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(54) **ULTRASONIC OBSERVATION APPARATUS, OPERATION METHOD OF THE SAME, AND COMPUTER READABLE RECORDING MEDIUM**

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A61B 8/00 (2006.01)

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(57) **ABSTRACT**

An apparatus including: a unit for analyzing a frequency of the received ultrasonic wave; a unit to extract feature data of the frequency spectrum by performing an approximation to the calculated-frequency spectrum; a storage to store feature data of a frequency spectrum extracted based upon the ultrasonic wave reflected from plural specimens, and to store the specimens as being classified into groups; a unit to calculate a degree of association between the extracted feature data and each group by using a statistics of a population including at least the feature data of each group; a unit to allow the degree of association of the specimen to each group to correspond to different color components, and to generate ultrasonic image data by using a parameter formed by combining the different color components, based upon the calculation result; and a display to display the image corresponding to the ultrasonic image data.

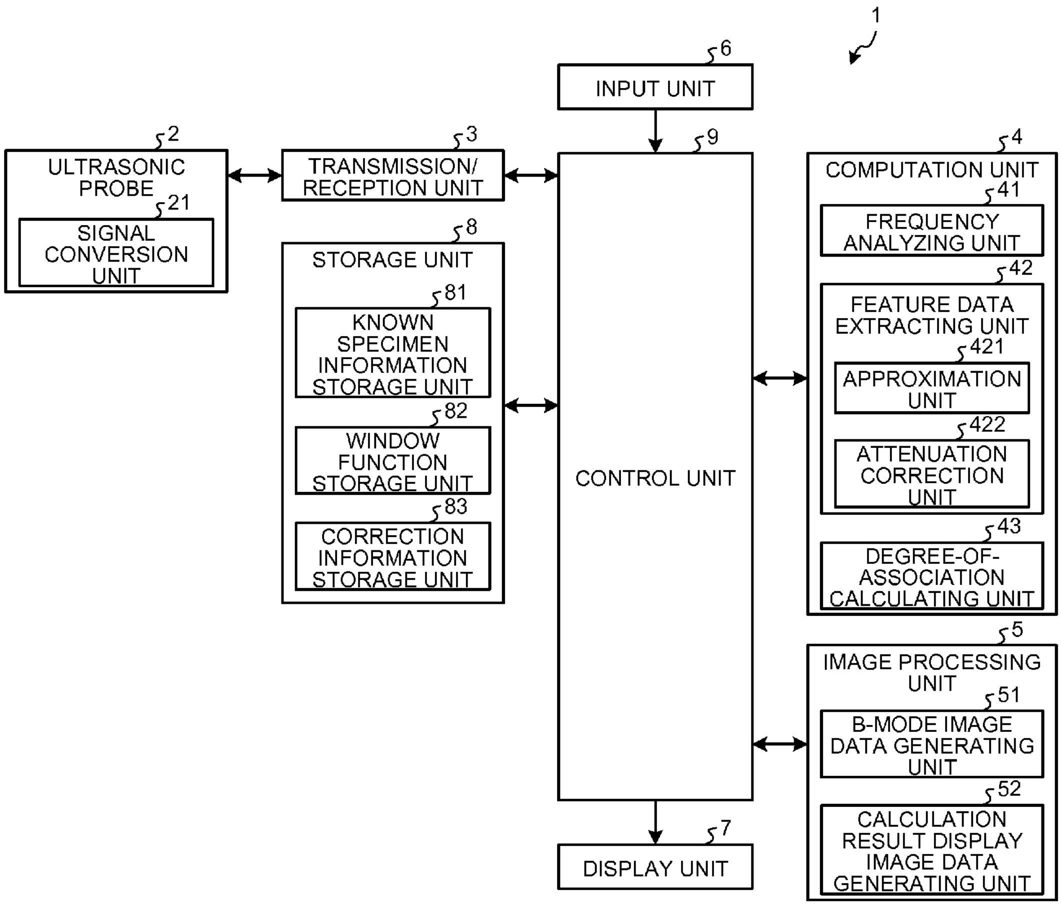


FIG.1

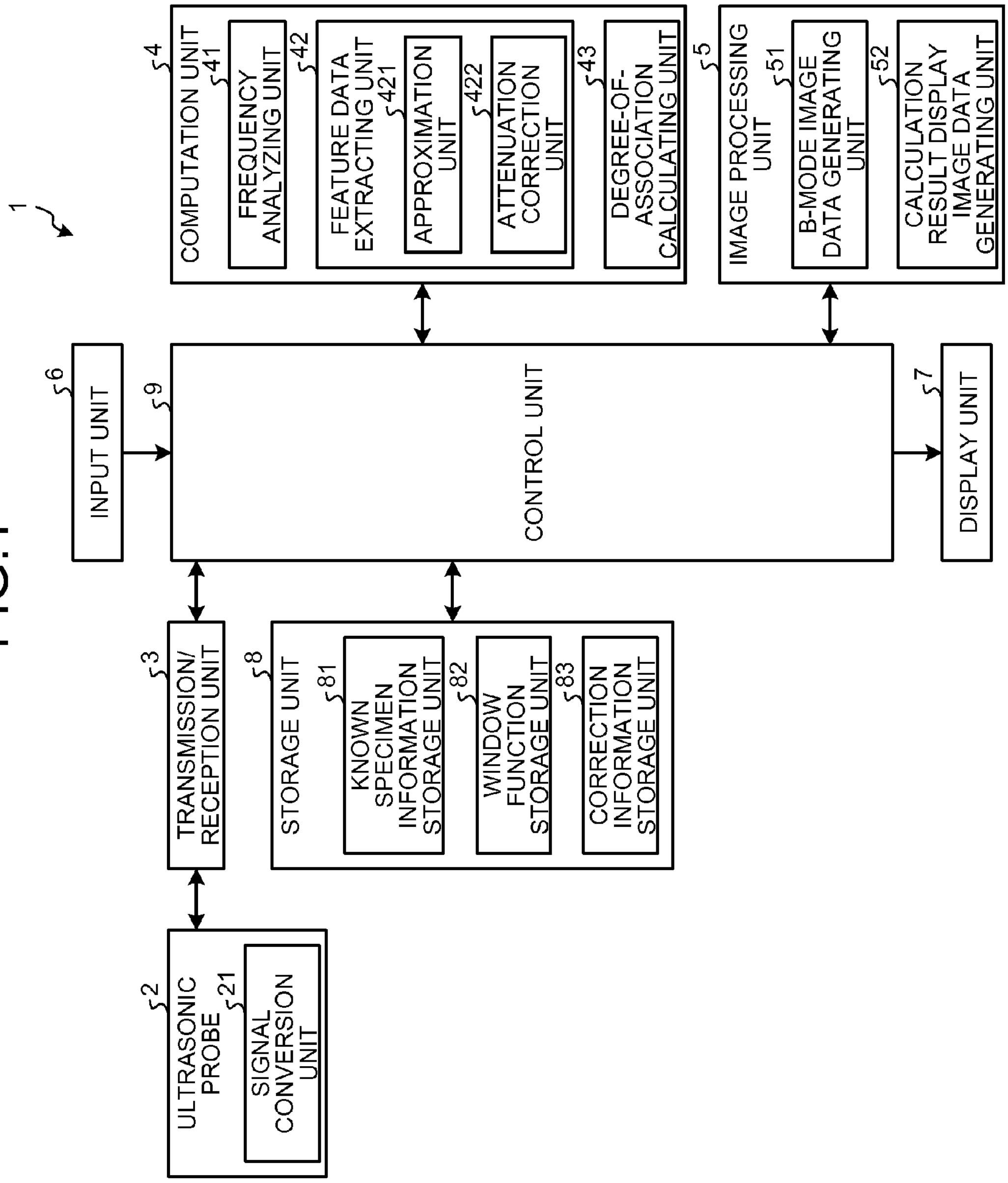

1
ULTRASONIC PROBE
2
SIGNAL CONVERSION UNIT
21
TRANSMISSION/ RECEPTION UNIT
3
STORAGE UNIT
8
KNOWN SPECIMEN INFORMATION STORAGE UNIT
81
WINDOW FUNCTION STORAGE UNIT
82
CORRECTION INFORMATION STORAGE UNIT
83
INPUT UNIT
6
CONTROL UNIT
9
DISPLAY UNIT
7
COMPUTATION UNIT
4
FREQUENCY ANALYZING UNIT
41
FEATURE DATA EXTRACTING UNIT
42
APPROXIMATION UNIT
421
ATTENUATION CORRECTION UNIT
422
DEGREE-OF-ASSOCIATION CALCULATING UNIT
43
IMAGE PROCESSING UNIT
5
B-MODE IMAGE DATA GENERATING UNIT
51
CALCULATION RESULT DISPLAY IMAGE DATA GENERATING UNIT
52

FIG.2

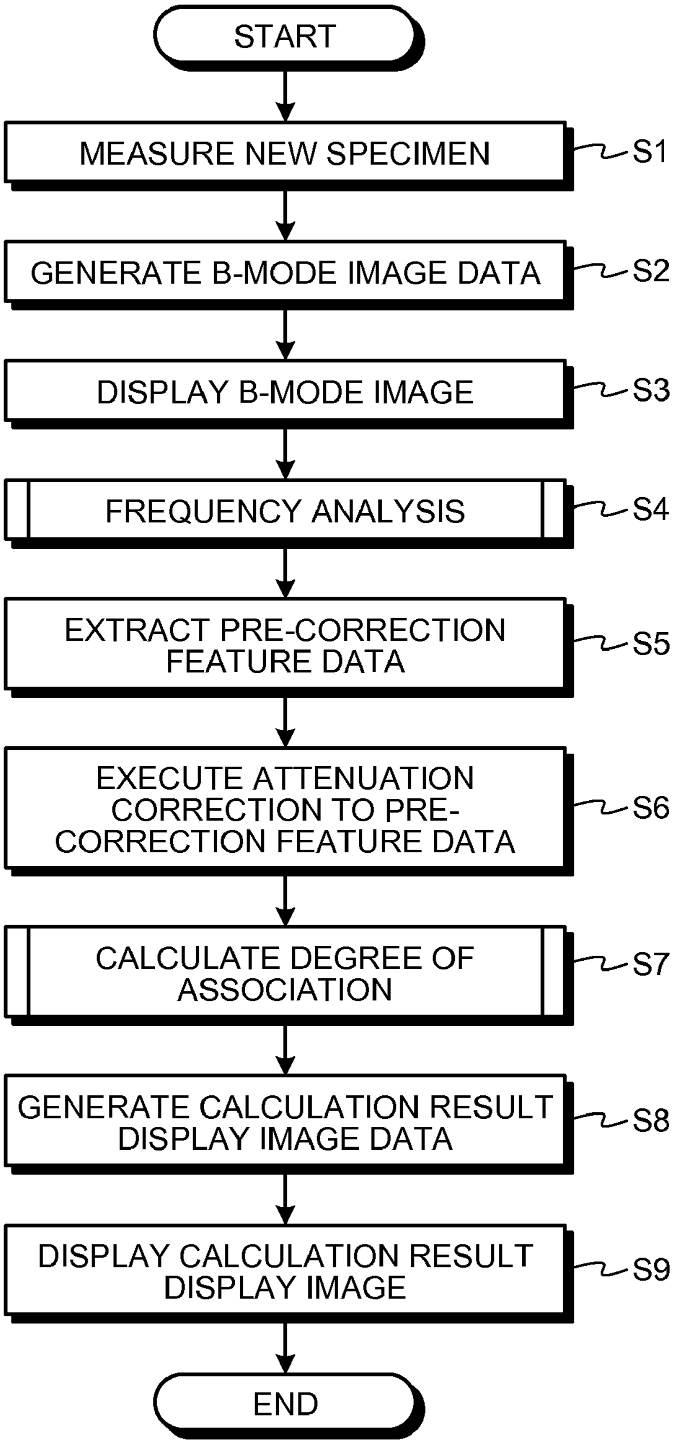

START
MEASURE NEW SPECIMEN
S1
GENERATE B-MODE IMAGE DATA
S2
DISPLAY B-MODE IMAGE
S3
FREQUENCY ANALYSIS
S4
EXTRACT PRE-CORRECTION FEATURE DATA
S5
EXECUTE ATTENUATION CORRECTION TO PRE-CORRECTION FEATURE DATA
S6
CALCULATE DEGREE OF ASSOCIATION
S7
GENERATE CALCULATION RESULT DISPLAY IMAGE DATA
S8
DISPLAY CALCULATION RESULT DISPLAY IMAGE
S9
END

