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(54) **ULTRASONIC DIAGNOSTIC APPARATUS AND REGION-OF-INTEREST**

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(57) **ABSTRACT**

Disclose is an ultrasonic diagnostic apparatus which transmits/receives an ultrasonic wave to/from a region including a carotid artery of an object, images an ultrasonic image, and comprises a thickness measurement unit configured to measure the thickness of an intima-media complex from the ultrasonic image, the ultrasonic diagnostic apparatus being provided with a region-of-interest setting unit configured to scan the ultrasonic image and set a region of interest including the intima-media complex on the ultrasonic image on the basis of the degree of concentration of contour slate points of the carotid artery, wherein the thickness measurement unit measures the thickness of the intima-media complex on the basis of boundaries within the set region of interest.

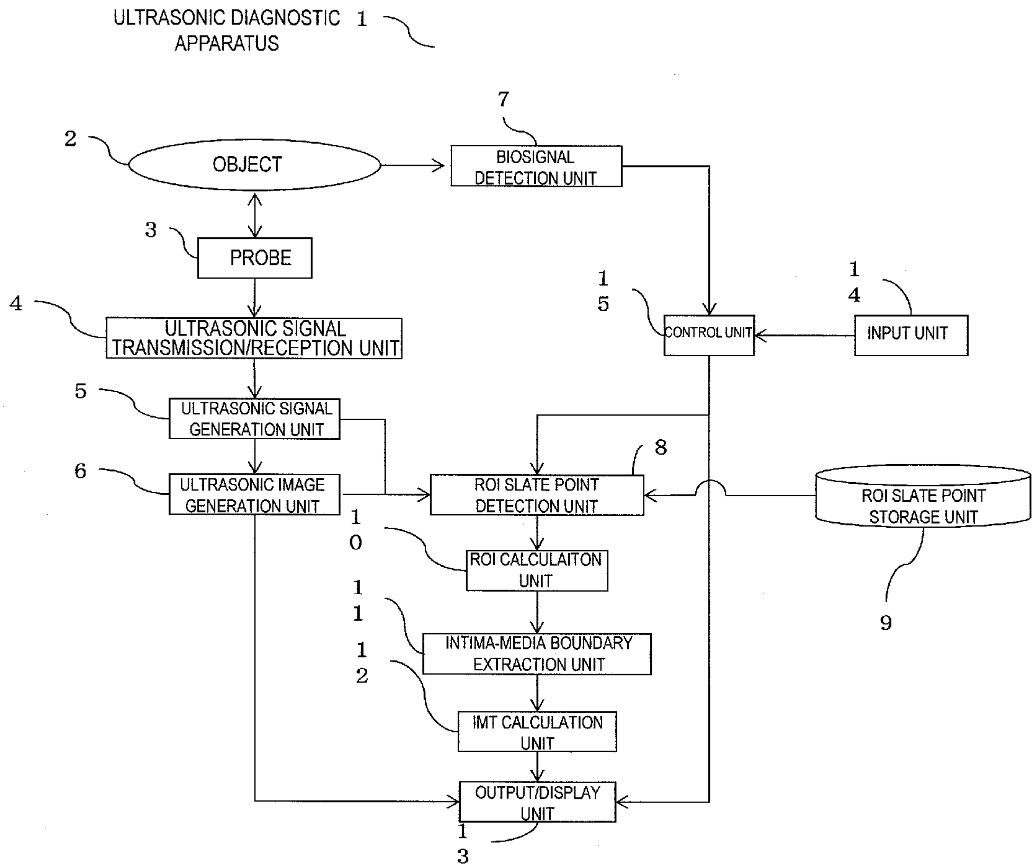


FIG. 1

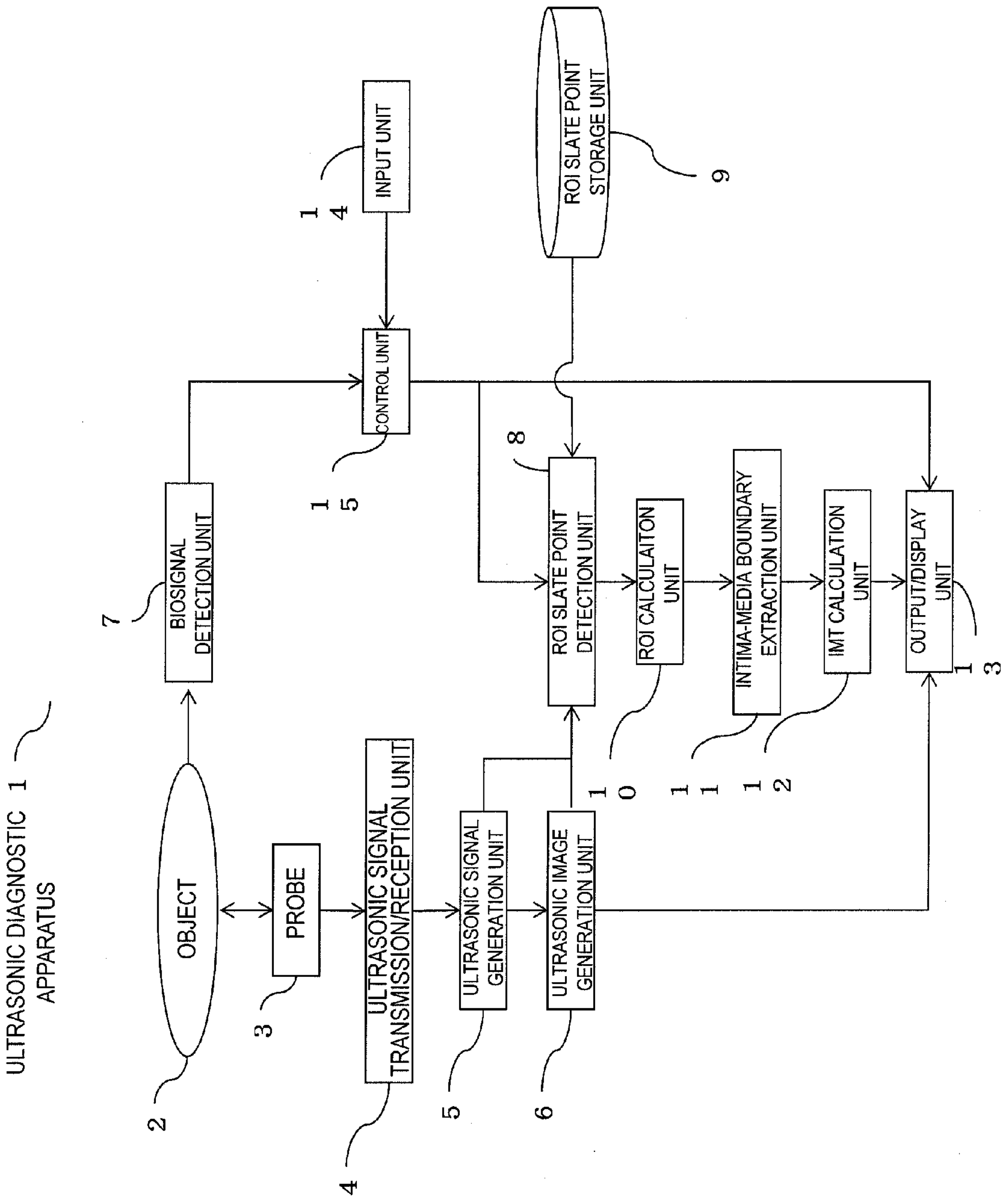

ULTRASONIC DIAGNOSTIC APPARATUS
1
OBJECT
2
PROBE
3
ULTRASONIC SIGNAL TRANSMISSION/RECEPTION UNIT
4
ULTRASONIC SIGNAL GENERATION UNIT
5
ULTRASONIC IMAGE GENERATION UNIT
6
BIOSIGNAL DETECTION UNIT
7
CONTROL UNIT
15
INPUT UNIT
14
ROI SLATE POINT STORAGE UNIT
9
ROI SLATE POINT DETECTION UNIT
8
ROI CALCULAITON UNIT
10
INTIMA-MEDIA BOUNDARY EXTRACTION UNIT
11
IMT CALCULATION UNIT
12
OUTPUT/DISPLAY UNIT
13

