
   the first to third processing steps are implemented in a plurality of ROIs within the motion vector distribution in order to produce a scalar-distribution image.

3. The ultrasonic image processing method as set forth in Claim 1, **characterized in that**:

   the conversion step includes
   a first processing step of setting a small region ROI to be noted within the motion vector distribution, applying a first-order spatial differential filter to each of a beam direction along a beam axis within the ROI, and an azimuthal direction

orthogonal to the beam direction, and calculating derivative information,
a second processing step of permuting the beam-direction derivatives and azimuthal-direction derivatives within the ROI with real-number components and imaginary-number components respectively, and thus converting the motion vector distribution within the ROI into a complex matrix,
a third processing step of performing eigenvalue expansion processing on the complex matrix so as to obtain eigenvalues, and
a fourth processing step of determining one scalar value to be calculated using a maximum value of absolute values of eigenvalues out of the eigenvalue matrix, using a sum total of the absolute values of the eigenvalues, or using the eigenvalues; and
the first to fourth processing steps are implemented in a plurality of ROIs within the motion vector distribution in order to produce a scalar-distribution image.

**4.** The ultrasonic image processing method as set forth in Claim 1, **characterized in that**:

at the conversion step,
a small region ROI to be noted is set within the motion vector distribution, beam-direction components and azimuthal-direction components within the ROI are permuted with real-number components and imaginary-number components respectively, and the motion vector distribution within the ROI is thus converted into a complex matrix,
a first-order spatial differential filter is applied to each of a beam direction along a beam axis within the set ROI and an azimuthal direction orthogonal to the beam direction in order to calculate derivative information, and a divergence operation is implemented based on the derivative information in order to determine a scalar value, and
a scalar distribution is produced from scalar values determined for a plurality of ROIs within the motion vector distribution.

**5.** The ultrasonic image processing method as set forth in Claim 1, **characterized in that**:

at the conversion step,
a small region ROI to be noted is set within the motion vector distribution, beam-direction components and azimuthal-direction components within the ROI are permuted with real-number components and imaginary-number components respectively, and the motion vector distribution within the ROI is thus converted into a complex matrix, and
a first-order spatial differential filter is applied to each of a beam direction and an azimuthal direction within the set ROI in order to calculate derivative information, a rotation operation is implemented based on the derivative information in order to determine a scalar value, and a scalar distribution is produced from scalar values determined for a plurality of ROIs within the motion vector distribution.

**6.** The ultrasonic image processing method as set forth in Claim 2, **characterized in that**:

at the third processing step, a first-order spatial differential filter is applied to a beam direction and an azimuthal direction within the set ROI in order to calculate derivative information, and an operation of obtaining a strain tensor is implemented based on the derivative information in order to determine a scalar value.

**7.** The ultrasonic image processing method as set forth in Claim 2, **characterized in that**:

at the third processing step, inner product calculation is performed on each pair of vectors adjoining in a beam direction or an azimuthal direction within the set ROI in order to determine a scalar value; and
a scalar distribution is produced from scalar values determined for a plurality of ROIs within the motion-vector distribution.

**8.** The ultrasonic image processing method as set forth in Claim 2, **characterized in that**:

at the third processing step, outer product calculation is performed on each pair of vectors adjoining in a beam direction or an azimuthal direction within the set ROI in order to obtain a tensor value, and a scalar value is determined from the sensor value or the absolute value of the sensor value.

**9.** The ultrasonic image processing method as set forth in Claim 2, **characterized in that**:

at the third processing step, the vector distribution in the set ROI is decomposed into a beam-direction component scalar distribution and an azimuthal-direction component scalar distribution, a similarity filter is applied to each of the scalar distributions in the respective directions, a smoothed vector distribution is constructed from each of the scalar distributions resulting from the application of the similarity filter, beam-direction components and azimuthal-direction

components within the ROI in the smoothed vector distribution are permuted with real-number components and imaginary-number components respectively in order to thus convert the vector distribution within the ROI into a complex matrix, and scalar values are determined.

**10.** The ultrasonic image processing method as set forth in Claim 2, **characterized in that**:

when a two-dimensional array type ultrasonic probe is used to acquire three-dimensional image information having a slice direction, which is orthogonal to a beam direction and an azimuthal direction, added thereto,
at the third processing step,
the vector distribution within the set ROI is decomposed into a beam-direction component scalar distribution, an azimuthal-direction component scalar distribution, and a slice-direction component scalar distribution, a similarity filter is applied to each of the scalar distributions in the respective directions, a smoothed vector distribution is constructed from each of the scalar distributions resulting from the application of the similarity filter, and scalar values are determined.

**11.** An ultrasonic image processing device **characterized in that**:

an irradiation unit that irradiates ultrasonic waves to a subject;
a detection unit that detects an ultrasonic signal of the subject;
an image data production unit that produces image data items of at least two frames, detection timings of which are different from each other, on the basis of a result of detection by the detection unit;
a motion-vector distribution image production unit that uses a plurality of frames out of the image data items to produce a vector-distribution image through predetermined motion-vector analysis processing;
a selection unit that selects a conversion method of converting the motion-vector distribution image into a scalar-distribution image; and
a conversion unit that converts the motion-vector distribution image into the scalar-distribution image according to the selected conversion method.

**12.** The ultrasonic image processing device as set forth in Claim 11, **characterized in that**:

the conversion unit includes
a first processing means that sets a small region ROI to be noted within the motion vector distribution, and permutes beam-direction components and azimuthal-direction components within the ROI with real-number components and imaginary-number components respectively so as to convert the motion vector distribution within the ROM into a complex matrix,
a second processing means that performs eigenvalue expansion processing on the complex matrix so as to obtain an eigenvalue matrix, and
a third processing means that determines one scalar value by obtaining a maximum value of absolute values of eigenvalues out of the eigenvalue matrix or obtaining a sum total of the absolute values of the eigenvalues; and
the conversion unit implements the first to third processing means in a plurality of ROIs within the motion vector distribution so as to produce a scalar distribution image.