FIG.3

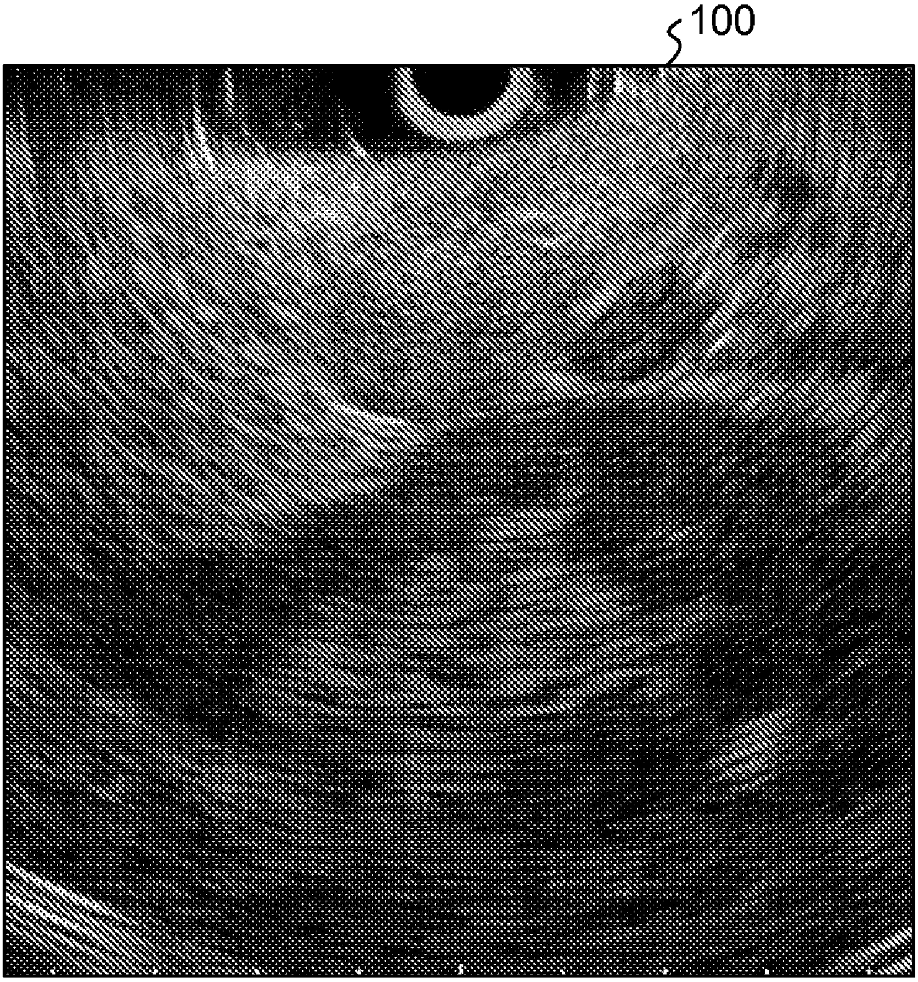


FIG.4

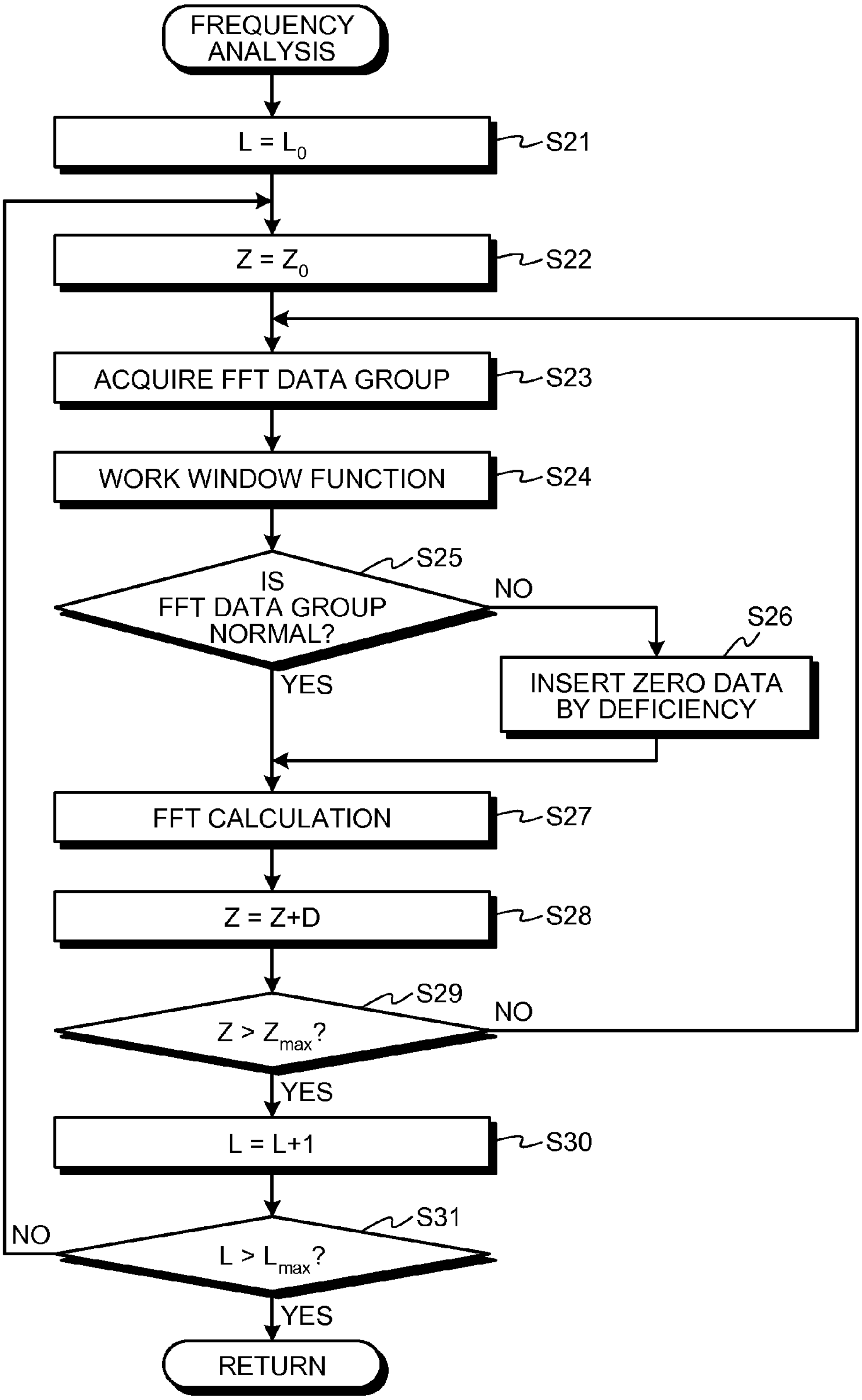

FREQUENCY ANALYSIS
L = L0
S21
Z = Z0
S22
ACQUIRE FFT DATA GROUP
S23
WORK WINDOW FUNCTION
S24
S25
IS FFT DATA GROUP NORMAL?
NO
YES
S26
INSERT ZERO DATA BY DEFICIENCY
FFT CALCULATION
S27
Z = Z+D
S28
S29
Z > Zmax?
NO
YES
L = L+1
S30
S31
L > Lmax?
NO
YES
RETURN