FIG. 2A

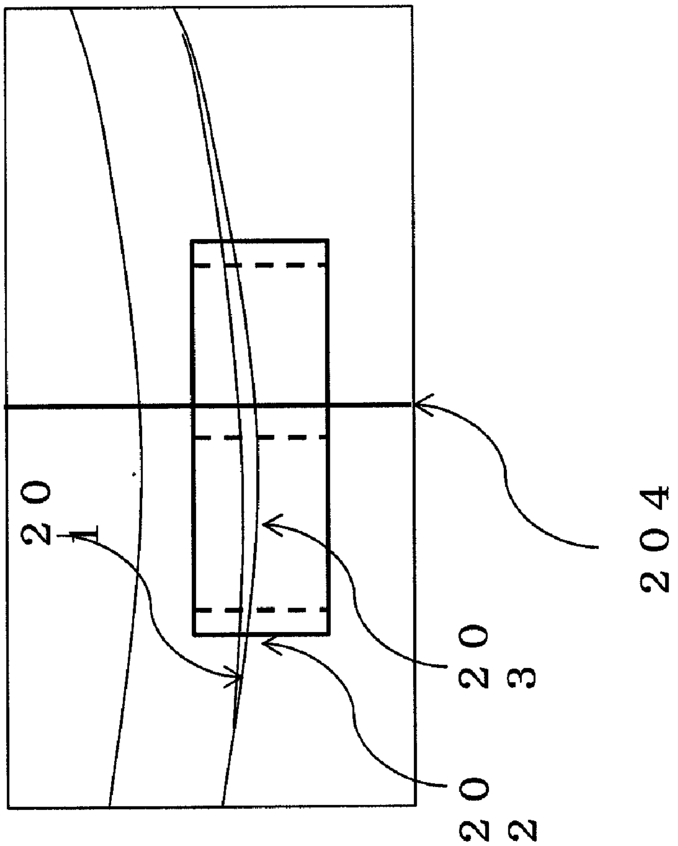


FIG. 2B

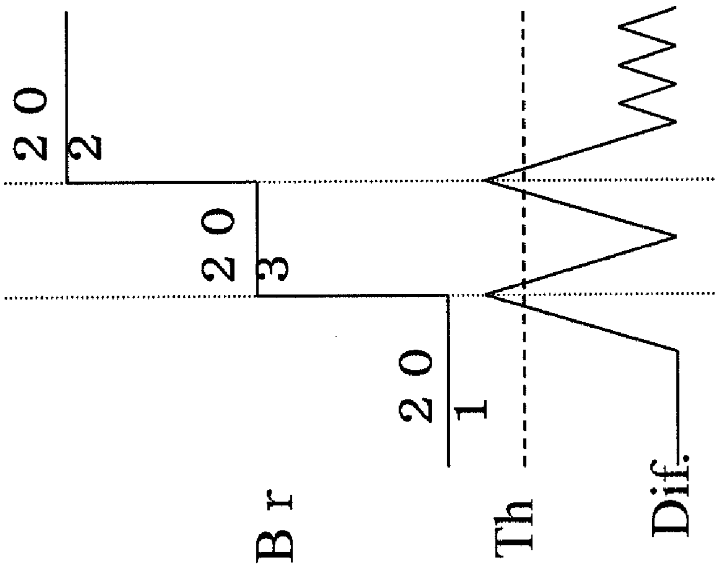


FIG. 3