**13.** The ultrasonic image processing device as set forth in Claim 11, **characterized in that**:

the conversion unit performs
first processing of setting a small region ROI to be noted within the motion vector distribution, and applying a first-order spatial differential filter to each of a beam direction along a beam axis within the ROI and an azimuthal direction orthogonal to the beam direction so as to calculate derivative information,
second processing of permuting the beam-direction derivatives and azimuthal-direction derivatives within the ROI with real-number components and imaginary-number components respectively so as to convert the motion vector distribution within the ROI into a complex matrix,
third processing of performing eigenvalue expansion processing on the complex matrix so as to obtain eigenvalues, and
fourth processing of determining one scalar value to be calculated using a maximum value of absolute values of eigenvalues out of the eigenvalue matrix, using a sum total of the absolute values of the eigenvalues, or using the eigenvalues; and
the conversion unit implements the first to fourth processing in a plurality of ROIs within the motion vector distribution so as to produce a scalar distribution image.

**14.** The ultrasonic image processing device as set forth in Claim 12, **characterized in that**:

the conversion unit includes means that calculates derivative information by applying a first-order spatial differential filter to each of a beam direction along a beam axis within a ROI set by

the first processing means and an azimuthal direction orthogonal to the beam direction, and determines a scalar value by implementing a divergence operation on the basis of the derivative information, and that produces a scalar-distribution image from the scalar values determined for a plurality of ROIs within the motion vector distribution.

**15.** An ultrasonic image processing program **characterized in that** the ultrasonic image processing program allows a computer to function as the ultrasonic image processing method set forth in any of Claims 1 to 9.

FIG. 1

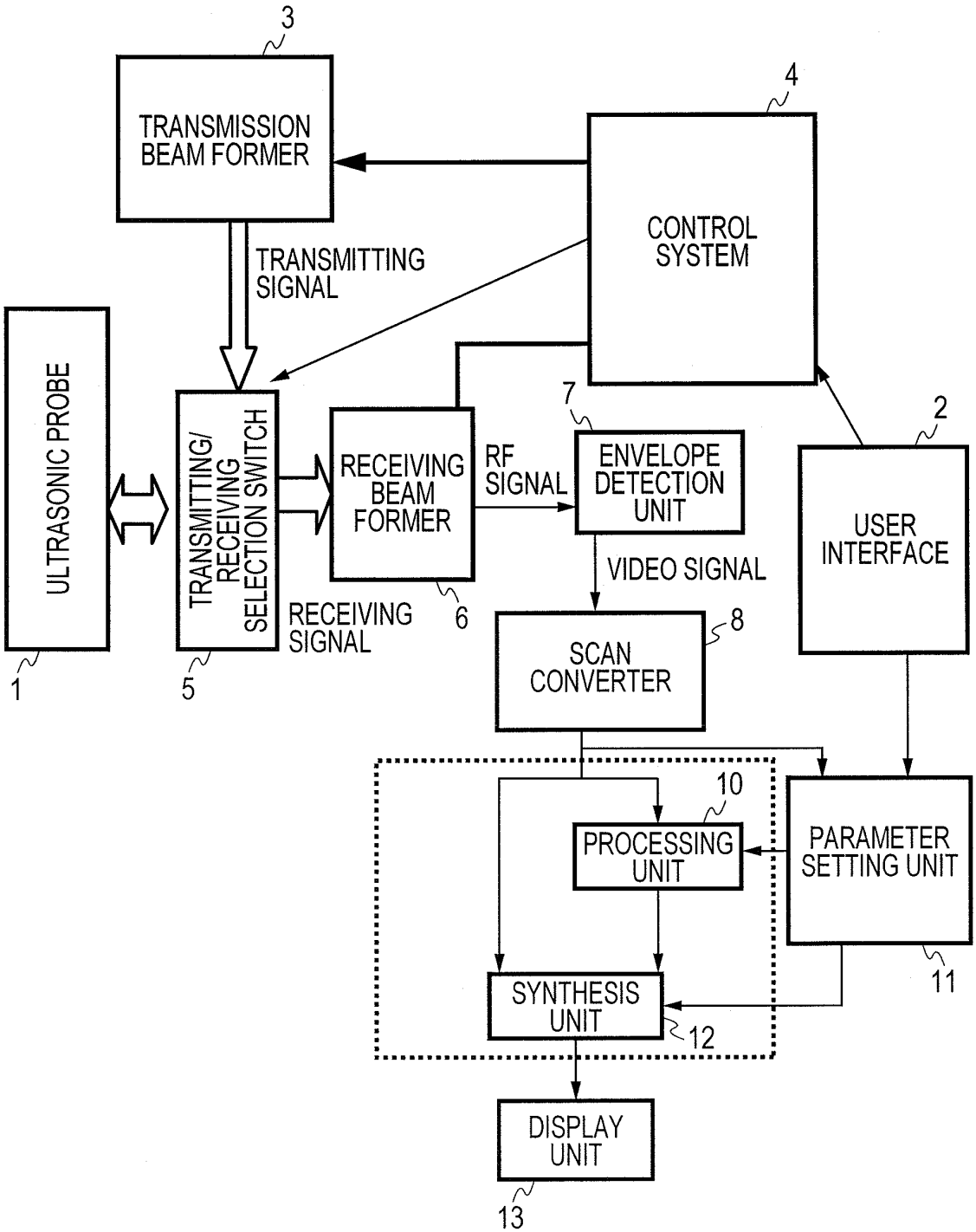

3
TRANSMISSION BEAM FORMER
4
CONTROL SYSTEM
TRANSMITTING SIGNAL
ULTRASONIC PROBE
TRANSMITTING/ RECEIVING SELECTION SWITCH
RECEIVING BEAM FORMER
7
RF SIGNAL
ENVELOPE DETECTION UNIT
2
USER INTERFACE
VIDEO SIGNAL
RECEIVING SIGNAL
6
8
SCAN CONVERTER
1
5
10
PROCESSING UNIT
PARAMETER SETTING UNIT
11
SYNTHESIS UNIT
12
DISPLAY UNIT
13