FIG.5

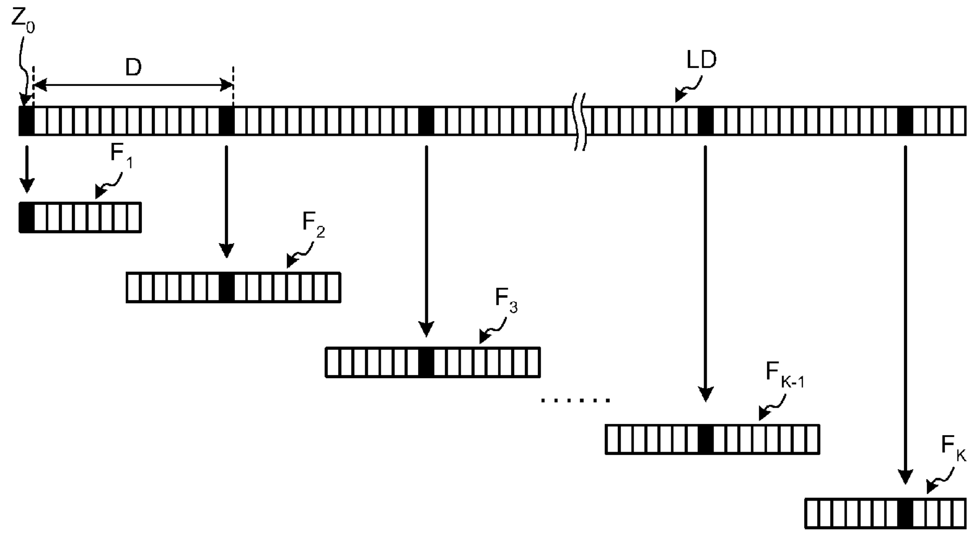


FIG.6

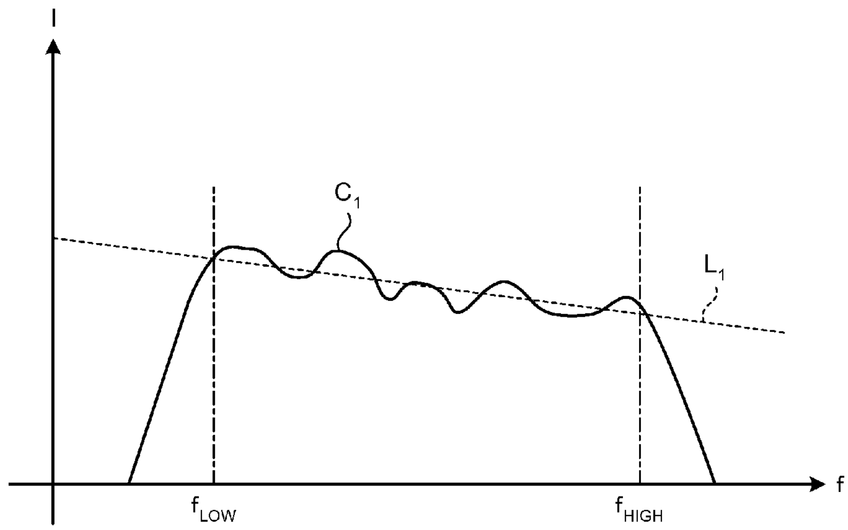


FIG.7

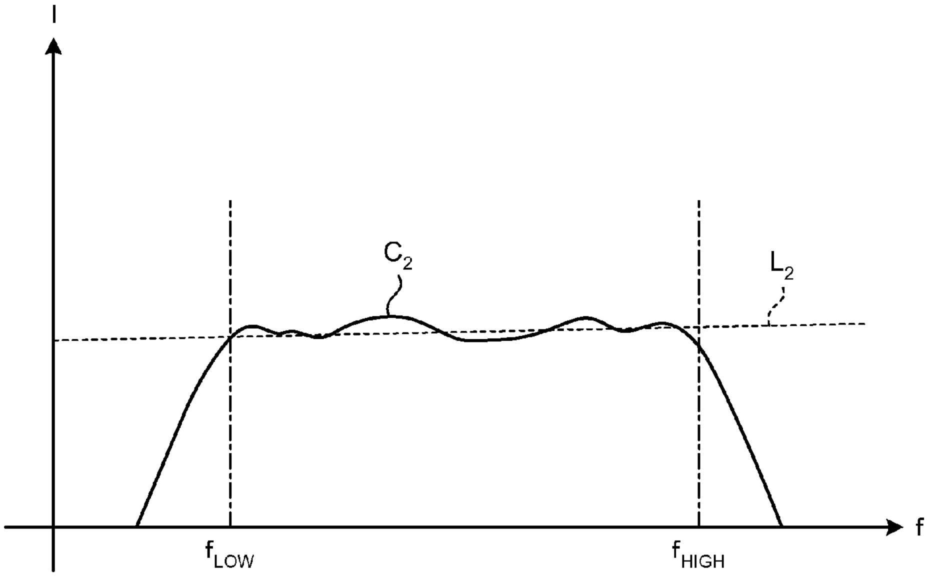


FIG.8

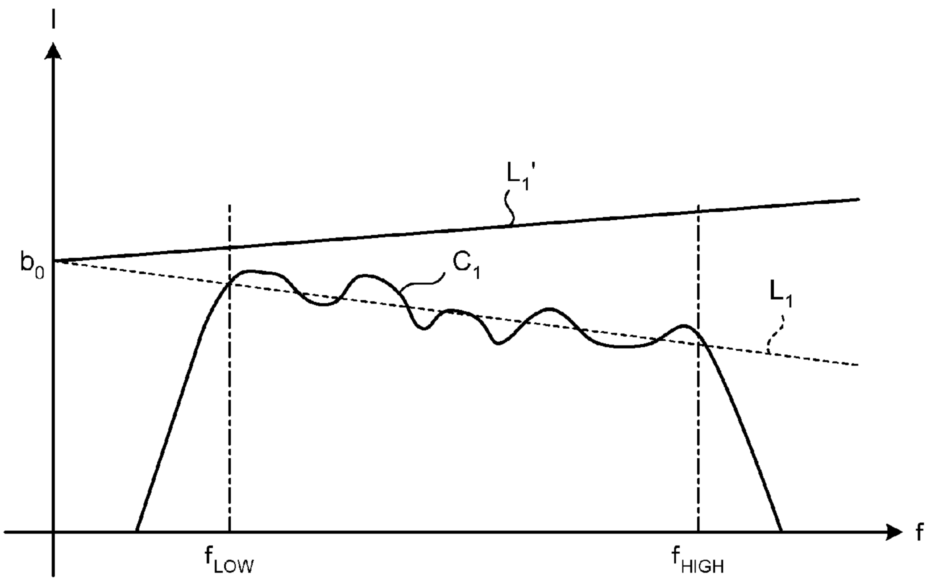


FIG.9

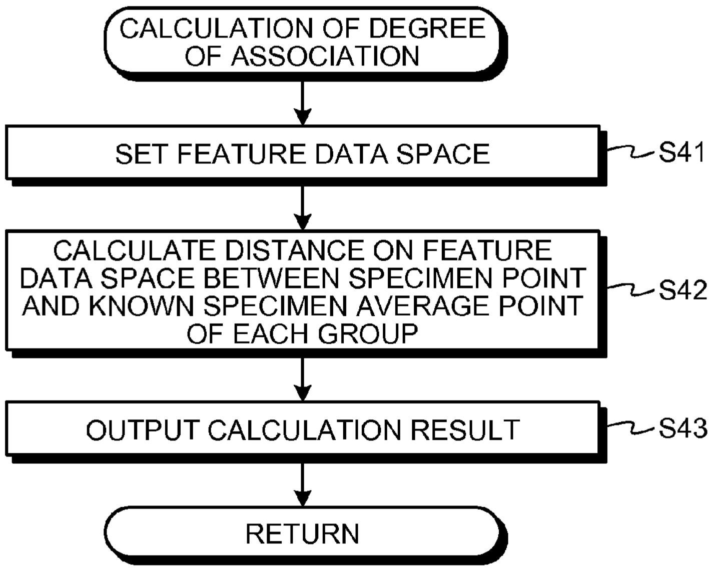

CALCULATION OF DEGREE OF ASSOCIATION
SET FEATURE DATA SPACE
S41
CALCULATE DISTANCE ON FEATURE DATA SPACE BETWEEN SPECIMEN POINT AND KNOWN SPECIMEN AVERAGE POINT OF EACH GROUP
S42
OUTPUT CALCULATION RESULT
S43
RETURN