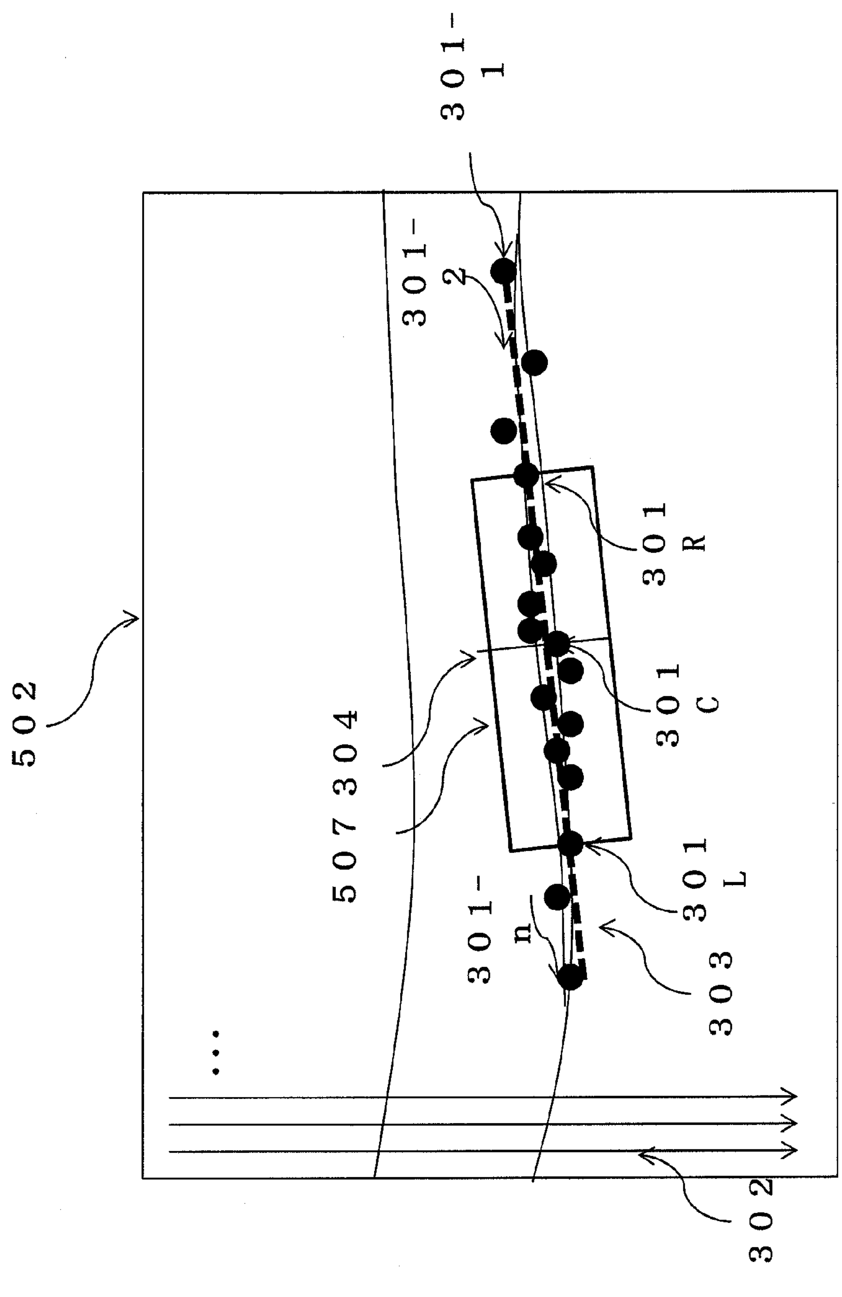


FIG. 4

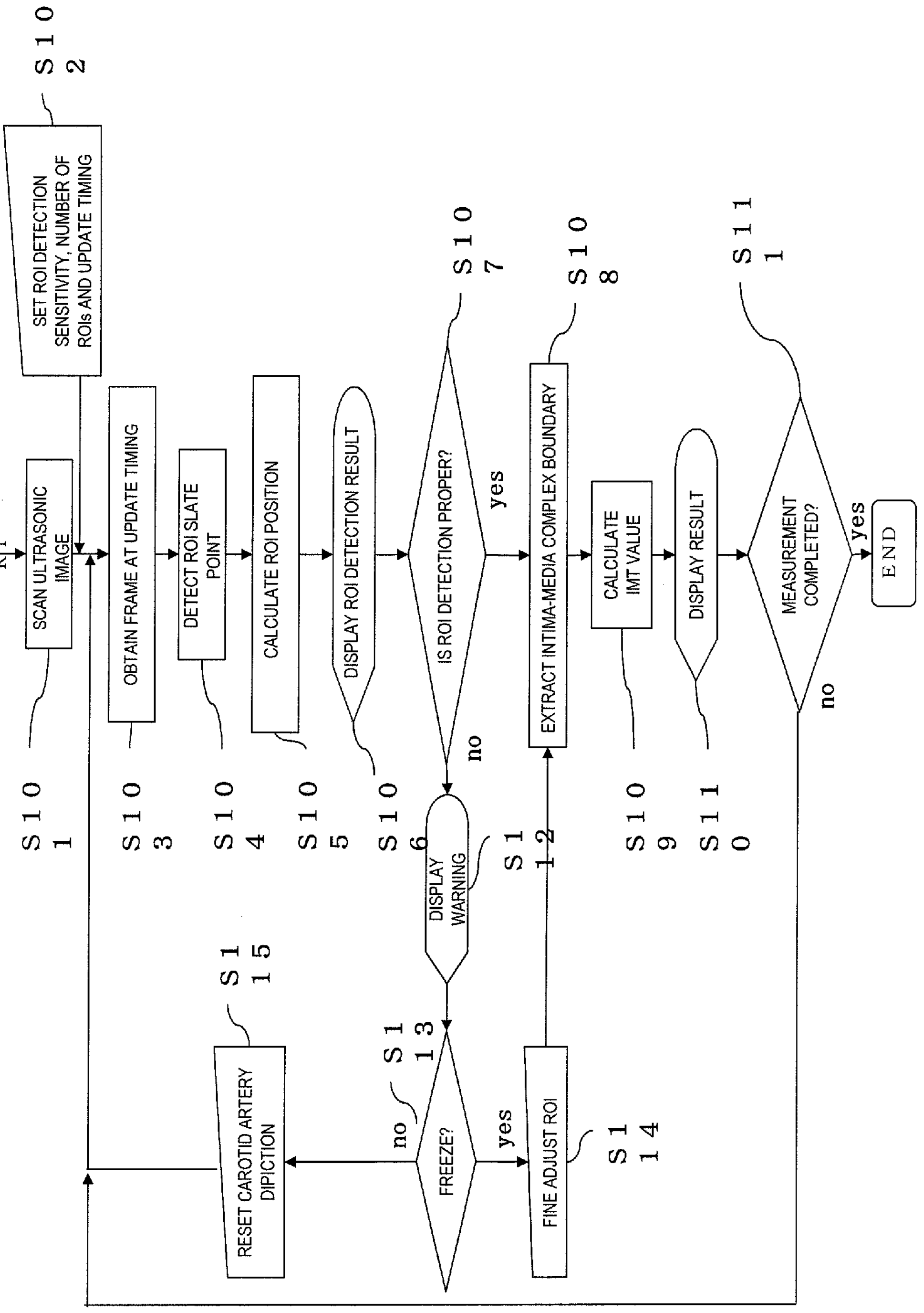
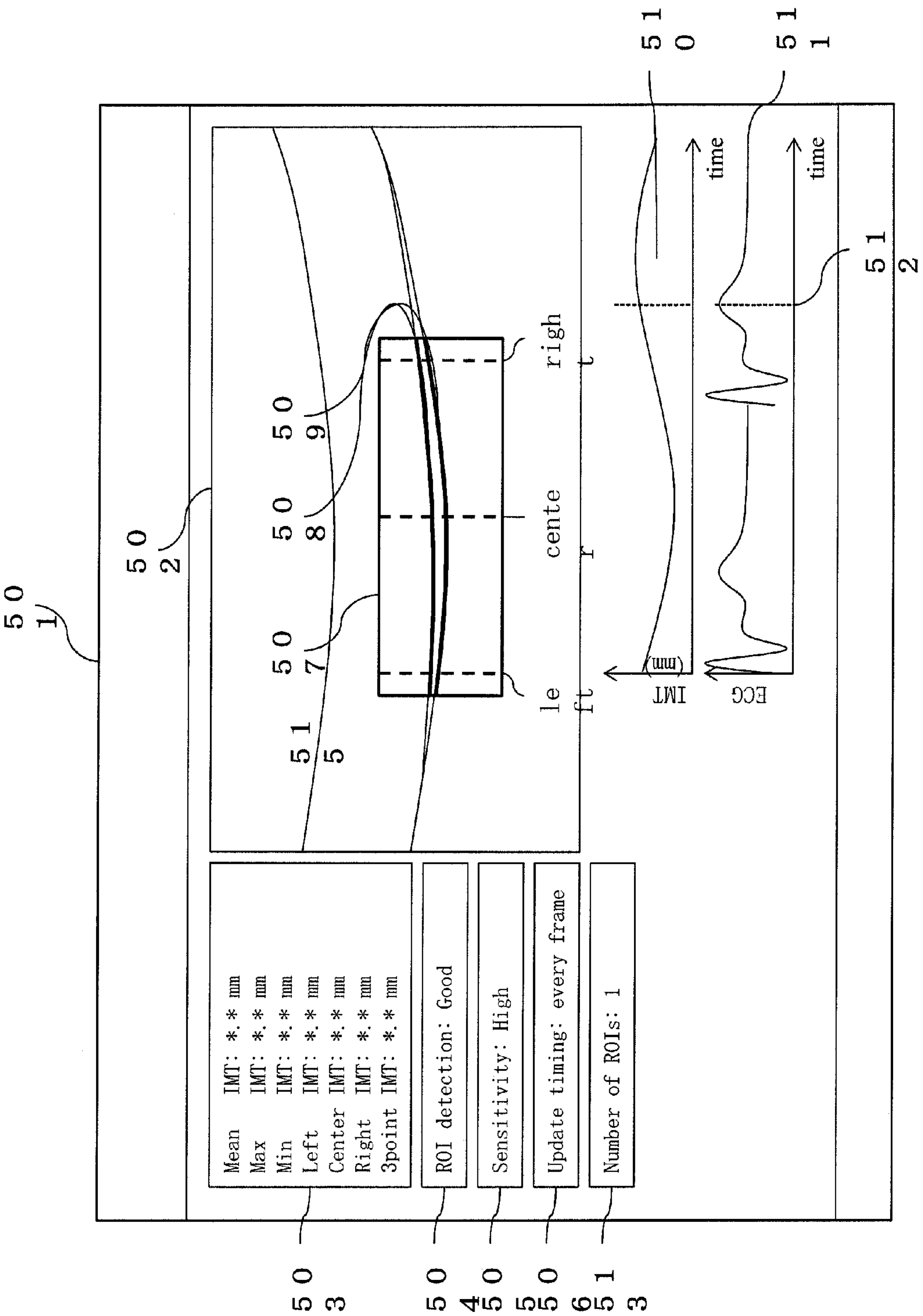