FIG. 2

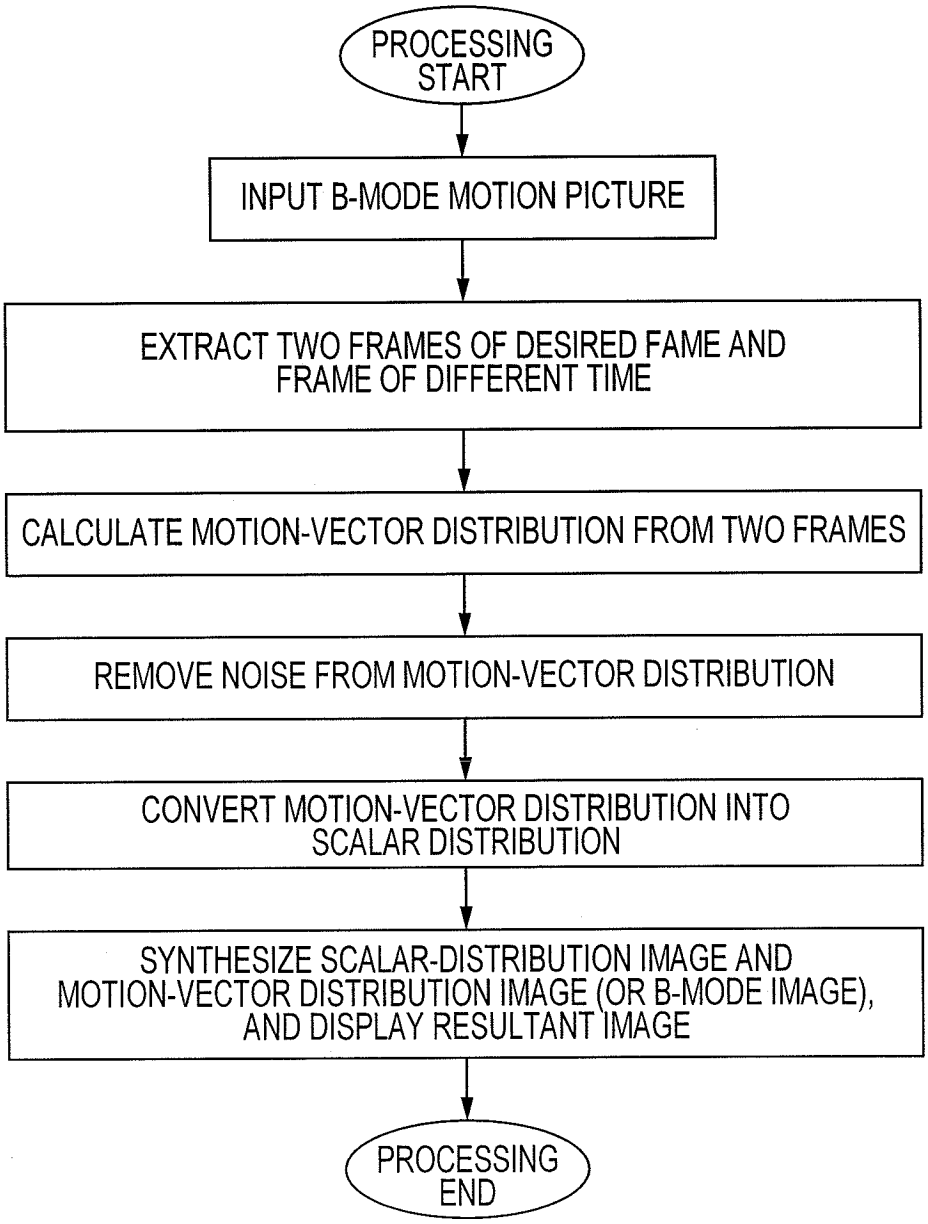

PROCESSING START
INPUT B-MODE MOTION PICTURE
EXTRACT TWO FRAMES OF DESIRED FAME AND FRAME OF DIFFERENT TIME
CALCULATE MOTION-VECTOR DISTRIBUTION FROM TWO FRAMES
REMOVE NOISE FROM MOTION-VECTOR DISTRIBUTION
CONVERT MOTION-VECTOR DISTRIBUTION INTO SCALAR DISTRIBUTION
SYNTHESIZE SCALAR-DISTRIBUTION IMAGE AND MOTION-VECTOR DISTRIBUTION IMAGE (OR B-MODE IMAGE), AND DISPLAY RESULTANT IMAGE
PROCESSING END