FIG.10

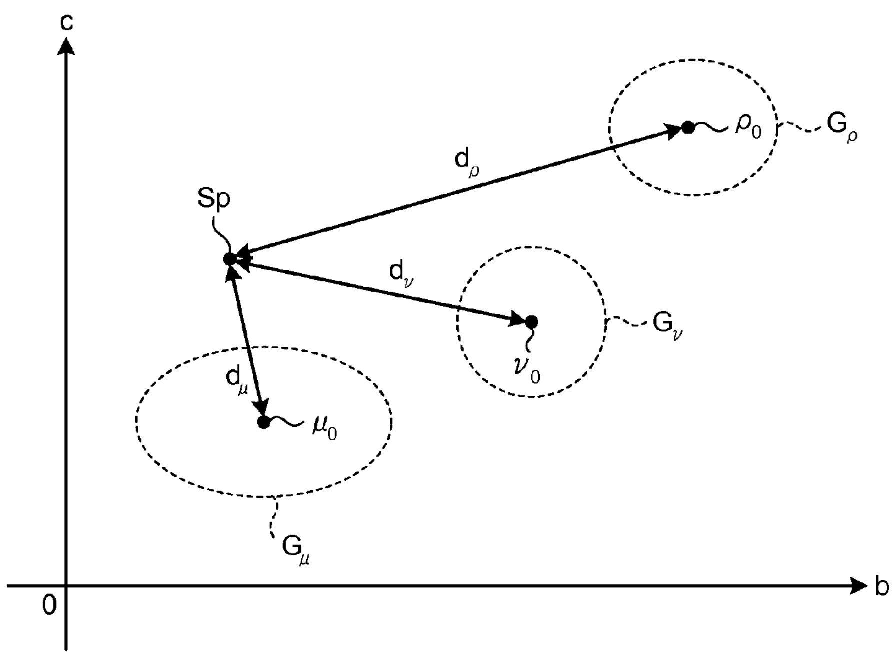

c
b
0
Sp
d_ρ
ρ_0
G_ρ
d_ν
ν_0
G_ν
d_μ
μ_0
G_μ

FIG.11

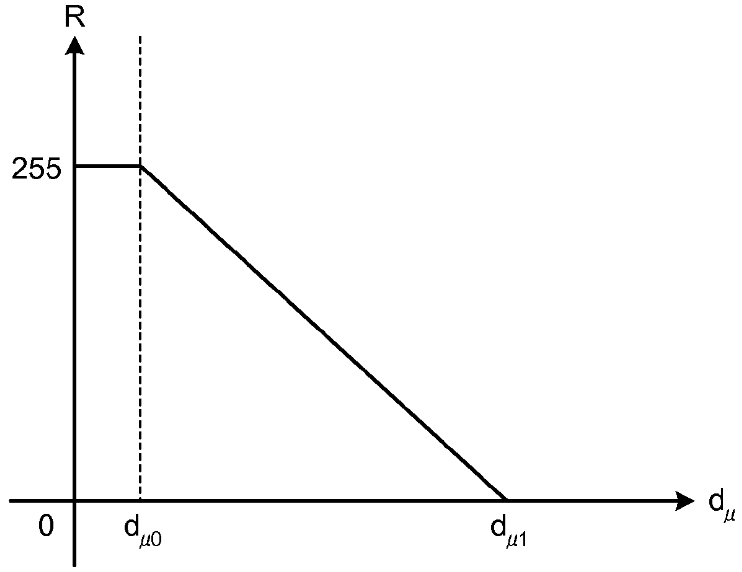


FIG.12

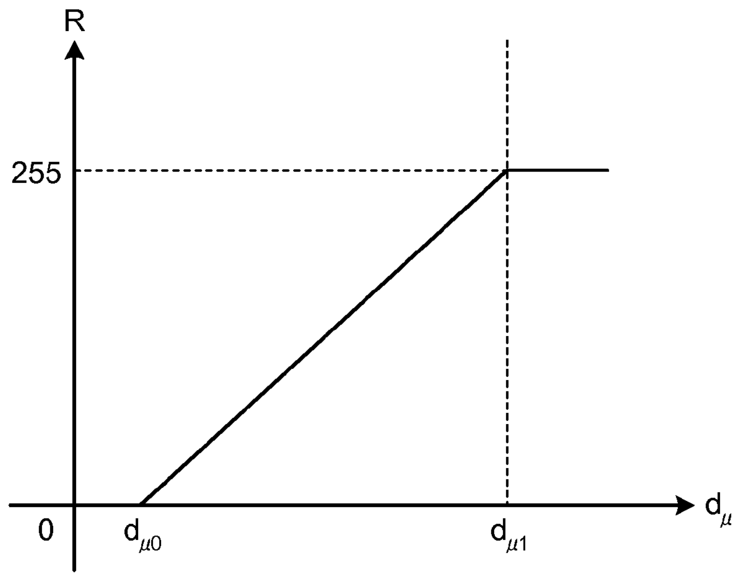


FIG.13

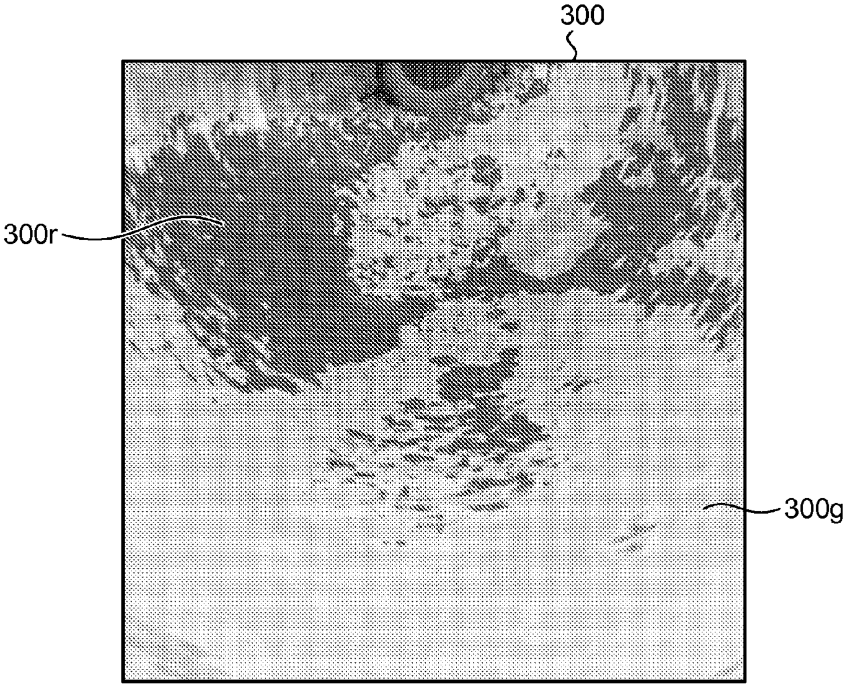


FIG.14

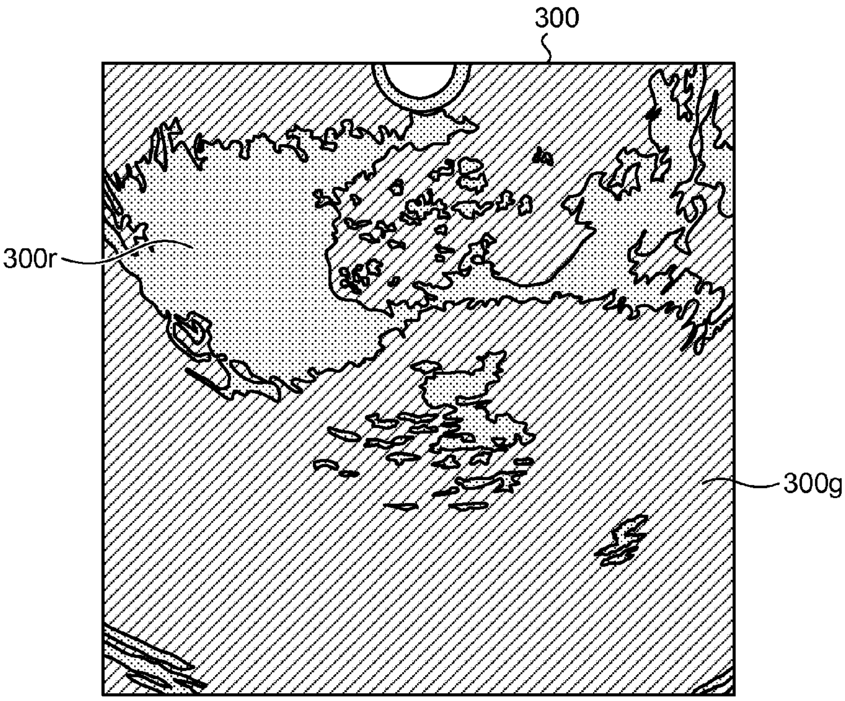


FIG.15

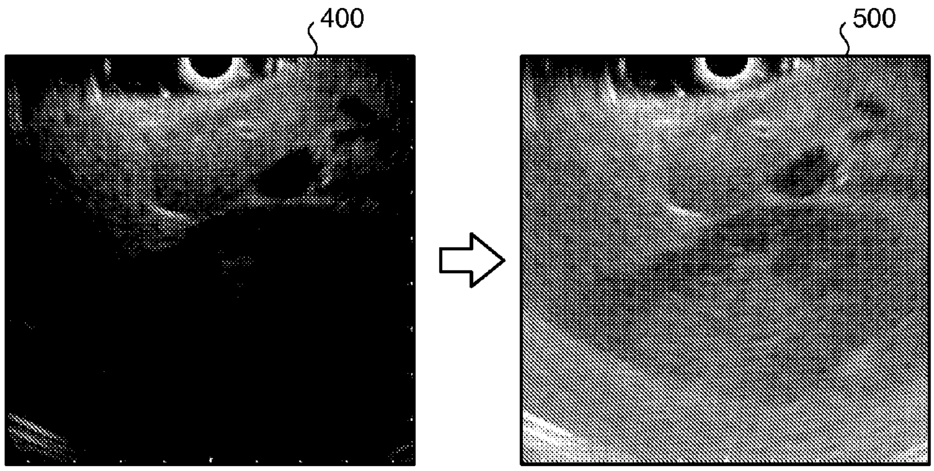


FIG.16

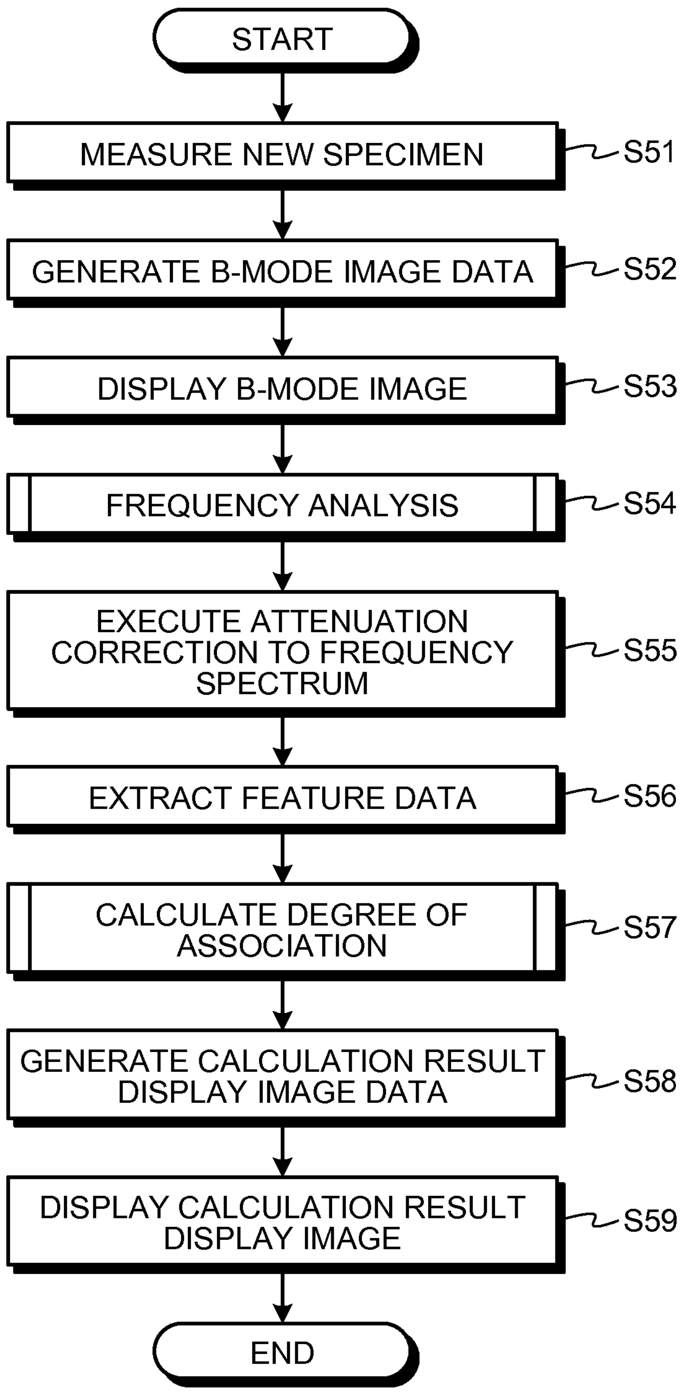
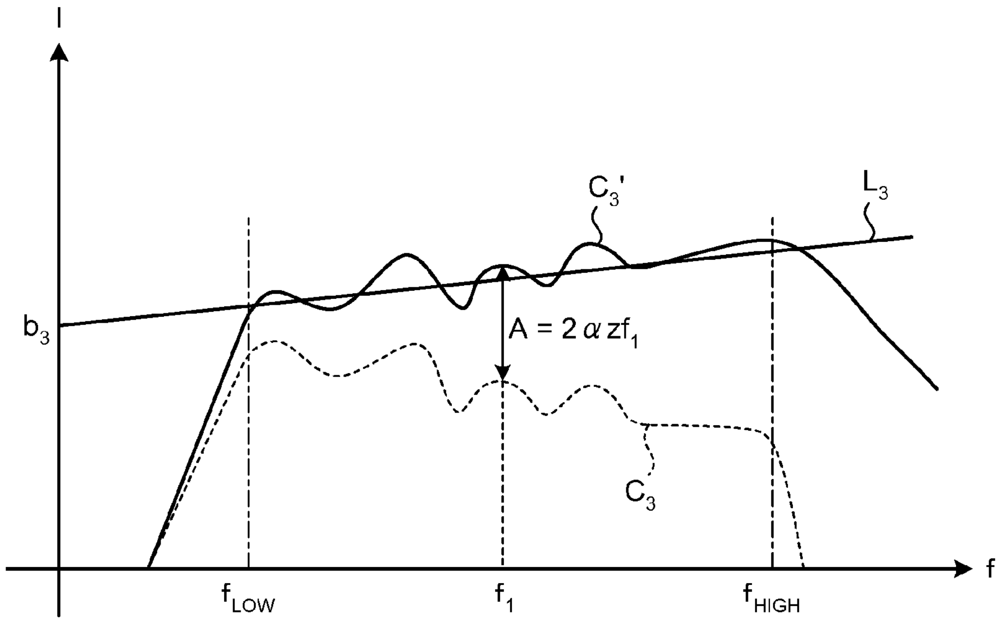
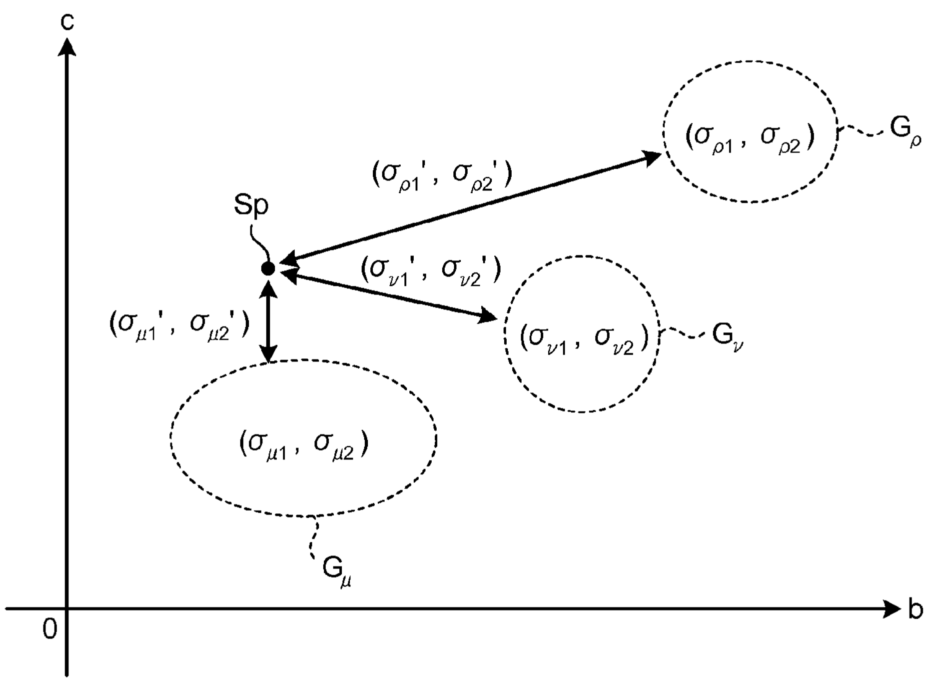

START
MEASURE NEW SPECIMEN
S51
GENERATE B-MODE IMAGE DATA
S52
DISPLAY B-MODE IMAGE
S53
FREQUENCY ANALYSIS
S54
EXECUTE ATTENUATION CORRECTION TO FREQUENCY SPECTRUM
S55
EXTRACT FEATURE DATA
S56
CALCULATE DEGREE OF ASSOCIATION
S57
GENERATE CALCULATION RESULT DISPLAY IMAGE DATA
S58
DISPLAY CALCULATION RESULT DISPLAY IMAGE
S59
END

FIG.17



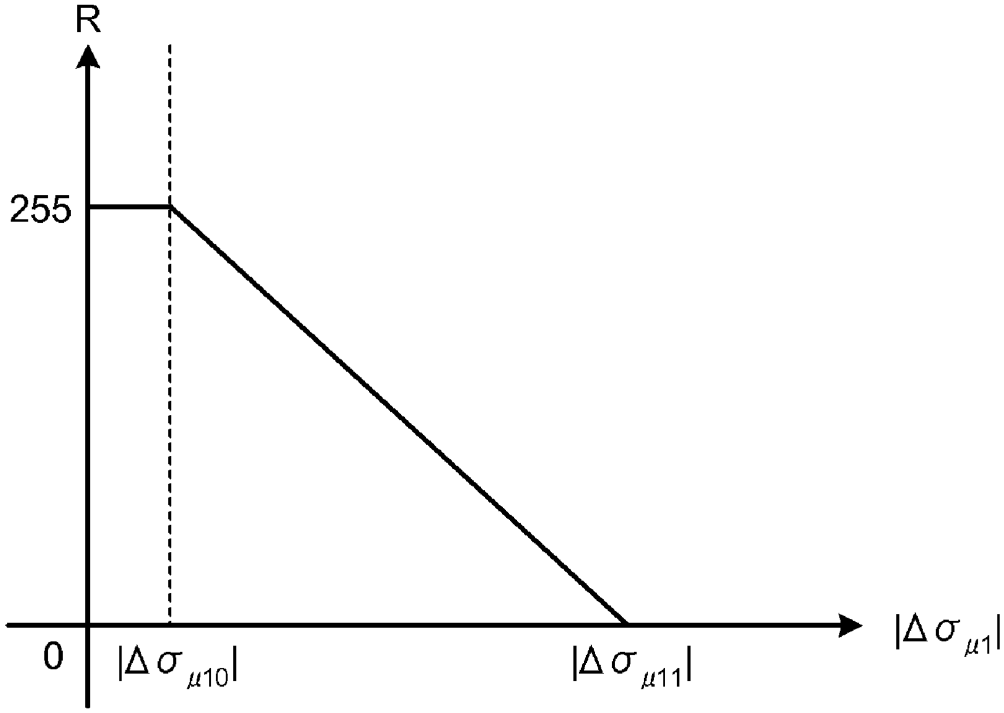
I
C3'
L3
b3
A = 2αzf1
C3
f
fLOW
f1
fHIGH

FIG.18



c
(σρ1 , σρ2)
Gρ
(σρ1', σρ2')
Sp
(σν1', σν2')
(σμ1', σμ2')
(σν1 , σν2)
Gν
(σμ1 , σμ2)
Gμ
0
b

FIG.19



ULTRASONIC OBSERVATION APPARATUS, OPERATION METHOD OF THE SAME, AND COMPUTER READABLE RECORDING MEDIUM

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation of PCT international application Ser. No. PCT/JP2011/076602 filed on Nov. 11, 2011 which designates the United States, incorporated herein by reference, and which claims the benefit of priority from Japanese Patent Applications No. 2010-253285, filed on Nov. 11, 2010, incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to an ultrasonic observation apparatus for observing a specimen tissue by use of ultrasonic wave, an operation method of the ultrasonic observation apparatus, and a computer readable recording medium.

[0004] 2. Description of the Related Art

[0005] There has conventionally been known an ultrasonic elastography as an examination technology of breast cancer by use of ultrasonic wave (e.g., see WO 2005/122906 A). The ultrasonic elastography is a technique of utilizing a phenomenon that a hardness of a cancer or a tumor tissue in a living body is different depending on a disease progression or on the living body. In this technique, a distorted amount or elasticity of a body tissue in an examination region is measured by use of ultrasonic wave with the examination region being externally pressed, and the result of the measurement is displayed as a tomographic view.

SUMMARY OF THE INVENTION

[0006] An ultrasonic observation apparatus according to the present invention transmits an ultrasonic wave to a specimen, and receives the ultrasonic wave reflected on the specimen, the apparatus including: a frequency analyzing unit configured to calculate a frequency spectrum by analyzing a frequency of the received ultrasonic wave; a feature data extracting unit configured to extract feature data of the frequency spectrum by performing an approximation to the frequency spectrum calculated by the frequency analyzing unit; a storage unit configured to store feature data of a frequency spectrum extracted based upon the ultrasonic wave reflected respectively from plural known specimens, and to store the plural known specimens as being classified into plural groups based upon information of each of the known specimens; a degree-of-association calculating unit configured to calculate a degree of association between the feature data extracted by the feature data extracting unit and each group by using a statistics of a population including at least the feature data of each group stored in the storage unit; an image processing unit configured to allow the degree of association of the specimen to each group to correspond to different color components, and to generate ultrasonic image data by using a parameter formed by combining the different color components, based upon the calculation result of the degree-of-association calculating unit; and a display unit configured to be capable of displaying the image corresponding to the ultrasonic image data generated by the image processing unit.

[0007] An operation method according to the present invention of an ultrasonic observation apparatus that transmits an ultrasonic wave to a specimen, and receives the ultrasonic wave reflected on the specimen, includes: calculating a frequency spectrum by analyzing a frequency of the received ultrasonic wave by a frequency analyzing unit; extracting feature data of the frequency spectrum by performing an approximation to the frequency spectrum by a feature data extracting unit; reading a feature data of each group from a storage unit that stores feature data of a frequency spectrum extracted based upon the ultrasonic wave reflected respectively from plural known specimens, and that stores the plural known specimens as being classified into plural groups based upon information of each of the known specimens, and calculating a degree of association between the feature data extracted by the feature data extracting unit and each group by using a statistics of a population including at least the feature data of each group; allowing the degree of association of the specimen to each group to correspond to different color components, and generating ultrasonic image data by using a parameter formed by combining the different color components, based upon the calculation result of the degree of association; and displaying the image corresponding to the ultrasonic image data on a display unit.