START
SCAN ULTRASONIC IMAGE
S101
SET ROI DETECTION SENSITIVITY, NUMBER OF ROIs AND UPDATE TIMING
S102
OBTAIN FRAME AT UPDATE TIMING
S103
DETECT ROI SLATE POINT
S104
CALCULATE ROI POSITION
S105
DISPLAY ROI DETECTION RESULT
S106
IS ROI DETECTION PROPER?
S107
yes
no
EXTRACT INTIMA-MEDIA COMPLEX BOUNDARY
S108
CALCULATE IMT VALUE
S109
DISPLAY RESULT
S110
MEASUREMENT COMPLETED?
S111
yes
no
END
DISPLAY WARNING
S112
FREEZE?
S113
yes
no
FINE ADJUST ROI
S114
RESET CAROTID ARTERY DIPICTION
S115

FIG. 5



501
502
503
504
505
506
507
508
509
510
511
512
513
515
left
center
right
IMT (mm)
ECG
time
time
Mean IMT: *.* mm
Max IMT: *.* mm
Min IMT: *.* mm
Left IMT: *.* mm
Center IMT: *.* mm
Right IMT: *.* mm
3point IMT: *.* mm
ROI detection: Good
Sensitivity: High
Update timing: every frame
Number of ROIs: 1