FIG. 3

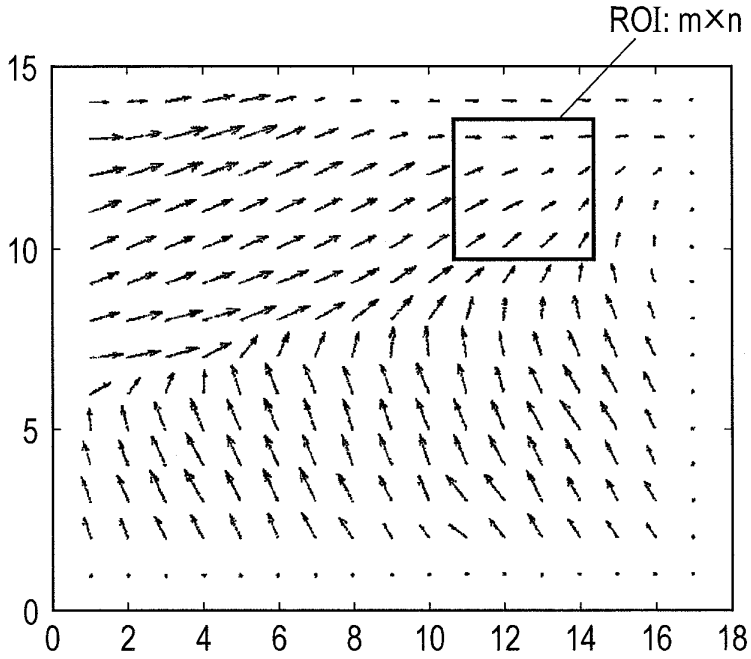

ROI: m×n
15
10
5
0
0
2
4
6
8
10
12
14
16
18

FIG. 4

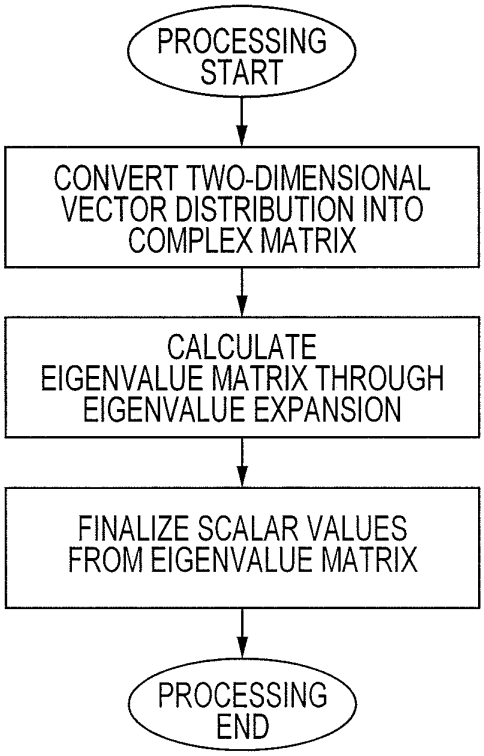
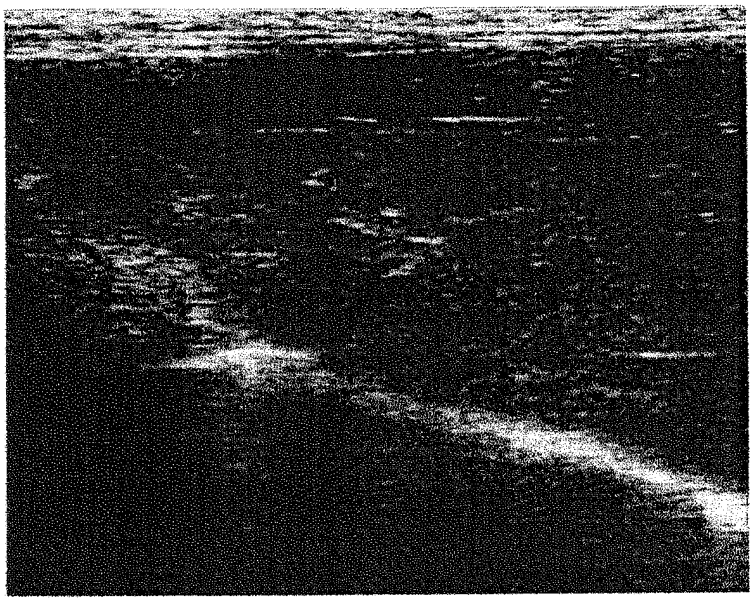

PROCESSING START
CONVERT TWO-DIMENSIONAL VECTOR DISTRIBUTION INTO COMPLEX MATRIX
CALCULATE EIGENVALUE MATRIX THROUGH EIGENVALUE EXPANSION
FINALIZE SCALAR VALUES FROM EIGENVALUE MATRIX
PROCESSING END

FIG. 5

(a)

B-MODE IMAGE



(b)

MOTION-VECTOR DISTRIBUTION

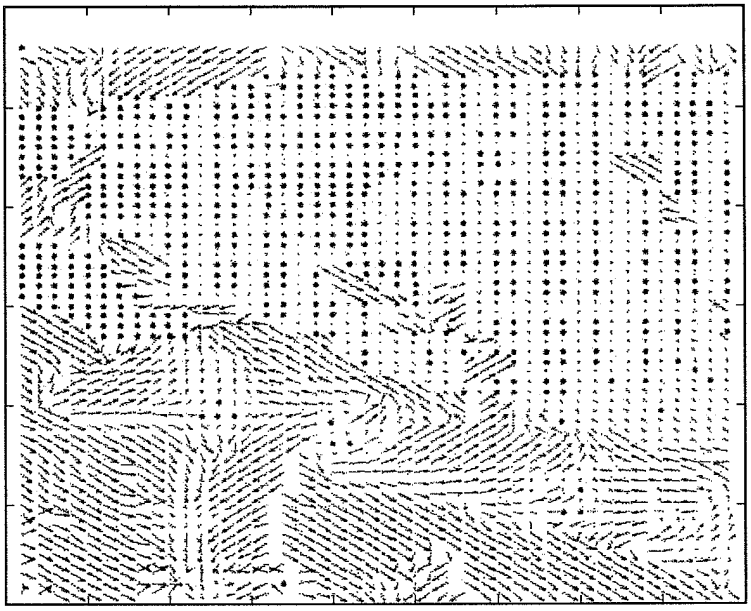
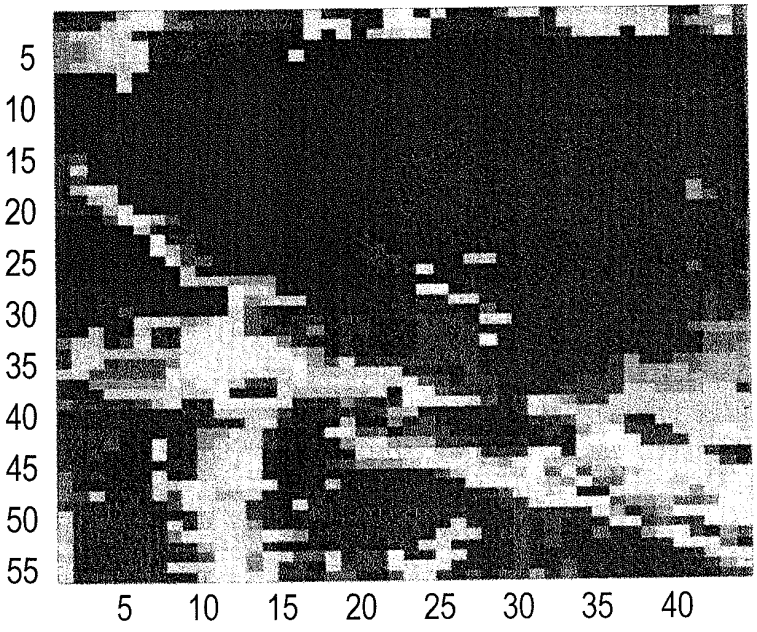


FIG. 6

(a)

CONVENTIONAL METHOD
(CONVERTING VECTOR LENGTHS INTO SCALARS)




(b)

EIGENVALUE DISTRIBUTION (MAXIMUM VALUE)