[0008] A non-transitory computer readable recording medium according to the present invention has an executable program recorded thereon, wherein the program instructs a processor to perform: calculating a frequency spectrum by analyzing a frequency of a received ultrasonic wave by a frequency analyzing unit; extracting feature data of the frequency spectrum by performing an approximation to the frequency spectrum by a feature data extracting unit; reading feature data of each group from a storage unit that stores feature data of a frequency spectrum extracted based upon the ultrasonic wave reflected respectively from plural known specimens, and that stores the plural known specimens as being classified into plural groups based upon information of each of the known specimens, and calculating a degree of association between the feature data extracted by the feature data extracting unit and each group by using a statistics of a population including at least the feature data of each group; allowing the degree of association of the specimen to each group to correspond to different color components, and generate ultrasonic image data by using a parameter formed by combining the different color components, based upon the calculation result of the degree of association; and displaying the image corresponding to the ultrasonic image data on a display unit.

[0009] The above and other features, advantages and technical and industrial significance of this invention will be better understood by reading the following detailed description of presently preferred embodiments of the invention, when considered in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee.

[0011] FIG. **1** is a block diagram illustrating a configuration of an ultrasonic observation apparatus according to a first embodiment of the present invention;

[0012] FIG. **2** is a flowchart illustrating an outline of a process of the ultrasonic observation apparatus according to the first embodiment of the present invention;

[0013] FIG. **3** is a view illustrating a display example of a B-mode image on a display unit of the ultrasonic observation apparatus according to the first embodiment of the present invention;

[0014] FIG. **4** is a flowchart illustrating an outline of a process executed by a frequency analyzing unit in the ultrasonic observation apparatus according to the first embodiment of the present invention;

[0015] FIG. **5** is a view schematically illustrating a data array of one sound ray;

[0016] FIG. **6** is a view illustrating an example (first example) of a frequency spectrum calculated by the frequency analyzing unit in the ultrasonic observation apparatus according to the first embodiment of the present invention;

[0017] FIG. **7** is a view illustrating an example (second example) of a frequency spectrum calculated by the frequency analyzing unit in the ultrasonic observation apparatus according to the first embodiment of the present invention;

[0018] FIG. **8** is a view illustrating a new straight line determined by a feature data after an attenuation correction is performed to the feature data related to the straight line illustrated in FIG. **6**;

[0019] FIG. **9** is a flowchart illustrating an outline of a process executed by a degree-of-association calculating unit in the ultrasonic observation apparatus according to the first embodiment of the present invention;

[0020] FIG. **10** is a view illustrating an example of a feature data space set by the degree-of-association calculating unit in the ultrasonic observation apparatus according to the first embodiment of the present invention;

[0021] FIG. **11** is a view illustrating an example of a way of assigning a color component to each pixel in calculation result display image data;

[0022] FIG. **12** is a view illustrating another example of a way of assigning a color component to each pixel in calculation result display image data;

[0023] FIG. **13** is a view illustrating a display example of a calculation result display image displayed on the display unit in the ultrasonic observation apparatus according to the first embodiment of the present invention;

[0024] FIG. **14** is a view schematically illustrating the image illustrated in FIG. **13** in black and white;

[0025] FIG. **15** is a view describing an effect of the attenuation correction process executed by the ultrasonic observation apparatus according to the first embodiment of the present invention;

[0026] FIG. **16** is a flowchart illustrating an outline of a process of an ultrasonic observation apparatus according to a second embodiment of the present invention;

[0027] FIG. **17** is a view schematically illustrating an outline of an attenuation correction process executed by the ultrasonic observation apparatus according to the second embodiment of the present invention;

[0028] FIG. **18** is a view describing a feature data space set by a degree-of-association calculating unit in an ultrasonic observation apparatus according to a third embodiment of the present invention, and a standard deviation of a feature point in the feature data space; and

[0029] FIG. **19** is a view illustrating a relationship between an absolute value of a difference in the standard deviation in the feature data space and a magnitude of a red component.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0030] Embodiments for carrying out the present invention (hereinafter referred to as "embodiments") will be described below with reference to the attached drawings.

First Embodiment

[0031] FIG. **1** is a block diagram illustrating a configuration of an ultrasonic observation apparatus according to a first embodiment of the present invention. The ultrasonic observation apparatus illustrated in FIG. **1** is an apparatus for observing a specimen by use of ultrasonic wave.

[0032] An ultrasonic observation apparatus **1** includes an ultrasonic probe **2** that outputs an ultrasonic pulse to the outside, and that receives an externally reflected ultrasonic echo, a transmission/reception unit **3** that transmits and receives an electric signal to and from the ultrasonic probe **2**, a computation unit **4** that performs predetermined computation to an electric echo signal obtained by converting the ultrasonic echo, an image processing unit **5** that generates image data corresponding to the electric echo signal obtained by converting the ultrasonic echo, an input unit **6** that is realized by using an interface such as a keyboard, a mouse, or a touch panel for accepting an input of various information, a display unit **7** that is realized by using a display panel such as a liquid crystal panel or an organic EL panel, and that can display various information including the image generated by the image processing unit **5**, a storage unit **8** that stores information involved with plural known specimens, and that stores the plural known specimens classified into plural groups, and a control unit **9** that controls the operation of the ultrasonic observation apparatus **1**.

[0033] The ultrasonic probe **2** includes a signal conversion unit **21** that converts the electric pulse signal received by the transmission/reception unit **3** into an ultrasonic pulse (acoustic pulse signal), and that converts the ultrasonic echo reflected on an external specimen into an electric echo signal. The ultrasonic probe **2** may be the one that allows an ultrasonic vibrator to mechanically scan, or the one that allows plural ultrasonic vibrators to electronically scan.

[0034] The transmission/reception unit **3** is electrically connected to the ultrasonic probe **2**, transmits the pulse signal to the ultrasonic probe **2**, and receives an echo signal, which is a reception signal, from the ultrasonic probe **2**. Specifically, the transmission/reception unit **3** generates a pulse signal based upon a waveform and transmission timing, set beforehand, and transmits the generated pulse signal to the ultrasonic probe **2**.

[0035] The transmission/reception unit **3** is electrically connected to the ultrasonic probe **2**, transmits the pulse signal to the ultrasonic probe **2**, and receives an echo signal from the ultrasonic probe **2**. Specifically, the transmission/reception unit **3** generates a pulse signal based upon a waveform and transmission timing, set beforehand, and transmits the generated pulse signal to the ultrasonic probe **2**. The transmission/reception unit **3** performs a process such as an amplification or filtering to the received echo signal, and then, generates a digital RF signal through an A/D conversion. Then, it outputs the digital RF signal. When the ultrasonic probe **2** is configured to electronically scan plural ultrasonic vibrators, the transmission/reception unit **3** has a multichannel circuit for synthesizing beams corresponding to the plural ultrasonic vibrators.

[0036] The computation unit **4** includes a frequency analyzing unit **41** that performs fast Fourier transform (FFT) to the digital RF signal outputted from the transmission/reception unit **3** so as to analyze a frequency of the echo signal, a feature data extracting unit **42** that performs an attenuation correction process for reducing a contribution of an attenuation generated according to the reception depth and the frequency of the ultrasonic wave, and an approximation process to the frequency spectrum (power spectrum) calculated by the frequency analyzing unit **41** during the propagation of the ultrasonic wave, in order to extract a feature data of a specimen, and a degree-of-association calculating unit **43** that calculates a degree of association between the feature data extracted by the feature data extracting unit **42** and each of the plural groups stored in the storage unit **8**.

[0037] The frequency analyzing unit **41** calculates the frequency spectrum of each sound ray (line data) by performing the fast Fourier transform to a FFT data group including predetermined amount of data. The frequency spectrum indicates a different tendency depending upon a tissue characterization of the specimen. This is because the frequency spectrum has a correlation with the size of the specimen serving as a scattering substance scattering the ultrasonic wave, a density, and an acoustic impedance.

[0038] The feature data extracting unit **42** includes an approximation unit **421** that calculates a pre-correction feature data, which is an amount before the execution of the attenuation correction process, by performing the approximation process to the frequency spectrum calculated by the frequency analyzing unit **41**, and an attenuation correction unit **422** that extracts the feature data by performing the attenuation correction process to the pre-correction feature data approximated by the approximation unit **421**.

[0039] The approximation unit **421** approximates the frequency spectrum with a primary expression according to a regression analysis, thereby extracting the pre-correction feature data characterizing the approximated primary expression. Specifically, the approximation unit **421** calculates a slope a_0 and an intercept b_0 of the primary expression according to the regression analysis, and calculates the intensity of a specific frequency within a frequency band of the frequency spectrum as the pre-correction feature data. In the first embodiment, the approximation unit **421** is supposed to calculate an intensity (Mid-band fit) $c_0=a_0 f_{MID}+b_0$ at a center frequency $f_{MID}=(f_{LOW}+f_{HIGH})/2$. However, this is only one example. The "intensity" here means any one of parameters including a voltage, power, sound pressure, and acoustic energy.

[0040] Among the three feature data, the slope a_0 has a correlation with the size of the scattering body of the ultrasonic wave, and it is generally considered that the slope has a smaller value, as the size of the scattering body is large. The intercept b_0 has a correlation with the size of the scattering body, the difference in the acoustic impedance, and the density (concentration) of the scattering body. Specifically, it is considered that the intercept b_0 has a larger value, as the size of the scattering body is large, as the acoustic impedance is large, and as the density (concentration) of the scattering body is large. The intensity at the center frequency f_{MID} (hereinafter merely referred to as "intensity") c_0 is an indirect parameter derived from the slope a_0 and the intercept b_0, and it gives a spectrum intensity at the center in the effective frequency band. Therefore, it is considered that the intensity c_0 has not only a correlation with the size of the scattering body, the difference in the acoustic impedance, and the density of the scattering body, but also a correlation with the brightness of the B-mode image to a certain extent. The approximate polynomial calculated by the feature data extracting unit **42** is not limited to the primary expression, but a second-order or higher-order approximate polynomial may be used.

[0041] The correction executed by the attenuation correction unit **422** will be described. An attenuation amount A of the ultrasonic wave can be expressed as:

$$A=2\alpha zf \quad (1)$$

Here, α is an attenuation rate, z is a reception depth of the ultrasonic wave, and f is a frequency. As is apparent from the equation (1), the attenuation amount A is in proportion to the frequency f. The specific value of the attenuation rate a for a living body is 0 to 1.0 (dB/cm/MHz), and more preferably 0.3 to 0.7 (dB/cm/MHz). The attenuation rate is determined according to a type of an organ to be observed. For example, when the organ to be observed is pancreas, it is determined that α=0.6 (dB/cm/MHz). It can be configured in the first embodiment that the value of the attenuation rate a can be changed by the input from the input unit **6**.

[0042] The attenuation correction unit **422** corrects the pre-correction feature data (slope a_0, intercept b_0, intensity c_0) extracted by the approximation unit **421** as described below.

$$a=a_0+2\alpha z \quad (2)$$

$$b=b_0 \quad (3)$$

$$c=c_0+2\alpha z f_{MID}(=af_{MID}+b) \quad (4)$$

As is apparent from the equations (2) and (4), the attenuation correction unit **422** makes a correction with a large correction amount, as the reception depth z of the ultrasonic wave is larger. According to the equation (3), the correction involved with the intercept is an identical transformation. This is because the intercept is not subject to the attenuation, since the intercept is the frequency component corresponding to the frequency 0 (Hz).

[0043] The degree-of-association calculating unit **43** calculates the degree of association between the feature data extracted by the feature data extracting unit **42** and each of the groups by using a statistic of a population including at least the feature data of the respective groups stored in the storage unit **8**. More specifically, the degree-of-association calculating unit **43** sets a feature data space, which has at least any one of the plural feature data extracted by the feature data extracting unit **42** as a component, and calculated, as the degree of association, the distance on the feature data space between a specimen point having the feature data, serving as the component in the set feature data space, out of the feature data of the frequency spectrum of the specimen as a coordinate in the feature data space, and a known specimen average point having an average of the feature data serving as the component in the feature data space out of the feature data of the plural groups of the known specimens as the coordinate of the feature data space.

[0044] The average and standard deviation of the feature data of the frequency spectrum of the ultrasonic reception signal reflects a change in a cell level such as an enlarged nucleus, and heteromorphy of nucleus in a specimen, or a change in a tissue such as increased fibra in interstitium, or replacement of a parenchymal tissue into a fiber, and it indicates a unique value according to the tissue characterization.

The "tissue characterization" here means any one of a cancer, endocrine tumor, mucinous tumor, normal tissue, and vessel channel. When the specimen is a pancreas, the tissue characterization includes chronic pancreatitis, and autoimmune pancreatitis. In view of the above circumstance, the groups stored in the storage unit **8** are desirably determined according to the type of the tissue characterization. Therefore, it is supposed in the description below that the groups stored in the storage unit **8** are determined according to the type of the tissue characterization.

[0045] The image processing unit **5** includes a B-mode image data generating unit **51** that generates B-mode image data from the echo signal, and a calculation result display image data generating unit **52** that generates calculation result display image data that is ultrasonic image data for displaying the calculation result of the degree of association by using the calculation result of the degree of association calculated by the degree-of-association calculating unit **43** and the B-mode image data generated by the B-mode image data generating unit **51**.

[0046] The B-mode image data generating unit **51** performs, to the digital signal, a signal processing using a known technique such as a bandpass filter, logarithmic conversion, gain process or contrast process, and generates the B-mode image data by decimating the data according to a data step width determined by a display range of the image on the display unit **7**.