FIG. 6

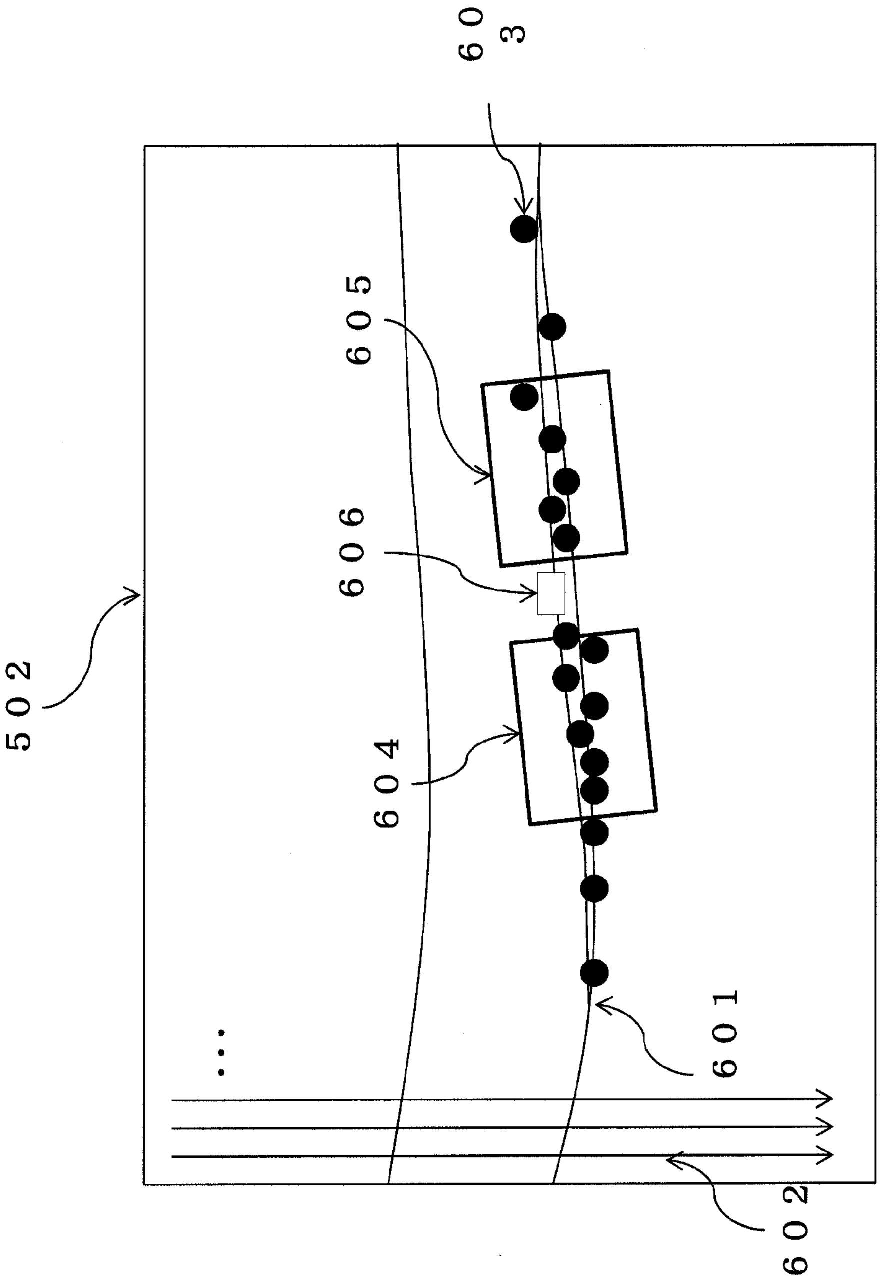


FIG. 7

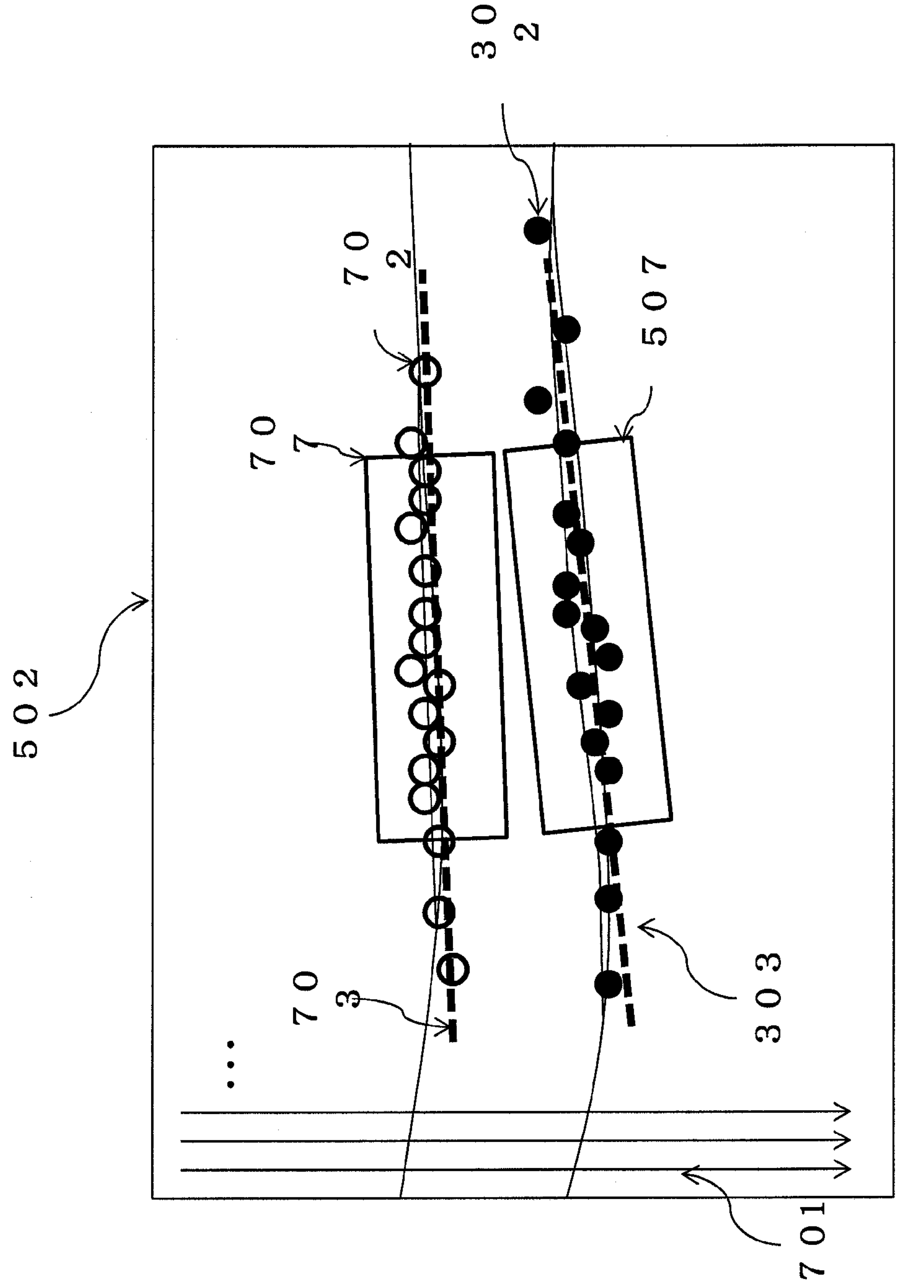


FIG. 8

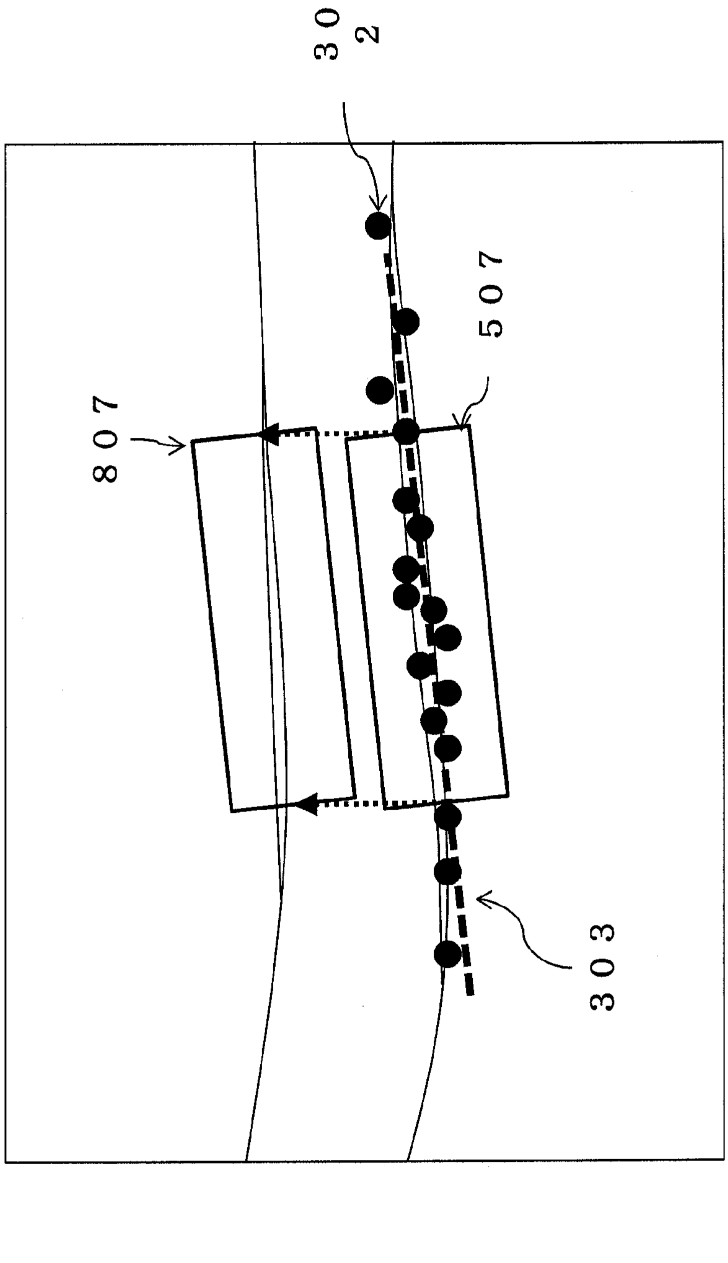
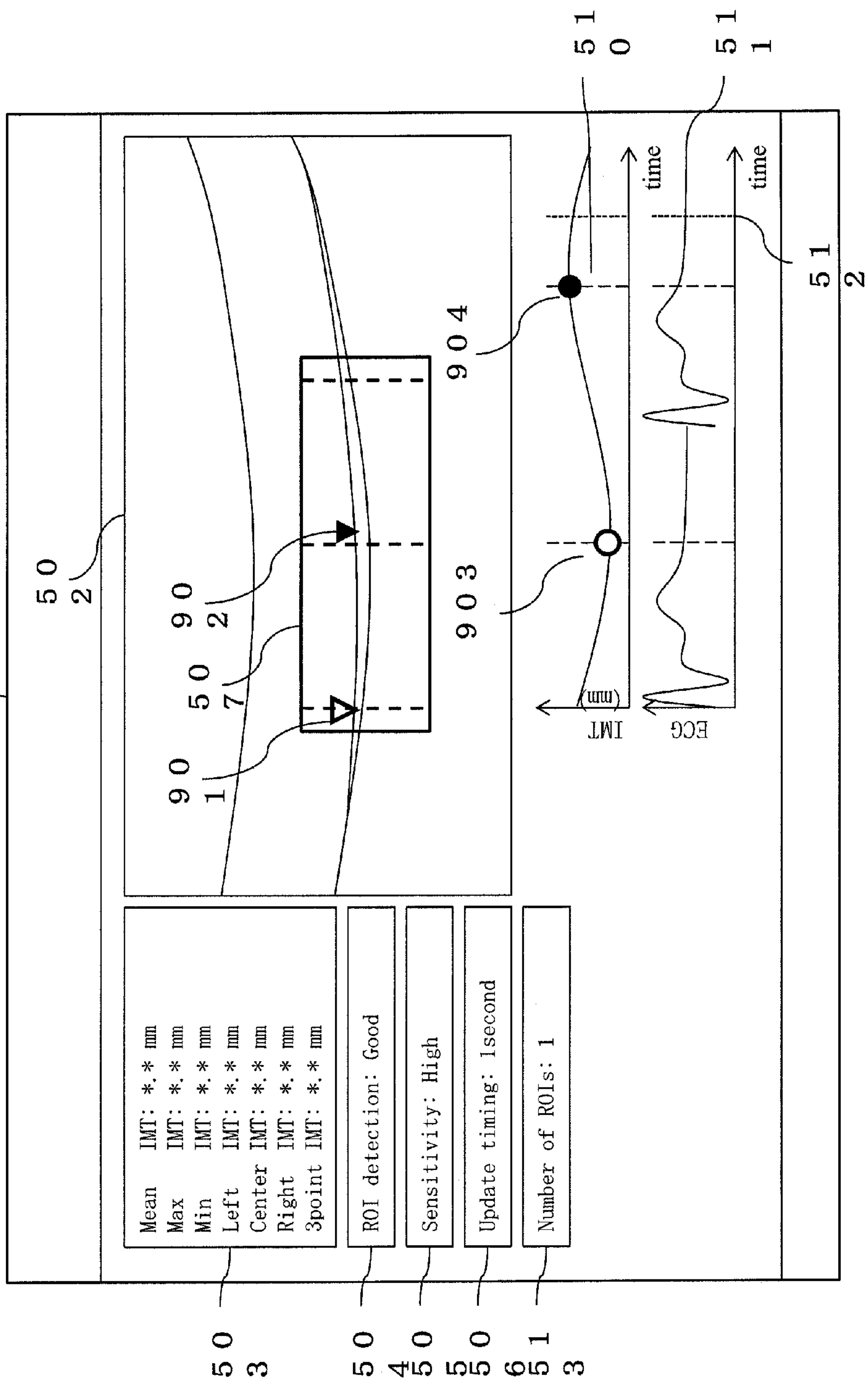