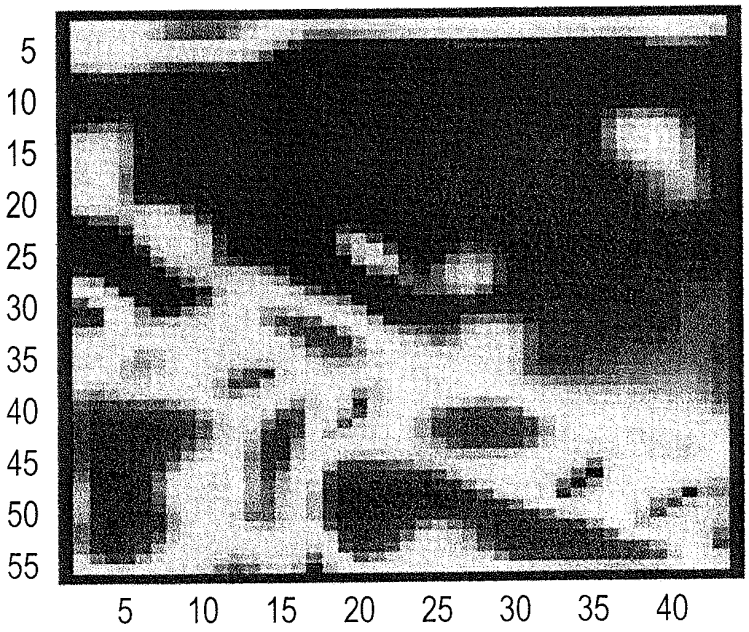
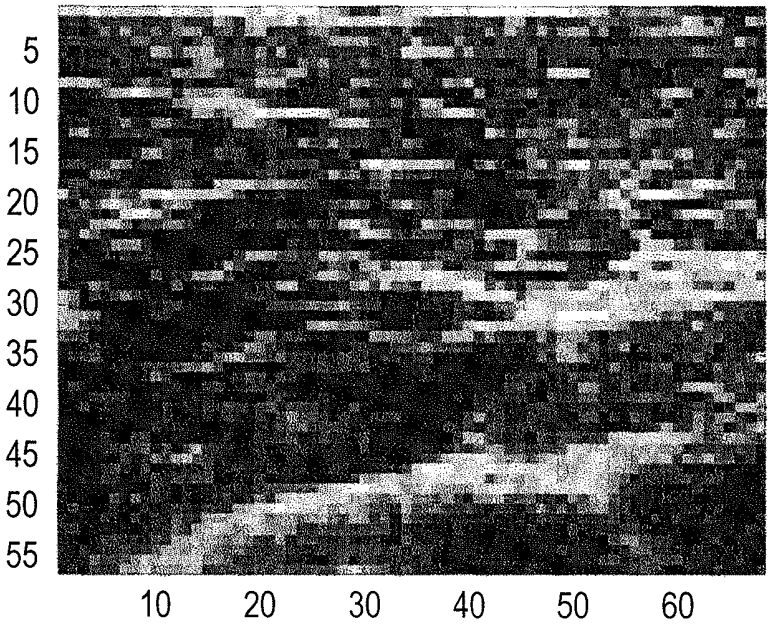


FIG. 7

(a)

B-MODE IMAGE




(b)

MOTION-VECTOR DISTRIBUTION

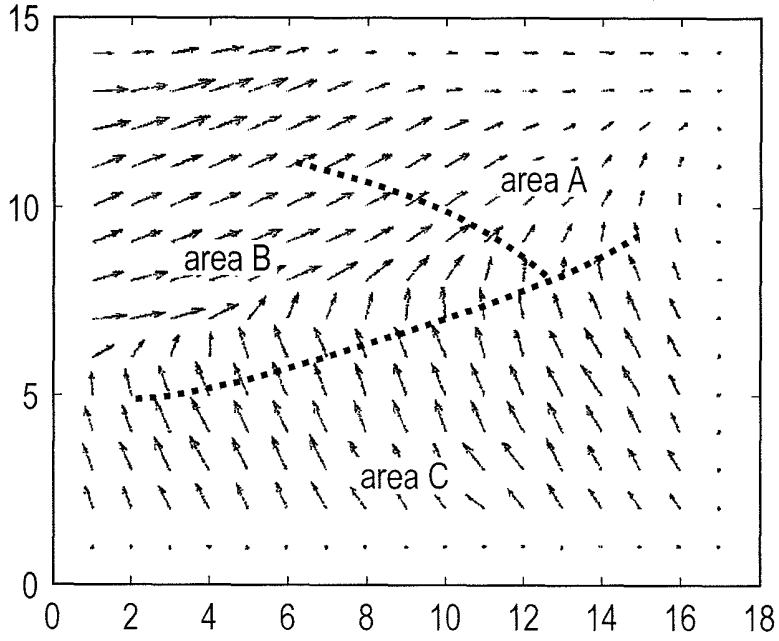
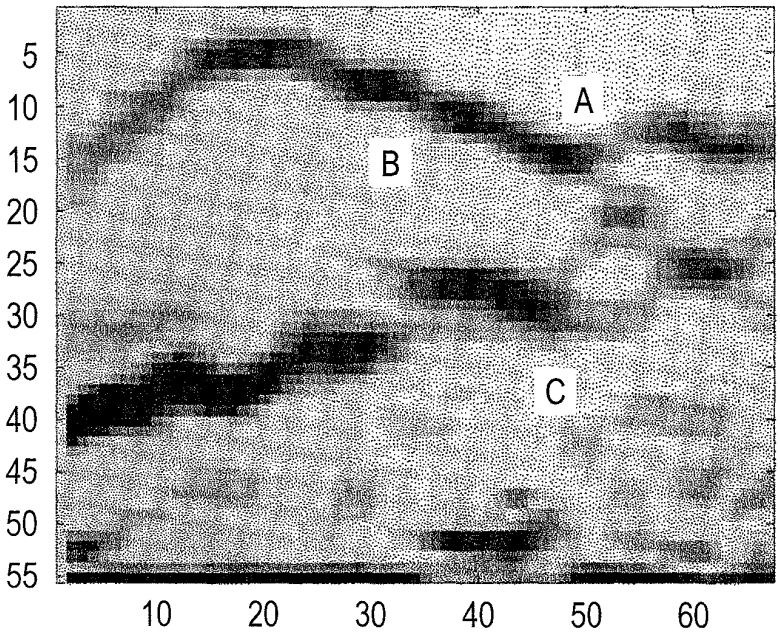


FIG. 8

(a)

DIVERGENCE (y COMPONENT)




(b)

ROTATION (ABSOLUTE VALUE)