[0047] The calculation result display image data generating unit **52** generates the calculation result display image data by using the B-mode image data generated by the B-mode image data generating unit **51**, the feature data extracted by the feature data extracting unit **42**, and the result calculated by the degree-of-association calculating unit **43**.

[0048] The storage unit **8** includes a known specimen information storage unit **81** that stores information of the known specimen, a window function storage unit **82** that stores a window function used for the frequency analyzing process executed by the frequency analyzing unit **41**, and a correction information storage unit **83** that stores correction information referred to during the execution of the process by the attenuation correction unit **422**.

[0049] The known specimen information storage unit **81** stores the feature data of the frequency spectrum extracted from the known specimen in association with the tissue characterization of the known specimen. The known specimen information storage unit **81** also stores the average and standard deviation of the feature data of the frequency spectrum involved with the known specimen together with all data of the feature data of the known specimen, wherein the average and the standard deviation is calculated for each of the groups classified based upon the information including the tissue characterization of the known specimen. The feature data of the known specimen is extracted in the same manner as in the first embodiment. It is to be noted that the process of extracting the feature data of the known specimen is not necessarily executed by the ultrasonic observation apparatus **1**. It is desirable that the information of the known specimen stored in the known specimen information storage unit **81** has high reliability for the tissue characterization. The window function storage unit **82** stores at least any one of window functions of Hamming, Hanning, and Blackman. The correction information storage unit **83** stores information involved with the transformation of the equations (2) to (4).

[0050] The storage unit **8** is realized by ROM that preliminarily stores an operating program of the ultrasonic observation apparatus according to the first embodiment or a program of starting a predetermined OS, and RAM that stores operation parameters or data for each process.

[0051] The components, other than the ultrasonic probe **2**, of the ultrasonic observation apparatus **1** thus configured are realized by using a computer provided with a CPU having a computation and control functions. The CPU provided to the ultrasonic observation apparatus **1** reads the information memorized and stored in the storage unit **8** and various programs including the operating program of the ultrasonic observation apparatus from the storage unit **8**, thereby executing the computation process involved with the operation method of the ultrasonic observation apparatus according to the first embodiment.

[0052] The operating program of the ultrasonic observation apparatus according to the first embodiment can be recorded on a computer-readable recording medium, such as hard disk, flash memory, CD-ROM, DVD-ROM, or flexible disk,

[0053] FIG. **2** is a flowchart illustrating an outline of a process of the ultrasonic observation apparatus **1** having the above-mentioned configuration. In FIG. **2**, the ultrasonic observation apparatus **1** firstly measures a new specimen by the ultrasonic probe **2** (step S**1**).

[0054] Then, the B-mode image data generating unit **51** generates the B-mode image data by using the echo signal for the B-mode image outputted from the transmission/reception unit **3** (step S**2**).

[0055] Next, the control unit **9** makes control to display the B-mode image corresponding to the B-mode image data generated by the B-mode image data generating unit **51** onto the display unit **7** (step S**3**). FIG. **3** is a view illustrating a display example of the B-mode image on the display unit **7**. The B-mode image **100** in FIG. **3** is a grayscale image in which values of R (red), G (green), and B (blue), which are variables when an RGB color system is employed as a color space, are matched to one another.

[0056] Then, the frequency analyzing unit **41** calculates the frequency spectrum by performing the frequency analysis according to the FFT calculation (step S**4**). The process (step S**4**) executed by the frequency analyzing unit **41** will be described in detail with reference to FIG. **4**. Firstly, the frequency analyzing unit **41** sets a sound ray number L of a sound ray that is a subject to be analyzed to an initial value L_0 (step S**21**). The initial value L_0 may be applied to a sound ray that the transmission/reception unit **3** receives first, or may be applied to a sound ray corresponding to one of boundary positions on the left and on the right of a region of interest set by the input unit **6**.

[0057] Next, the frequency analyzing unit **41** calculates all frequency spectrums on plural data positions set on one sound ray. Firstly, the frequency analyzing unit **41** sets an initial value Z_0 on a data position Z (corresponding to the reception depth) representative of a series of data group (FFT data group) acquired for the FFT calculation (step S**22**). FIG. **5** is a view schematically illustrating a data array of one sound ray. On the sound ray LD illustrated in FIG. **5**, a white rectangle or a black rectangle indicates one data. The sound ray LD is discretized with a time interval corresponding to the sampling frequency (e.g., 50 MHz) in the A/D conversion executed by the transmission/reception unit **3**. In FIG. **5**, the first data on the sound ray LD is set as the initial value Z_0 on the data position Z. FIG. **5** illustrates only one example, and any position can be set as the position of the initial value Z_0. For example, the data position Z corresponding to the upper end of the region of interest may be set as the initial value Z_0.

[0058] Then, the frequency analyzing unit **41** acquires the FFT data group on the data position Z (step S**23**), and allows the window function stored in the window function storage unit **82** to work on the acquired FFT data group (step S**24**). Allowing the window function to work on the FFT data group as described above avoids that the FFT data group becomes discontinuity on the boundary, and can prevent the occurrence of artifacts.

[0059] Next, the frequency analyzing unit **41** determines whether the FFT data group on the data position Z is a normal data group or not (step S**25**). The FFT data group has to have a power-of-2 data number. The data number of the FFT data group is supposed to be 2^n (n is a positive integer) hereinafter. The case where the FFT data group is normal means that the data position Z is on the 2^{n-1}-th position from the head of the FFT data group. In other words, the case where the FFT data group is normal means that there are $2^{n-1}-1$ (=N) data before the data position Z, and there are 2^{n-1} (=M) data after the data position Z. In FIG. **5**, the FFT data groups F_2, F_3, and F_{K-1} are normal, but the FFT data groups F_1 and F_K are abnormal. In FIG. **5**, it is set such that n=4 (N=7, M=8).

[0060] When the FFT data group on the data position Z is normal as a result of the determination in step S**25** (step S**25**: Yes), the frequency analyzing unit **41** moves to a later-described step S**27**.

[0061] When the FFT data group on the data position Z is abnormal as a result of the determination in step S**25** (step S**25**: No), the frequency analyzing unit **41** inserts zero data by a deficiency to generate the normal FFT data group (step S**26**). The window function is worked on the FFT data group that is determined to be abnormal in step S**25** before the zero data is added. Therefore, even if the zero data is inserted to the FFT data group, a data discontinuity does not occur. The frequency analyzing unit **41** moves to the later-described step S**27** after step S**26**.

[0062] In step S**27**, the frequency analyzing unit **41** acquires the frequency spectrum by performing the FFT calculation by use of the FFT data group (step S**27**). FIGS. **6** and **7** are views illustrating the frequency spectrum calculated by the frequency analyzing unit **41**. In FIGS. **6** and **7**, an abscissa axis f indicates a frequency, and an ordinate axis I indicates an intensity. In frequency spectrum curves C_1 and C_2 illustrated in FIGS. **6** and **7** respectively, the lower-limit frequency f_{LOW} and the upper-limit frequency f_{HIGH} of the frequency spectrum are parameters determined based upon the frequency band of the ultrasonic probe **2** and the frequency band of the pulse signal transmitted by the transmission/reception unit **3**. For example, they are set such that f_{LOW}=3 MHz, and f_{HIGH}=10 MHz. A straight line L_1 illustrated in FIG. **6** and a straight line L_2 illustrated in FIG. **7** will be described for the later-described feature data extracting process. In the first embodiment, the curve and the straight line are composed of a set of discrete points. This is applied to the later-described embodiments.

[0063] Next, the frequency analyzing unit **41** adds a predetermined data step width D to the data position Z to calculate the data position Z of the FFT data group that is the next subject to be analyzed (step S**28**). The data step width D desirably agrees with the data step width utilized for generating the B-mode image data by the B-mode image data generating unit **51**. However, if the computation amount of the frequency analyzing unit **41** is intended to be reduced, the data step width larger than the data step width utilized by the B-mode image data generating unit **51** may be set. FIG. **5** illustrates the case where D=15.

[0064] Then, the frequency analyzing unit **41** determines whether the data position Z is larger than a final data position Z_{max} or not (step S**29**). The final data position Z_{max} may be a data length of the sound ray LD, or may be the data position corresponding to the lower end of the region of interest. When the data position Z is larger than the final data position Z_{max} as a result of the determination (step S**29**: Yes), the frequency analyzing unit **41** increments the sound ray number L by 1 (step S**30**). On the other hand, when the data position Z is not more than the final data position Z_{max} (step S**29**: No), the frequency analyzing unit **41** returns to step S**23**. In this way, the frequency analyzing unit **41** performs the FFT calculation to the $[\{(Z_{max}-Z_0)/D\}+1]$ (=K) FFT data groups with respect to one sound ray LD. Here, [X] indicates the maximum integer not exceeding X.

[0065] When the sound ray number L to which 1 is added in step S**30** is larger than a final sound ray number L_{max} (step S**31**: Yes), the frequency analyzing unit **41** returns to the main routine illustrated in FIG. **2**. On the other hand, when the sound ray number L to which 1 is added in step S**30** is not more than the final sound ray number L_{max} (step S**31**: No), the frequency analyzing unit **41** returns to step S**22**.

[0066] In this way, the frequency analyzing unit **41** executes the FFT calculation K times to each of $(L_{max}-L_0+1)$ sound rays. The final sound ray number L_{max} may be applied to the final sound ray received by the transmission/reception unit **3**, or may be applied to the sound ray corresponding to one of left and right boundaries of the region of interest, for example. The total number $(L_{max}-L_0+1)\times K$ of the FFT calculation executed to all sound rays by the frequency analyzing unit **41** is set as P below.

[0067] Subsequent to the frequency analyzing process in step S**4** described above, the approximation unit **421** extracts the pre-correction feature data by performing the regression analysis to P frequency spectrums calculated by the frequency analyzing unit **41** as the approximation process (step S**5**). Specifically, the approximation unit **421** calculates the primary expression, which approximates the frequency spectrum in the frequency band ($f_{low}<f<f_{HIGH}$), according to the regression analysis, thereby extracting the slope a_0, the intercept b_0, and the intensity c_0 characterizing the primary expression as the pre-correction feature data. The straight line L_1 in FIG. **6** and the straight line L_2 in FIG. **7** are regression lines obtained by performing the regression analysis to the frequency spectrum curves C_1 and C_2 respectively in step S**5**.

[0068] Thereafter, the attenuation correction unit **422** performs the attenuation correction process to the pre-correction feature data extracted by the approximation unit **421** (step S**6**). For example, when the sampling frequency of the data is 50 MHz, the time interval of the data sampling is 20 (nsec). If the sound speed is supposed to be 1530 (m/sec), the sampling distance interval of the data becomes 1530 (m/sec)×20 (nsec)/2=0.0153 k (mm). If the data step number from the first data of the sound ray LD to the data position of the FFT data group that is the subject for the process is k, the data position Z becomes 0.0153 k (mm). The attenuation correction unit **422** calculates the slope a, the intercept b, and the intensity c, which are the feature data of the frequency spectrum, by substituting the data position Z obtained in this way into the reception depth z in the above-mentioned equations (2) to (4).

FIG. **8** is a view illustrating a straight line determined by the feature data obtained by performing the attenuation process to the feature data involved with the straight line L_1 illustrated in FIG. **6**. The equation representing the straight line L_1' illustrated in FIG. **8** is:

$$I=af+b=(a_0+2\alpha Z)f+b_0 \quad (5)$$

As is apparent from the equation (5), the straight line L_1' has a slope larger than that of the straight line L_1, and an intercept equal to the intercept of the straight line L_1.

[0069] Thereafter, the degree-of-association calculating unit **43** calculates the degree of association between the specimen and the groups of the known specimens stored in the storage unit **8** based upon the feature data extracted by the feature data extracting unit **42** and the known specimen information stored in the known specimen information storage unit **81** (step S7).

[0070] The process (step S7) executed by the degree-of-association calculating unit **43** will be described in detail with reference to the flowchart in FIG. **9**. Firstly, the degree-of-association calculating unit **43** sets the feature data space used for calculating the degree of association (step S**41**). In the first embodiment, the independent parameters are two out of the three feature data that are the slope a, the intercept b, and the intensity c. Therefore, a two-dimensional space having any two of the three feature data as components can be set as the feature data space. Alternatively, a one-dimensional space having any one of the three feature data as a component can be set as the feature data space. In step S**41**, it is supposed that the feature data space to be set is determined beforehand. However, an operator may select a desired feature data space by the input unit **6**.

[0071] FIG. **10** is a view illustrating an example of the feature data space set by the degree-of-association calculating unit **43**. In the feature data space illustrated in FIG. **10**, the abscissa axis indicates the intercept b, and the ordinate axis indicates the intensity c. A point Sp in FIG. **10** indicates a point (hereinafter referred to as a "specimen point") having the intercept b and the intensity c calculated for the specimen to be examined as a coordinate in the feature data space. Regions G_μ, G_ν, and G_ρ illustrated in FIG. **10** respectively indicate groups in which a tissue characterization of the known specimen stored in the known specimen information storage unit **81** is μ, ν, and ρ. In the case of FIG. **10**, three groups G_μ, G_ν, and G_ρ are present in the regions not intersecting with one another in the feature data space.