FIG. 9


501
502
503
504
505
506
507
510
511
512
513
901
902
903
904
Mean IMT: *.* mm
Max IMT: *.* mm
Min IMT: *.* mm
Left IMT: *.* mm
Center IMT: *.* mm
Right IMT: *.* mm
3point IMT: *.* mm
ROI detection: Good
Sensitivity: High
Update timing: 1second
Number of ROIs: 1
IMT
(mm)
ECG
time
time

ULTRASONIC DIAGNOSTIC APPARATUS AND REGION-OF-INTEREST

FIELD OF THE INVENTION

[0001] The present invention relates to an ultrasonic diagnostic apparatus and region-of-interest setting method therefore capable of setting a region of interest (ROI) which is a target for measuring intima-media thickness (IMT) in an ultrasonic image of a carotid artery of an imaged object so as to measure an IMT value.

DESCRIPTION OF RELATED ART

[0002] IMT measurement is known as effective for finding arterial sclerosis in an object to be examined. IMT measurement requires the procedure that a medical service worker (an examiner) such as a doctor or a clinical laboratory technologist obtains an ultrasonic image by applying an ultrasonic probe onto a carotid artery part of the object and sets an ROI on the obtained ultrasonic image.

[0003] The examiner may set an ROI manually. However, if an examiner executes manual ROI setting operation related to IMT measurement for all of patients, effective image diagnosis cannot be performed.

[0004] Given this factor, Patent Document **1** discloses an ROI setting method related to IMT measurement. Patent Document **1** proposes the ROI setting method which sets the position of an artery having the minimum brightness as a lumen, extracts the region close to an ultrasonic probe from the position of lumen as an anterior wall of the blood vessel and the region apart from the lumen position as a posterior wall of the blood vessel.

PRIOR ART DOCUMENTS

[0005] Patent Document 1: JP-A-2007-283035

[0006] However, Patent Document 1 merely proposes the process for setting an ROI on the anterior wall and the posterior wall of a blood vessel and dose not consider the process for setting an ROI corresponding to a plurality of slate points of a contour related to IMT measurement in a blood vessel, therefore accuracy in ROI setting related to IMT measurement still remains as an unsolved problem.

[0007] The objective of the present invention is to provide an ultrasonic diagnostic apparatus and the ROI setting method capable of improving accuracy of ROI setting related to IMT measurement.

BRIEF SUMMARY OF THE INVENTION

[0008] In order to achieve the above-described objective, the present invention executes imaging an ultrasonic image of a region including a carotid artery part in an object and sets an ROI region including an intima-media complex based on the degree of concentration of contour slate points in the carotid artery by scanning the ultrasonic image, so as to measure the intima-media thickness in the ROI region.

[0009] In concrete terms, the ultrasonic diagnostic apparatus of the present invention scans an ultrasonic image by transmitting/receiving ultrasonic waves to/from a region including a carotid artery of an object and comprises a thickness measurement unit configured to measure thickness of an intima-media complex from the ultrasonic image, further comprising an ROI setting unit configured to scan the ultrasonic image and set an ROI region including the intima-media complex on the ultrasonic image based on the degree of concentration of contour slate points of the carotid artery, wherein the thickness measurement unit measures thickness of the intima-media complex based on the boundary in the set ROI.

[0010] Also, the ROI setting method of the ultrasonic diagnostic apparatus related to the present invention executes imaging of an ultrasonic image by transmitting/receiving ultrasonic waves to/from a region including a carotid artery of an object, and includes a first step that measures thickness of an intima-media complex from the ultrasonic image by the thickness measurement unit, comprising a second step that scans the ultrasonic image and sets an ROI region including the intima-media complex on the ultrasonic image based on the degree of concentration of contour slate points of the carotid artery by a region-of-interest setting unit, wherein the first step measures thickness of the intima-media complex based on a boundary in the set ROI region by the thickness measurement unit.

[0011] In the above-described configuration of the present invention, accuracy of ROI setting can be improved since an ROI can be set referring to a plurality of concentrated contour slate points (pixel points) by imaging an ultrasonic image by transmitting/ receiving ultrasonic waves to/from a region including a carotid artery in an object, scanning the ultrasonic image and setting an ROI including the intima-media complex based on the degree of concentration of contour slate points of the carotid artery by a region-of-interest setting unit.

EFFECT OF THE INVENTION

[0012] The present invention is effective in providing the ultrasonic diagnostic apparatus and the region setting method capable of improving accuracy of ROI setting in IMT measurement.

BRIEF DESCRIPTION OF THE DIAGRAMS

[0013] FIG. **1** is a block diagram showing a configuration example of the ultrasonic diagnostic apparatus in a first embodiment of the present invention.

[0014] FIG. **2**A is a view for explaining the characteristic of brightness change in a carotid wall.

[0015] FIG. **2**B is a view for explaining brightness change on a line **204** in FIG. **2**A.

[0016] FIG. **3** is a view for explaining the principle of ROI setting in the first embodiment of the present invention.

[0017] FIG. **4** is a flowchart for explaining an operation example of the ultrasonic diagnostic apparatus in the first embodiment of the present invention.

[0018] FIG. **5** is a view for explaining a screen display example of the ultrasonic diagnostic apparatus in the first embodiment of the present invention.

[0019] FIG. **6** is a view for explaining the principle of ROI setting in a second embodiment of the present invention.

[0020] FIG. **7** is a view for explaining the principle of ROI setting in a third embodiment of the present invention.

[0021] FIG. **8** is a view for explaining an example different from FIG. **7** related to the third embodiment of the present invention.

[0022] FIG. **9** is a view for explaining a screen display example of the ultrasonic diagnostic apparatus in a fourth embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0023] The first embodiment of the ultrasonic diagnostic apparatus and the ROI setting method to which the present invention is applied will be described below. In the following description, the same function parts are represented by the same reference numerals, and the duplicative description thereof is omitted. The first embodiment exemplifies the case that the number of ROI is one.

Embodiment 1

[0024] FIG. **1** is a block diagram showing the outline of the ultrasonic diagnostic apparatus in the first embodiment of the present invention.

[0025] In the first embodiment, an ultrasonic probe **3**, an ultrasonic transmission/reception unit **4**, an ultrasonic signal generation unit **5** and an ultrasonic image generation unit **6** take on the function to "execute imaging of an ultrasonic image by transmitting/receiving ultrasonic waves to/from a region including a carotid artery of an object".