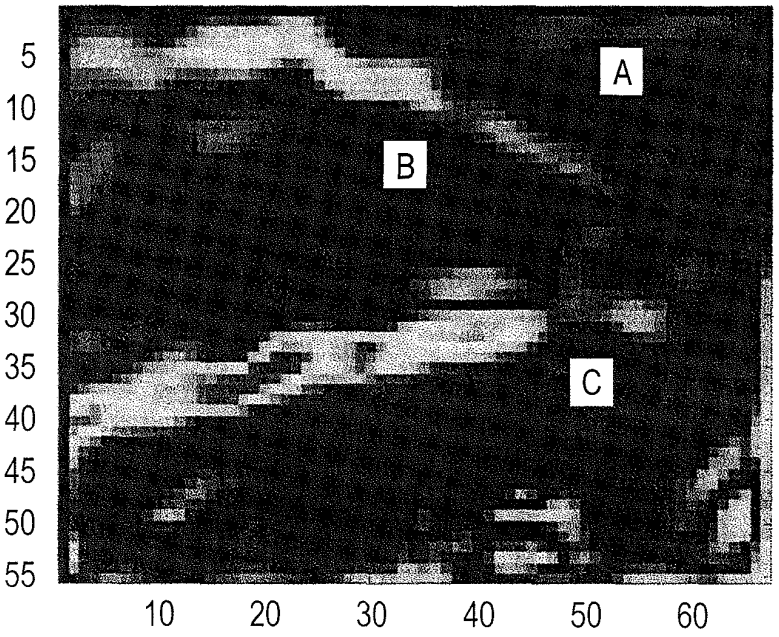


FIG. 9

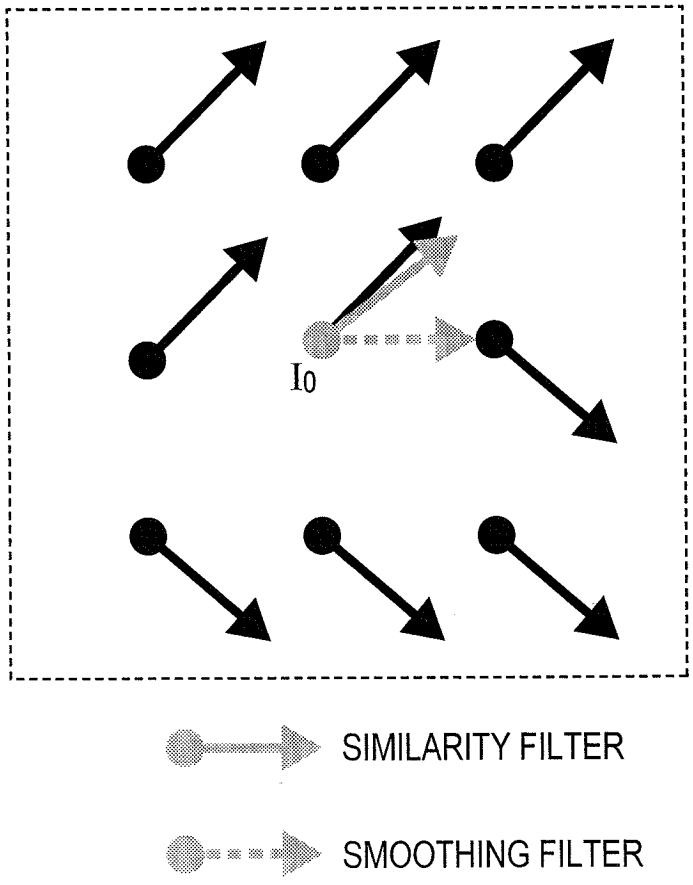


FIG. 10

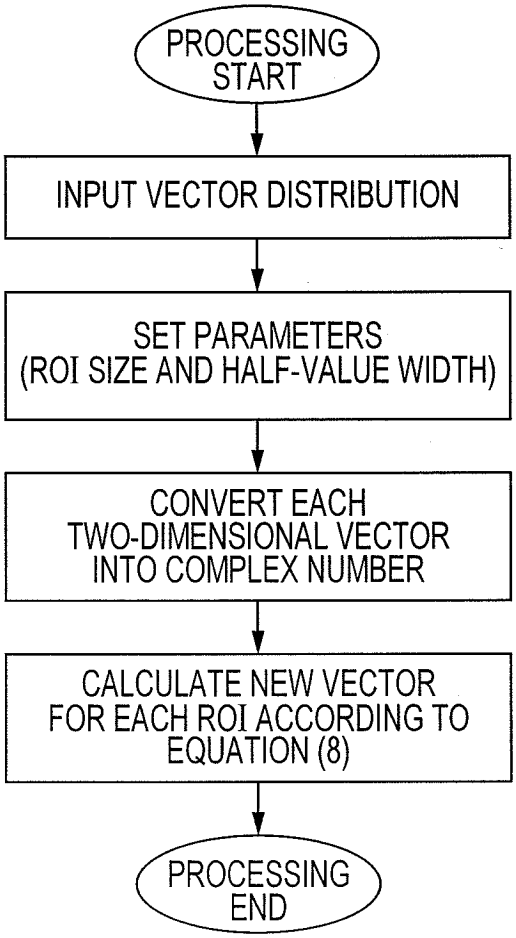
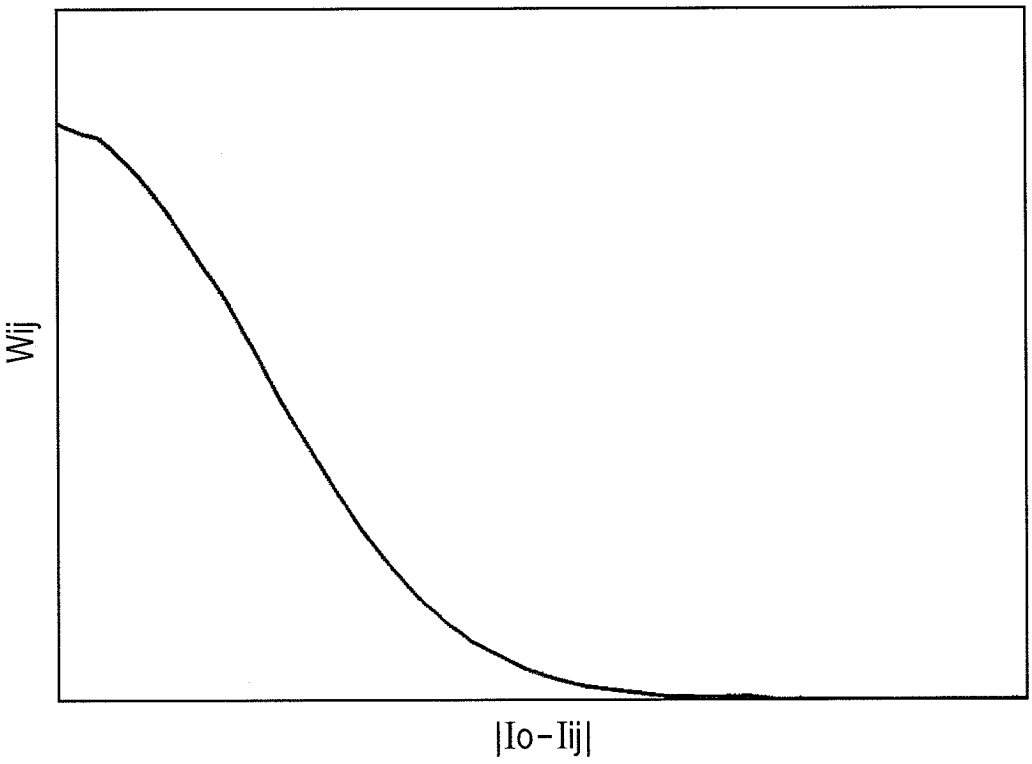