[0072] In the first embodiment, even in obtaining the feature data of the known specimen, the grouping is executed by using the feature data, which is obtained by performing the attenuation correction to the pre-correction feature data of the frequency spectrum obtained by the frequency analysis, as an index. Therefore, the different groups can clearly be separated. Since the feature data to which the attenuation correction is performed is used in the first embodiment, in particular, the regions of the respective groups can be obtained as being clearly separated, compared to the case where the feature data that is extracted without being subjected to the attenuation correction is used.

[0073] After step S41, the degree-of-association calculating unit **43** calculates distances d_μ, d_ν, and d_ρ on the feature data space between the specimen point Sp and respective points μ_0, ν_0, and ρ_0 (these points are hereinafter referred to as "known specimen average points") that are included in the groups G_μ, G_ν, and G_ρ, and that have an average of the intercepts b and the intensities c of the frequency spectrum of the FFT data group as the coordinate in the feature data space (step S**42**). The degree-of-association calculating unit **43** calculates the distance between all specimen points of the frequency spectrum and the known specimen average point on the feature data space in step S**42**. If the scale of the b-axis component and the scale of the c-axis component on the feature data space are greatly different, a weighting is desirably executed in order to equalize the contribution of each distance, as needed.

[0074] Next, the degree-of-association calculating unit **43** outputs the distance calculated in step S**42** as the calculation result (step S**43**). Thus, the degree-of-association calculation process in step S7 is ended.

[0075] The degree-of-association calculating unit **43** may determine the tissue characterization of the specimen based upon the calculation result subsequent to step S**43**. In this case, however, the known specimen information storage unit **81** has to store the feature data of the known specimen and the tissue characterization in association with each other. When the specimen point Sp is extremely apart from the known specimen average points μ_0, ν_0, and ρ_0, the reliability of the determination result of the tissue characterization is low even if the minimum values of the distances d_μ, d_ν, and d_ρ are obtained. Therefore, when the distances d_μ, d_ν, and d_ρ are greater than a predetermined threshold value, the degree-of-association calculating unit **43** may output an error signal. When any two of the distances d_μ, d_ν, and d_ρ assume the minimum value, the degree-of-association calculating unit **43** may select all tissue characterizations corresponding to the minimum value as candidates, or may select any one of the tissue characterization according to a prescribed rule. In the latter case, a method in which a priority order of the tissue characterization having high malignancy such as a cancer is set high may be employed. When any two or more of the distances d_μ, d_ν, and d_ρ assume the minimum value, the degree-of-association calculating unit **43** may output an error signal.

[0076] After step S7 described above, the calculation result display image data generating unit **52** generates the calculation result display image data by using the B-mode image data generated by the B-mode image data generating unit **51**, the feature data calculated by the feature data extracting unit **42**, and the result calculated by the degree-of-association calculating unit **43** (step S8). In this case, the calculation result display image data generating unit **52** assigns a color component (a variable composing a color space) serving as visual information to each pixel according to the distance between the specimen point Sp and the known specimen average point on the feature data space. For example, in the feature data space illustrated in FIG. **10**, a red component (R) is assigned to the distance d_μ between the specimen point Sp and the known specimen average point μ_0, a green component (G) is assigned to the distance d_ν between the specimen point Sp and the known specimen average point ν_0, and a blue component (B) is assigned to the distance d_ρ between the specimen point Sp and the known specimen average point ρ_0, and the pixel value is changed according to the distance.

[0077] FIG. **11** is a view illustrating an example of a way of assigning the color component to each pixel in the calculation result display image data. Specifically, FIG. **11** is a view illustrating the relationship between the distance d_μ between the specimen point Sp and the known specimen average point μ_0 on the feature data space and the magnitude of the red component R. In FIG. 11, the red component R assumes 255 (the maximum value in 8-bit notation), when the distance d_μ satisfies $0 \leqq d_\mu \leqq d_{\mu 0}$. The value of the red component R linearly decreases when the distance d_μ satisfies $d_{\mu 0} < d_\mu \leqq d_{\mu 1}$, and when the distance d_μ satisfies $d_\mu > d_{\mu 1}$, it becomes zero. The magnitude of the red component has been described above. The magnitudes of the green component and the blue component can be determined according to the distances d_ν and d_ρ, respectively. The color space may be composed of variables of complementary colors such as cyan, magenta, and yellow, instead of the variables of the RGB color system. Alternatively, three attributes of light (color phase, brightness, saturation), which are different from the others, may be assigned to the distances d_μ, d_ν, and d_ρ. In this case, the attribute value is changed according to the distance. A pattern determined according to the distance may be assigned to any one of the distances d_μ, d_ν, and d_ρ.

[0078] FIG. **12** is a view illustrating another example of a way of assigning the color component to each pixel in the calculation result display image data, and it is a view illustrating the relationship between the distance d_μ and the magnitude of the red component R as in FIG. **11**. In FIG. **12**, the value of the red component R is zero when the distance d_μ satisfies $0 \leqq d_\mu \leqq d_{\mu 0}$. When the distance d_μ satisfies $d_{\mu 0} < d_\mu \leqq d_{\mu 1}$, the red component R linearly increase, and when the distance d_μ satisfies $d_\mu > d_{\mu 1}$, it assumes 255. As described above, the magnitude of the color component assigned to each pixel in the calculation result display image data may arbitrarily be set.

[0079] The display unit **7** displays the calculation result display image generated by the calculation result display image data generating unit **52** (step S9). FIG. **13** is a view illustrating a display example of the calculation result display image displayed on the display unit **7**. FIG. **14** is a view schematically illustrating the image illustrated in FIG. **13** in black and white. Compared to the B-mode image **100**, an calculation result display image **300** illustrated in these figures are colored, so that the color difference according to each group is made clear. More specifically, the calculation result display image data **300** roughly includes a green region **300***g* and a red region **300***r*. The boundary between two regions is illustrated with a yellow color (not illustrated in FIG. **14**). As illustrated in FIG. **14**, each region is not formed of a single color. For example, the green region **300***g* is a region where greenish pixels are collected. Similarly, the red region **300***r* is a region where reddish pixels are collected. Therefore, an observer can clearly recognize the difference in the groups, i.e., the difference in the tissue characterization.

[0080] FIG. **15** is a view describing the effect of the attenuation correction process executed by the ultrasonic observation apparatus **1**. An image **400** in FIG. **15** is a calculation result display image to which the attenuation correction is not executed. The calculation result display image in this case is a grayscale image in which the intercept b is equally assigned to R (red), G (green), and B (blue) with respect to the B-mode image generated by the B-mode image data generating unit **51**. In the calculation result display image **400**, the signal intensity is reduced due to the influence of the attenuation on the region (lower region in FIG. **14**) having the large reception depth, so that the image becomes dark. On the other hand, a calculation result display image **500** obtained by performing the attenuation correction to the same B-mode image has uniform brightness over the screen.

[0081] According to the first embodiment of the present invention, plural known specimens are classified into plural groups based upon the feature data of the frequency spectrum extracted on the basis of the ultrasonic wave reflected on each of the plural known specimens, and the degree of association between the feature data of the specimen extracted based upon the frequency spectrum of the ultrasonic signal and each group by using the statistic of the population including the feature data of each group. The ultrasonic image data having the display manner corresponding to the feature data of the specimen is generated based upon the calculation result. Accordingly, the difference in the tissue can clearly be distinguished without using the distorted amount or elasticity of the living tissue. Consequently, the specimen can precisely be observed, whereby the reliability in the observation result can be enhanced.

[0082] In the first embodiment, the attenuation correction is performed to the pre-correction feature data extracted from the frequency spectrum. Therefore, the influence of the attenuation caused by the propagation of the ultrasonic wave can be eliminated, whereby the tissue characterization can be distinguished with higher accuracy.

Second Embodiment

[0083] In the second embodiment of the present invention, the feature data extracting process executed by the feature data extracting unit is different from that in the first embodiment. The configuration of the ultrasonic observation apparatus according to the second embodiment is the same as that of the ultrasonic observation apparatus **1** in the first embodiment. Therefore, the components corresponding to those in the ultrasonic observation apparatus **1** are identified by the same numerals in the description below.

[0084] In the feature data extracting process in the second embodiment, the attenuation correction unit **422** firstly performs the attenuation correction process to the frequency spectrum calculated by the frequency analyzing unit **41**. Thereafter, the approximation unit **421** performs the approximation process to the frequency spectrum to which the attenuation correction is performed by the attenuation correction unit **422**, thereby extracting the feature data of the frequency spectrum.

[0085] FIG. **16** is a flowchart illustrating the outline of the process of the ultrasonic observation apparatus according to the second embodiment. In FIG. **16**, the processes in steps S**51** to S**54** respectively correspond to the processes in steps S**1** to S**4** in FIG. **2**.

[0086] In step S**55**, the attenuation correction unit **422** performs the attenuation correction process to the frequency spectrum calculated by the frequency analyzing unit **41** according to the FFT calculation (step S**55**). FIG. **17** is a view schematically illustrating the outline of the process in step S**55**. As illustrated in FIG. **17**, the attenuation correction unit **422** performs the correction in which the attenuation amount A in the above-mentioned equation (1) is added to the intensity I to all frequencies f, thereby obtaining a new frequency spectrum curve C_3' with respect to the frequency spectrum curve C_3. Thus, the frequency spectrum from which the contribution of the attenuation caused by the propagation of the ultrasonic wave is reduced can be obtained.

[0087] Thereafter, the approximation unit **421** extracts the feature data of the frequency spectrum by performing the regression analysis to all frequency spectrums to which the attenuation correction is executed by the attenuation correction unit **422** (step S**56**). Specifically, the approximation unit **421** calculates the slope a, the intercept b, and the intensity c at the center frequency f_{MID} according to the regression analysis. A straight line L_3 illustrated in FIG. **17** is a regression line (intercept b_3) obtained by performing the feature data extracting process to the frequency spectrum curve C_3 in step S**56**.

[0088] The processes in steps S**57** to S**59** respectively correspond to the processes in steps S**7** to S**9** in FIG. **2**.

[0089] Even in the second embodiment, the degree-of-association calculating unit **43** can be configured to determine the tissue characterization of the specimen by using the calculated degree of association, as in the first embodiment. In this case, the known specimen information storage unit **81** stores the feature data of the known specimen in association with the tissue characterization.

[0090] According to the second embodiment of the present invention, plural known specimens are classified into plural groups based upon the feature data of the frequency spectrum extracted on the basis of the ultrasonic wave reflected on each of the plural known specimens, and the degree of association between the feature data of the specimen extracted based upon the frequency spectrum of the ultrasonic signal and each group by using the statistic of the population including the feature data of each group. The ultrasonic image data having the display manner corresponding to the feature data of the specimen is generated based upon the calculation result. Accordingly, the difference in the tissue can clearly be distinguished without using the distorted amount or elasticity of the living tissue. Consequently, the specimen can precisely be observed, whereby the reliability in the observation result can be enhanced.

[0091] In the present second embodiment, the feature data is extracted after the attenuation correction is performed to the frequency spectrum. Therefore, the influence of the attenuation caused by the propagation of the ultrasonic wave can be eliminated, whereby the tissue characterization can be distinguished with higher accuracy.

Third Embodiment

[0092] In the third embodiment of the present invention, the tissue characterization determining process executed by the degree-of-association calculating unit is different from that in the first embodiment. The configuration of the ultrasonic observation apparatus according to the third embodiment is the same as that of the ultrasonic observation apparatus **1** in the first embodiment. Therefore, the components corresponding to those in the ultrasonic observation apparatus **1** are identified by the same numerals in the description below.

[0093] The degree-of-association calculating unit **43** forms new populations by adding feature data (a, b, c) to the groups G_μ, G_ν, and G_ρ (see FIG. **10**) composing the tissue characterizations μ, ν, and ρ, and then, obtains the standard deviation for each feature data in the data composing each tissue characterization. As in the first embodiment, the degree-of-association calculating unit **43** may determine the tissue characterization of the specimen by using the calculated degree of association. In this case, the known specimen information storage unit **81** stores the feature data of the known specimen in association with the tissue characterization.

[0094] Then, the degree-of-association calculating unit **43** calculates the difference (hereinafter merely referred to as "difference in the standard deviation") between the standard deviation of each feature data in the groups G_μ, G_ν, and G_ρ in the original population including only the known specimens and the standard deviation of each feature data in the groups G_μ, G_ν, and G_ρ in the new population to which a new specimen is added. Here, the degree-of-association calculating unit **43** may calculate the difference in the standard deviation for only the standard deviation of the feature data selected beforehand from plural feature data. In this case, the operator may select any feature data, or the ultrasonic observation apparatus **1** may automatically select any feature data.