[0026] Also, an ROI slate point detecting unit **8**, an ROI slate point storing unit **9** and ROI calculating unit **10** take on the function to "scan the ultrasonic image and set an ROI region including the intima-media complex on the ultrasonic image based on the degree of concentration of contour slate points of the carotid artery by a region-of-interest setting unit".

[0027] Also, an intima-media complex contour extracting unit **11** and an IMT calculating unit **12** take on the function to "measure intima-media thickness (IMT) from the ultrasonic image by a thickness measurement unit".

[0028] Also, the ultrasonic diagnostic apparatus in the present embodiment has an input unit **14** for an examiner to set ultrasonic imaging condition, etc., a control unit **15** for executing programs to image an ultrasonic image or to measure IMT via setting inputted by the input unit **14** and an output/display unit for outputting/displaying measurement results of the ultrasonic image or the IMT, so as to coordinate the respective functions.

[0029] Next, configuration of an ultrasonic diagnostic apparatus **1** in the first embodiment will be described in detail.

[0030] The ultrasonic diagnostic apparatus **1** comprises the ultrasonic probe **3**, the ultrasonic transmission/reception unit **4**, the ultrasonic signal generation unit **5**, the ultrasonic image generation unit **6**, the biosignal detection unit **7**, the ROI slate point detecting unit **8**, the ROI slate point storing unit **9**, the ROI calculation unit **10**, the intima-media boundary extracting unit **11**, the IMT calculation unit **12**, the output/display unit **13**, the input unit **14** and the control unit **15**.

[0031] The ultrasonic probe **3** transmits/receives ultrasonic waves to/from target tissue in an object via transducers. The kind of ultrasonic probe **3** is categorized mainly by its scanning method such as the linear type, the convex type and the sector type. There is also a case that the ultrasonic probe **3** is merely a probe.

[0032] The ultrasonic transmission/reception unit **4** transmits ultrasonic waves to the ultrasonic probe **3** and receives the reflected echo signals from the object via the ultrasonic probe **3**.

[0033] The ultrasonic signal generation unit **5** executes signal processing on the reflected echo signals from the transmission/reception unit **4** via a phasing circuit or an amplification circuit in accordance with imaging setting of the device so as to acquire the formed ultrasonic signals.

[0034] The ultrasonic generation unit **6** generates an ultrasonic image based on imaging setting of the device using the signals inputted from the ultrasonic signals generation unit **5**.

[0035] The biosignal detection unit **7** detects biosignals of an object **2** and converts them into signal data. Biosignals include ECG (Electro Cardio Gram) or PCG (Phono Cardio Gram), and ECG will be exemplified in the present embodiment.

[0036] The ROI slate point detecting unit **8** detects slate points of an ROI on the ultrasonic image generated by the ultrasonic image generation unit **6**, using the ROI slate points storing unit **9**.

[0037] The ROI slate point storing unit **9** stores the slate points for extracting the characteristic of the signal at the position which is adequate for IMT measurement, and operates the ROI slate point detecting unit **8** on the basis of these slate points .

[0038] The ROI calculation unit **10** calculates the position and the size of an ROI from the ROI slate point group detected by the ROI slate point detecting unit **8**.

[0039] The ultrasonic probe **3**, the ultrasonic transmission/reception unit **4**, the ultrasonic signals generation unit **5** and the ultrasonic image generation unit **6** transmit/receive ultrasonic waves to/from a region including a carotid artery of an object and scan an ultrasonic image thereof.

[0040] The intima-media boundary extracting unit **11** and the IMT calculation unit **12** measure thickness of an intima-media complex from the ultrasonic image.

[0041] The ROI slate point detecting unit **8**, the ROI slate point storing unit **9** and ROI calculation unit **10** scan the ultrasonic image and calculate the position of a region of interest including the intima-media complex based on the degree of concentration of contour slate points in the carotid artery.

[0042] Further, the intima-media boundary extracting unit **11** and the IMT calculation unit **12** execute a boundary extracting process of the carotid artery with respect to the region of interest of which the position is calculated, and measure thickness of the intima-media complex from the boundary.

[0043] FIG. **2**A, FIG. **2**B and FIG. **3** will be used for explaining the principle in the process from the detection of ROI slate points to calculation of the position and the size thereof.

[0044] First, the process of detecting ROI slate points will be described using FIG. **2**A.

[0045] FIG. **2**A is a view for explaining the characteristic of brightness change in a carotid wall . Though FIG. **2**A is actually a B-mode image, only contour lines will be used for explanation.

[0046] In the example of a B-mode image of an ultrasonic image, a first characteristic of brightness change is that a lumen **201** which is a bloodstream part of a carotid artery is depicted with low brightness, and an intima-media complex **203** of an intima and a media disposed on the outside of the carotid artery is depicted with higher brightness than the bloodstream.

[0047] A second characteristic of brightness change is that an outer membrane **202** disposed on the outside of the intima-media complex **203** of the carotid artery is depicted with even higher brightness than the intima-media complex **203**.

[0048] Next, an example of analyzing the first characteristic of brightness change and the second characteristic of brightness change will be described using the profile of a line **204** referring to FIG. **2**B.

[0049] FIG. **2**B is a view for explaining brightness change on the line **204** in FIG. **2**A.

[0050] In FIG. **2**B, from the upper left in the diagram, the lumen **201**, the intima-media complex **203** and the outer membrane **202** of a carotid artery are disposed in that order. Brightness change Br of the respective regions is indicated by a two-stage process as shown in the diagram.

[0051] In other words, the brightness change on the left side in the diagram is shown as the first brightness change, the brightness change on the right side in the diagram is shown as the second brightness change, and the characteristic of the respective brightness changes is stored in the ROI slate point storing unit **9**.

[0052] A threshold value Th is provided to every change of the first and the second brightness changes. While the threshold value Th in the first brightness change and the second brightness change is set as the same value in FIG. **2**B, the threshold value in the first brightness value and the second brightness value can be set arbitrarily.

[0053] FIG. **2**B shows an example of the case that the value of a differentiation Dif of the first brightness change and the threshold value Th are compared, and a differentiation Dif of the second brightness change and the threshold Th are further compared. The pixel value wherein both values of the differentiation Dif of the first brightness change and the differentiation Dif of the second brightness change are greater than the threshold value is set as ROI slate point data (slate point data **301** in FIG. **3** to be described later).

[0054] In the case that the detection can be executed by using one of the first brightness change or the second brightness change, only one of them may be used.

[0055] Since the conventional ROI setting is executed by only brightness change without detecting ROI slate points, the brightness change which existing on an image and is similar to an intima-media complex could have been falsely recognized as an ROI . However, if the ROI setting range is specified by slate point data as shown in FIG. **2**B, possible false recognition in the conventional ROI setting can be eliminated.

[0056] Detection of ROI slate points based on the characteristic of brightness change in an intima-media complex is executed by the above-described procedure.

[0057] Next, the process for calculating the position and the size of an ROI will be described referring to FIG. **3**. FIG. **3** is a view for explaining the principle of ROI setting in the first embodiment of the present invention.

[0058] First, a slate point data **301-1** is plotted on the ultrasonic image in which a coronary artery to be displayed on an image display region **502** of the screen is depicted. Then plural sets of slate point data **301-2**~**301**-n are acquired by the same procedure, and plural sets of slate point data **301-2**~**301**-n are plotted on the ultrasonic image in the same manner. The coordinate points of the plotted slate data **301-1**~**301**-n on the ultrasonic image are stored to be read out in the subsequent process.