PROCESSING START
INPUT VECTOR DISTRIBUTION
SET PARAMETERS (ROI SIZE AND HALF-VALUE WIDTH)
CONVERT EACH TWO-DIMENSIONAL VECTOR INTO COMPLEX NUMBER
CALCULATE NEW VECTOR FOR EACH ROI ACCORDING TO EQUATION (8)
PROCESSING END

FIG. 11




(EXAMPLE OF ONE-SIDED GAUSSIAN DISTRIBUTION)

FIG. 12

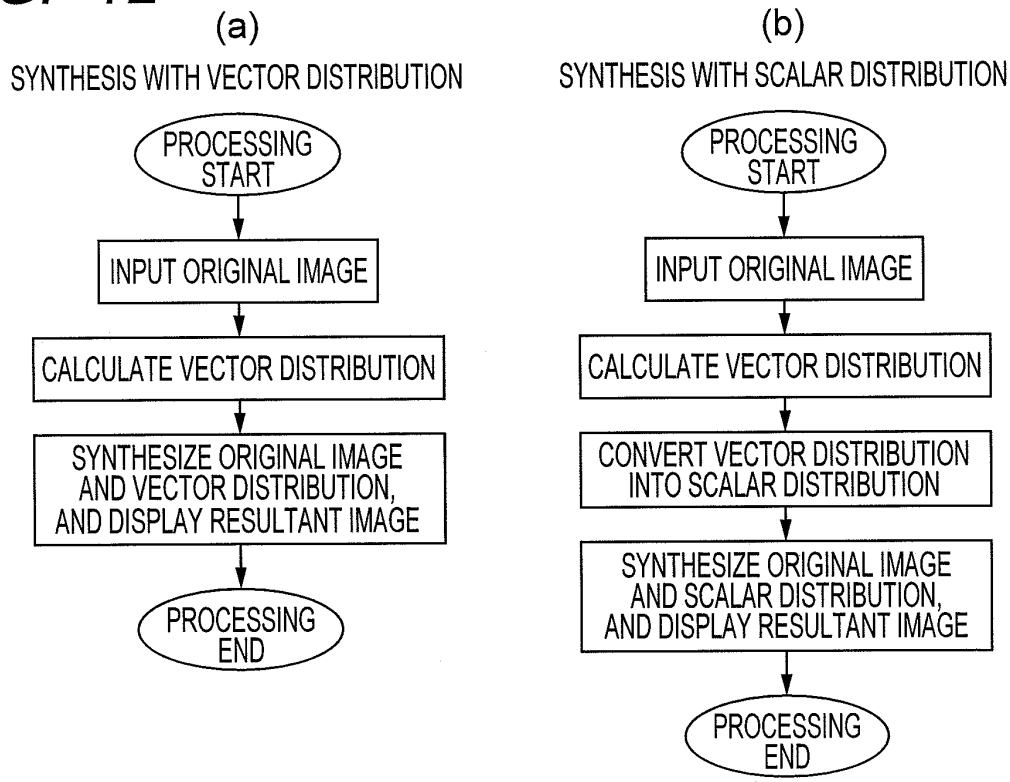
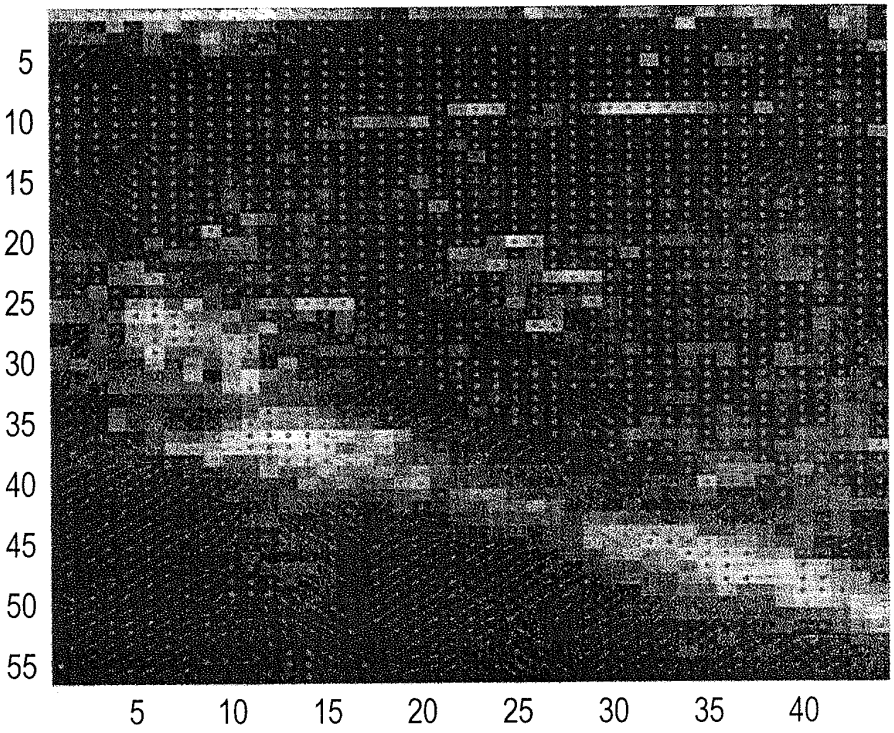