[0095] FIG. **18** is a view schematically illustrating the standard deviation of each group and the standard deviation of the new population, when the feature data space illustrated in FIG. **10** is used. In FIG. **18**, the standard deviation of the intercept b is supposed to be $\sigma_{\mu1}$, and the standard deviation of the intensity c is supposed to be $\sigma_{\mu2}$ in the group G_μ. The standard deviation of the intercept b is supposed to be $\sigma_{\nu1}$, and the standard deviation of the intensity c is supposed to be $\sigma_{\nu2}$ in the group G_ν. The standard deviation of the intercept b is supposed to be $\sigma_{\rho1}$, and the standard deviation of the intensity c is supposed to be $\sigma_{\rho2}$ in the group G_ρ. On the other hand, the standard deviation of the intercept b is supposed to be $\sigma_{\mu1}'$, and the standard deviation of the intensity c is supposed to be $\sigma_{\mu2}'$ in the population formed by adding the specimen point Sp to the group G_μ. The standard deviation of the intercept b is supposed to be $\sigma_{\nu1}'$, and the standard deviation of the intensity c is supposed to be $\sigma_{\nu2}'$ in the population formed by adding the specimen point Sp to the group G_ν. The standard deviation of the intercept b is supposed to be $\sigma_{\rho1}'$, and the standard deviation of the intensity c is supposed to be $\sigma_{\rho2}'$ in the population formed by adding the specimen point Sp to the group G_ρ. In this case, the above-mentioned difference in the standard deviation is obtained such as $\Delta\sigma_{\mu1}=\sigma_{\mu1}'-\sigma_{\mu1}$, $\Delta\sigma_{\mu2}=\sigma_{\mu2}'-\sigma_{\mu2}$, $\Delta\sigma_{\nu1}=\sigma_{\nu1}'-\sigma_{\nu1}$, ... When the variables in the RGB color system are used, the red component, the green component, and the blue component may respectively be assigned to the differences in the standard deviation $\Delta\sigma_{\mu1}$, $\Delta\sigma_{\nu1}$, and $\Delta\sigma_{\rho1}$ in the intercept b, for example. Alternatively, three attributes of light (color phase, brightness, saturation), which are different from the others, may be assigned to the differences in the standard deviation $\Delta\sigma_{\mu1}$, $\Delta\sigma_{\nu1}$, and $\Delta\sigma_{\rho1}$. In this case, the attribute value is changed according to the difference in the standard deviation. A pattern determined according to the distance may be assigned to any one of the differences in the standard deviation $\Delta\sigma_{\mu1}$, $\Delta\sigma_{\nu1}$, and $\Delta\sigma_{\rho1}$.

[0096] FIG. **19** is a view illustrating one example of the relationship between the absolute value $|\Delta\sigma_{||1}|=|\sigma_{||1}'-\sigma_{\mu1}|$ and the magnitude of the red component R. In FIG. **19**, when the absolute value $|\Delta\sigma_{||1}|$ satisfies $0\leqq|\Delta\sigma_{\mu1}|\leqq|\Delta\sigma_{\mu10}|$, the magnitude of the red component R is 255 (8-bit notation). When the absolute value $|\Delta\sigma_{\mu1}|$ satisfies $|\Delta\sigma_{\mu10}|<|\Delta\sigma_{\mu1}|\leqq|\Delta\sigma_{\mu11}|$, the magnitude of the red component R linearly decreases, and when the absolute value $|\Delta\sigma_{\mu1}|$ satisfies $|\Delta\sigma_{\mu1}|>|\Delta\sigma_{\mu11}|$, it is zero. Even in the third embodiment, the magnitude of the color component assigned to each pixel in the calculation result display image data may arbitrarily be set.

[0097] The degree-of-association calculating unit **43** may calculate a value, which is obtained by weighting to the difference in the standard deviation of all feature data for each group, and may determine the tissue characterization corresponding to the group having the minimum value as the tissue characterization of the specimen. In this case, when the feature data has the slope a, the intercept b, and the intensity c, the degree-of association calculating unit **43** calculates w_a·(the difference in the standard deviation of a)+w_b·(the difference in the standard deviation of b)+w_c·(the difference in the standard deviation of c) by setting the weights respectively corresponding to the slope a, the intercept b, and the intensity c as w_a, w_b, and w_c, and determines the tissue characterization of the specimen based upon the calculated value. The operator may arbitrarily set the weights w_a, w_b, and w_c, or the ultrasonic observation apparatus **1** may automatically set the weights w_a, w_b, and w_c.

[0098] The degree-of-association calculating unit **43** may calculate a square root of a value obtained by performing the weighting to the square of the difference in the standard deviation of all feature data for each group, and may determine the tissue characterization corresponding to the group having the minimum square root as the tissue characterization of the specimen. In this case, when the feature data has the slope a, the intercept b, and the intensity c, the degree-of-association calculating unit **43** calculates $\{w'_a$·(the difference in the standard deviation of a)^2+w'_b·(the difference in the standard deviation of b)^2+w'_c·(the difference in the standard deviation of c)$^2\}^{1/2}$ by setting the weights respectively corresponding to the slope a, the intercept b, and the intensity c as w'_a, w'_b, and w'_c, and determines the tissue characterization of the specimen based upon the calculated value. The operator may arbitrarily set the weights w'_a, w'_b, and w'_c, or the ultrasonic observation apparatus **1** may automatically set the weights w'_a, w'_b, and w'_c.

[0099] According to the third embodiment described above, the specimen can precisely be observed, whereby the reliability in the observation result can be enhanced, as in the first embodiment. According to the third embodiment, the influence of the attenuation caused by the propagation of the ultrasonic wave can be eliminated, whereby the tissue characterization can be distinguished with higher accuracy.

[0100] In the third embodiment, the degree-of-association calculating unit **43** determines the tissue characterization based upon the difference in the standard deviation of each feature data between the original population and the population formed by adding a new specimen. However, this is only one example. For example, the degree-of-association calculating unit **43** may determine the tissue characterization based upon the difference in the average of each feature data between the original population and the population formed by adding a new specimen.

[0101] The embodiments for carrying out the present invention have been described above. The present invention is not limited to the above-mentioned first to third embodiments. Specifically, the present invention can include various forms without departing from the technical scope described in the claims.

[0102] Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

What is claimed is:

1. An ultrasonic observation apparatus that transmits an ultrasonic wave to a specimen, and receives the ultrasonic wave reflected on the specimen, comprising:

a frequency analyzing unit configured to calculate a frequency spectrum by analyzing a frequency of the received ultrasonic wave;

a feature data extracting unit configured to extract feature data of the frequency spectrum by performing an approximation to the frequency spectrum calculated by the frequency analyzing unit;

a storage unit configured to store feature data of a frequency spectrum extracted based upon the ultrasonic wave reflected respectively from plural known specimens, and to store the plural known specimens as being classified into plural groups based upon information of each of the known specimens;

a degree-of-association calculating unit configured to calculate a degree of association between the feature data extracted by the feature data extracting unit and each group by using a statistics of a population including at least the feature data of each group stored in the storage unit;

an image processing unit configured to allow the degree of association of the specimen to each group to correspond to different color components, and to generate ultrasonic image data by using a parameter formed by combining the different color components, based upon the calculation result of the degree-of-association calculating unit; and

a display unit configured to be capable of displaying the image corresponding to the ultrasonic image data generated by the image processing unit.

2. The ultrasonic observation apparatus according to claim **1**, wherein

the feature data extracting unit extracts plural feature data,

the storage unit stores an average of the respective feature data in each of the plural groups,

the degree-of-association calculating unit sets feature data space having at least any one of the plural feature data as a component, and calculates, as the degree of association, a distance on the feature data space between a specimen point that has a feature data, which serves as the component of the feature data space, out of the feature data of the frequency spectrum of the specimen as a coordinate on the feature data space, and a known specimen average point that has an average of the feature data, which serve as the component of the feature data space, out of the feature data in the group of the plural known specimens as a coordinate on the feature data space.

3. The ultrasonic observation apparatus according to claim **2**, wherein

the image processing unit determines a pixel value of the ultrasonic image data according to the distance between the specimen point and the known specimen average point.

4. The ultrasonic observation apparatus according to claim **1**, wherein

the degree-of-association calculating unit calculates a standard deviation of a feature data in a new population formed by adding a feature data of the specimen to the feature data belonging to the same group, and calculates the difference between the standard deviation and the standard deviation of the feature data belonging to the same group as the degree of association.

5. The ultrasonic observation apparatus according to claim **4**, wherein

the image processing unit determines the pixel value of the ultrasonic image data according to the difference between the standard deviation of the feature data in the new population and the standard deviation of the feature data belonging to the same group.

6. The ultrasonic observation apparatus according to claim **1**, wherein

the plural specimens having the feature data belonging to the same group have the same tissue characterization.

7. The ultrasonic observation apparatus according to claim **1**, wherein

the feature data extracting unit includes:

an approximation unit configured to extract pre-correction feature data, which is an amount before an attenuation correction process for reducing a contribution of an attenuation caused according to a reception depth and a frequency of the ultrasonic wave during the propagation of the ultrasonic wave to the frequency spectrum is executed, through an execution of an approximation process to the frequency spectrum calculated by the frequency analyzing unit; and

an attenuation correction unit configured to extract the feature data of the frequency spectrum by performing the attenuation correction process to the pre-correction feature data extracted by the approximation unit.

8. The ultrasonic observation apparatus according to claim **7**, wherein

the approximation unit approximates the frequency spectrum with a polynomial according to a regression analysis.

9. The ultrasonic observation apparatus according to claim **8**, wherein

the approximation unit approximates the frequency spectrum with a primary expression, and

extracts plural feature data including at least two of a slope of the primary expression, an intercept of the primary expression, and an intensity determined by using the slope, the intercept, and a specific frequency included in a frequency band of the frequency spectrum.

10. The ultrasonic observation apparatus according to claim **7**, wherein

the attenuation correction unit makes a great correction, as the reception depth of the ultrasonic wave is larger.

11. The ultrasonic observation apparatus according to claim **1**, wherein

the feature data extracting unit includes:

an attenuation correction unit configured to execute an attenuation correction process for reducing a contribution of an attenuation caused according to a reception depth and a frequency of the ultrasonic wave during the propagation of the ultrasonic wave to the frequency spectrum; and

an approximation unit configured to extract the feature data of the frequency spectrum by performing the approximation process to the frequency spectrum that is corrected by the attenuation correction unit.

12. The ultrasonic observation apparatus according to claim **11**, wherein

the approximation unit approximates the frequency spectrum with a polynomial according to a regression analysis.

13. The ultrasonic observation apparatus according to claim **12**, wherein

the approximation unit approximates the frequency spectrum with a primary expression, and

extracts plural feature data including at least two of a slope of the primary expression, an intercept of the primary expression, and an intensity determined by using the slope, the intercept, and a specific frequency included in a frequency band of the frequency spectrum.

14. The ultrasonic observation apparatus according to claim **11**, wherein

the attenuation correction unit makes a great correction, as the reception depth of the ultrasonic wave is larger.

15. An operation method of an ultrasonic observation apparatus that transmits an ultrasonic wave to a specimen, and receives the ultrasonic wave reflected on the specimen, comprising:

calculating a frequency spectrum by analyzing a frequency of the received ultrasonic wave by a frequency analyzing unit;

extracting feature data of the frequency spectrum by performing an approximation to the frequency spectrum by a feature data extracting unit;

reading a feature data of each group from a storage unit that stores feature data of a frequency spectrum extracted based upon the ultrasonic wave reflected respectively from plural known specimens, and that stores the plural known specimens as being classified into plural groups based upon information of each of the known specimens, and calculating a degree of association between the feature data extracted by the feature data extracting unit and each group by using a statistics of a population including at least the feature data of each group;

allowing the degree of association of the specimen to each group to correspond to different color components, and generating ultrasonic image data by using a parameter formed by combining the different color components, based upon the calculation result of the degree of association; and

displaying the image corresponding to the ultrasonic image data on a display unit.

16. A non-transitory computer readable recording medium on which an executable program is recorded, wherein the program instructs a processor to perform:

calculating a frequency spectrum by analyzing a frequency of a received ultrasonic wave by a frequency analyzing unit;

extracting feature data of the frequency spectrum by performing an approximation to the frequency spectrum by a feature data extracting unit;

reading feature data of each group from a storage unit that stores feature data of a frequency spectrum extracted based upon the ultrasonic wave reflected respectively from plural known specimens, and that stores the plural known specimens as being classified into plural groups based upon information of each of the known specimens, and calculating a degree of association between the feature data extracted by the feature data extracting unit and each group by using a statistics of a population including at least the feature data of each group;

allowing the degree of association of the specimen to each group to correspond to different color components, and generate ultrasonic image data by using a parameter formed by combining the different color components, based upon the calculation result of the degree of association; and

displaying the image corresponding to the ultrasonic image data on a display unit.

* * * * *

patsnap

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摘要(译)

一种装置，包括：用于分析所接收的超声波的频率的单元;通过对计算出的频谱进行近似来提取频谱特征数据的单元;存储器，用于存储基于从多个样本反射的超声波提取的频谱的特征数据，并将样本存储为分组;通过使用至少包括每个组的特征数据的总体的统计来计算所提取的特征数据与每个组之间的关联度的单元;允许样本与每个组的关联度对应于不同颜色分量的单元，并且基于计算结果，通过使用通过组合不同颜色分量形成的参数来生成超声图像数据;显示器，用于显示与超声波图像数据对应的图像。