(a)
SYNTHESIS WITH VECTOR DISTRIBUTION
PROCESSING START
INPUT ORIGINAL IMAGE
CALCULATE VECTOR DISTRIBUTION
SYNTHESIZE ORIGINAL IMAGE AND VECTOR DISTRIBUTION, AND DISPLAY RESULTANT IMAGE
PROCESSING END
(b)
SYNTHESIS WITH SCALAR DISTRIBUTION
PROCESSING START
INPUT ORIGINAL IMAGE
CALCULATE VECTOR DISTRIBUTION
CONVERT VECTOR DISTRIBUTION INTO SCALAR DISTRIBUTION
SYNTHESIZE ORIGINAL IMAGE AND SCALAR DISTRIBUTION, AND DISPLAY RESULTANT IMAGE
PROCESSING END

FIG. 13


5
10
15
20
25
30
35
40
45
50
55
5
10
15
20
25
30
35
40

# FIG. 14

【NUMBER 1】

$$A = \begin{pmatrix} A_{11X}+iA_{11Y} & A_{12X}+iA_{12Y} & \cdots & A_{1mX}+iA_{1mY} \\ A_{21X}+iA_{21Y} & \cdots & \cdots & A_{2mX}+iA_{2mY} \\ \cdots & \cdots & \cdots & \cdots \\ A_{m1X}+iA_{m1Y} & \cdots & \cdots & A_{mmX}+iA_{mmY} \end{pmatrix}$$

【NUMBER 2】

$$Ap_k = A\lambda_k \ (k \leq m)$$

$\lambda_k$: EIGENVALUE (COMPLEX NUMBER)

$p_k$: EIGENVECTOR (m ROWS AND I COLUMNS)

【NUMBER 3】

$$divA = \nabla \cdot A = \frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y}$$

【NUMBER 4】

$$\begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix}$$

【NUMBER 5】

$$rotA = \nabla \times A = \frac{\partial A_y}{\partial x} + \frac{\partial A_x}{\partial y}$$

【NUMBER 6】

$$S_{xy} = \frac{1}{2}\left(\frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y}\right)$$

【NUMBER 7】

$$I_{ij} = A_{Xij} + iA_{Yij}$$

【NUMBER 8】

$$I_0' = \frac{\sum I_{ij}W_{ij}}{\sum W_{ij}}$$

【NUMBER 9】

$$I_{ijk} = (A_{Xijk}, A_{Yijk}, A_{Zijk})$$

【NUMBER 10】

$$I_0' = \frac{\sum I_{ijk}W_{ijk}}{\sum W_{ijk}}$$

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2009/005750

A. CLASSIFICATION OF SUBJECT MATTER
*A61B8/08*(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)
A61B8/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2009
Kokai Jitsuyo Shinan Koho 1971-2009 Toroku Jitsuyo Shinan Koho 1994-2009

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X<br>A | JP 2008-079792 A (Hitachi, Ltd.),<br>10 April 2008 (10.04.2008),<br>particularly, paragraphs [0014] to [0017]<br>& US 2008/0077011 A1 | 1,11,15<br>2-10,12-14 |
| A | JP 2007-330764 A (Toshiba Corp.),<br>27 December 2007 (27.12.2007),<br>entire text; all drawings<br>& US 2008/0262354 A1 & EP 1872724 A1<br>& WO 2007/080895 A1 | 1-15 |
| A | JP 08-010260 A (Fujitsu Ltd.),<br>26 January 1996 (26.01.1996),<br>entire text; all drawings<br>(Family: none) | 1-15 |

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"O" document referring to an oral disclosure, use, exhibition or other means
"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 | Date of mailing of the international search report |
|---|---|
| 20 November, 2009 (20.11.09) | 08 December, 2009 (08.12.09) |
| Name and mailing address of the ISA/<br>Japanese Patent Office<br><br>Facsimile No. | Authorized officer<br><br>Telephone No. |

Form PCT/ISA/210 (second sheet) (April 2007)

## REFERENCES CITED IN THE DESCRIPTION

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### Patent documents cited in the description


- JP 2004135929 A **[0004]**
- JP 2008079792 A **[0004]**
- JP 2004129773 A **[0004]**

| | | | |
|---|---|---|---|
| 专利名称(译) | 超声波图像处理方法和装置，以及超声波图像处理程序 | | |
| 公开(公告)号 | EP2347716A1 | 公开(公告)日 | 2011-07-27 |
| 申请号 | EP2009824569 | 申请日 | 2009-10-29 |
| [标]申请(专利权)人(译) | 株式会社日立医药 | | |
| 申请(专利权)人(译) | 日立医疗器械股份有限公司 | | |
| 当前申请(专利权)人(译) | 日立医疗器械股份有限公司 | | |
| [标]发明人 | MASUI HIRONARI<br>AZUMA TAKASHI | | |
| 发明人 | MASUI, HIRONARI<br>AZUMA, TAKASHI | | |
| IPC分类号 | A61B8/08 A61B8/00 G06T7/20 | | |
| CPC分类号 | A61B8/08 A61B8/463 A61B8/469 A61B8/483 A61B8/5246 A61B8/5276 G06T7/215 G06T2207/10132 | | |
| 优先权 | 2008287290 2008-11-10 JP | | |
| 其他公开文献 | EP2347716B1<br>EP2347716A4 | | |
| 外部链接 | Espacenet | | |


摘要(译)

超声波图像处理方法和装置，以及超声波图像处理程序，其可以对应于根据诊断或治疗的区域或目的而不同的分析方法。超声图像处理方法包括图像数据创建步骤，其存储通过照射部分用超声波照射对象并通过检测部分检测来自对象的超声信号而获得的检测结果，并创建不同的至少两帧图像数据。在基于所存储的检测结果的检测定时中，运动矢量分布图像创建步骤基于通过使用多个图像数据帧的预定运动矢量分析来创建运动矢量分布图像，以及转换步骤，基于多个建立的感兴趣区域（ROI）将矢量分布图像转换为标量分布图像。

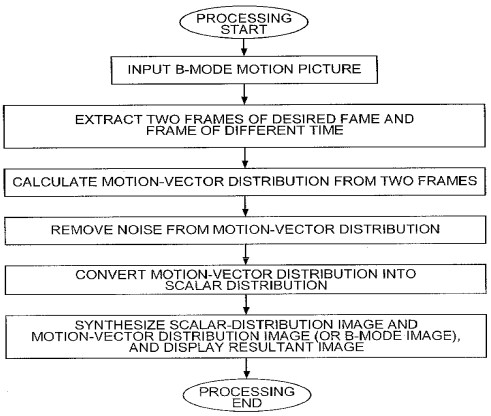
FIG. 2