[0059] Next, the pixel points of the ultrasonic image are scanned, for example in the direction of **302**, and a region in the ultrasonic image on which the plotted plural sets of slate point data **301-1**~**01**-n are unevenly distributed is searched. From the result of searching, the concentration rate of slate point data **301-1**~**301**-n in one region is searched.

[0060] For example, the process for acquiring the degree of concentration is, to first define a regression line **303** which passes through the maximum number of slate point data **301-1**~**301**-n. The start point and the endpoint of the regression line **303** passes through the edge points in the left-and-right direction of the distributed slate point data **301-1**~**301**-n. In other words, the position where the regression line **303** exists is the point where the slate point data **301-1**~**301**-n are concentrated, which is the index of concentration ratio.

[0061] Here, the index for the degree of concentration is defined, when plural sets of 2-dimensional coordinate points (xi, yj) of the slate point data exist, by the length of a distance between the respective coordinate points and a threshold.

[0062] Also, the threshold value is obtained by, for example an average value μ which is zero and a standard deviation σ. In other words, the index of concentration ratio is respectively defined that $-\sigma+\mu\sim+\sigma+\mu$ (68%) is the range of value which is most concentrated (best value range), $-2\ \sigma+\mu\sim+2\ \sigma+\mu$ (95%) is the range of value which is more concentrated (better value range) and $-3\ \sigma+\mu\sim+3\ \sigma+\mu$ (99%) is the concentrated range of value (good value range) . The best value range, the better value range and the good value range may be defined also as, for example a narrow value range, a wider value range and a further wide value range as far as they are defined by three stages, without being limited to an average value μ and a standard deviation σ.

[0063] Then the shape of the ROI **507** is set as a rectangle, and the position of the ROI **507** is set, for example at the center of a point **301**C where the slate point data **301-1**~**301**-n is most concentrated on the regression line **303**. The point **301**C can be selected by an examiner from among the best value range, the better value range and the good value range using the input unit **14** according to the condition of image quality, etc. of the carotid artery image obtained from the object.

[0064] Also, a point **301**L which is at the farthest left among the slate point data **301-1**~**301**-n and a point **301**R at the farthest right thereof plotted on the regression line **303** are set as the ends of the ROI **507**.

[0065] Calculation of the slate point data **301**C is executed by comparing the respective coordinate values of the stored coordinates of the slate point data **301-1**~**301**-n on the image, and setting the slate point data **301-1**~**301**-n having the most number of approximated coordinate values, i.e. which is at the nearest coordinate point to the concentrated coordinate values, as the slate point data **301**C based on the comparison result. The position and the size of the ROI **507** in the direction parallel to the regression line **303** are determined by the above-described method.

[0066] Next, the position and the size in the direction vertical to the regression line **303** is determined by, for example drawing a vertical line **304** of the regression line **303** in the direction passing through the slate point data **301**C, acquiring the maximum range between the slate point data **301***c* passing through the vertical line **304** and the other slate point data, and calculating the function related to the acquired maximum range (double here). The direction vertical to the regression line **303** is also calculated by the above-described method, thus the position and the size of the ROI **507** is determined.

[0067] While the case that a rectangle shape is used for an ROI profile of an intima-media complex is exemplified in the present embodiment, an arbitrary shape besides a rectangle may also be used.

[0068] Also, the size of an ROI may be set as the width of standard deviation of the coordinate value of the slate point data **301-1**~**301**-n in the direction of the regression line **303** and the direction vertical thereto.

[0069] In another method, by assuming that density distribution of the ROI slate point group is subjected to a certain

2-dimensional distribution and presuming the density distribution, the center of the 2-dimensional distribution may be set as the center of an ROI, the extensity may be set as the size, and the direction of extensity may be set as the gradient of the ROI.

[0070] The ROI slate point storing unit **9** may be set so that the sensitivity related to the signal noise ratio can be adjusted. For example, the extent of allowing the influence of noise, etc. is adjusted by setting the threshold value to the brightness derivative value or the lumen-side brightness value. A concrete example of adjustment is that when the threshold value with respect to the brightness derivative value is set as a small value the influence of noise is tolerated and an intima-media complex can be detected even when it is somewhat indistinct.

[0071] Also, when the threshold value with respect to the lumen-side brightness derivative value is set as a small value, an intima-media complex can be detected even when noise on the lumen side is great. This setting is operated by an examiner using the input unit **14**.

[0072] The intima-media complex extracting unit **11** extracts the lumen side boundary and the outer-membrane side boundary within an ROI . The boundary extracting unit **12** extracts the lumen side boundary and the outer-membrane side boundary based on the position of a parting line. For example, the boundary extracting unit **12** extracts the lumen side boundary within the range limited toward the lumen side from the lumen side parting line, and also extracts the outer-membrane side boundary within the range limited toward the outer-membrane side from the outer-membrane side parting line. The kind of the boundary extracting method to be used here is based on a limited search, the edge detection, the region growing, an active contour model, and so on.

[0073] The boundary extracting unit **12** executes boundary extracting method based on the limited search by limiting the range of the lumen side boundary of an intima-media region to the lumen side. Also, it extracts the outer-membrane side boundary by limiting the range to the outer-membrane side. The processing by this boundary extracting method is applied to the entire rows in an ROI for extracting the boundary. The groups of these positions are set as the lumen side boundary and the outer-membrane side boundary.

[0074] The extracting method based on the edge detection calculates the contour of an object by the change of brightness in an image. Also, the contour here means the place where the brightness in an image changes drastically, i.e. the boundary of the region in the object.

[0075] The region growing method uses a threshold value by applying the fact that "the region within the same tissue has a small brightness change" and that "brightness change occurs between different tissues", and executes enlargement (or reduction) of a region while taking in the interconnecting pixels from the target region so as to extract the entire target region.

[0076] The boundary extracting method based on an active contour model is the image region extraction by an active contour represented by a Snake. The characteristic of the boundary extracting method based on an active contour model is that it is resistant to noise and is capable of acquiring smooth and continuous contours.

[0077] The IMT calculation unit **12** calculates the distance between the boundary on the side of the lumen **201** and the boundary on the side of the outer-membrane **202**. The calculated value is the IMT. Further, the IMT calculation unit **12** calculates values such as the average value, the maximum value and the minimum value in an ROI.

[0078] The output/display unit **13** outputs the boundary or measured values to a measurement report or displays them on the display region **502** on a screen of the ultrasonic diagnostic apparatus **1**. The concrete examples of the output/display unit **13** are referred to as an image display unit such as a liquid crystal monitor and a CRT monitor.

[0079] The input unit **14** is user interface for an examinee to execute initial setting for IMT measurement or manual operation for correcting the position of a detected ROI. The concrete examples of the input unit **14** are devices such as a keyboard, a trackball, a mouse or a switch.

[0080] The control unit **15** controls the entire system. In concrete terms, the control unit **15** receives the information on power or timing of signal transmission/reception and controls the ultrasonic transmission/reception unit **4** to acquire desired ultrasonic signals. Also, the control unit **15** generates a timing signal which operates the ROI slate point detecting unit **8** from the phase of a biosignal outputted from the biosignal detecting unit **7**. The concrete example of the control unit **15** is a device such as a CPU.

[0081] Next, an operation example of the ultrasonic diagnostic apparatus in the first embodiment related to the present invention will be described using FIG. **3**, FIG. **4** and FIG. **5**.

[0082] FIG. **4** is a flowchart showing an operation example of the ultrasonic diagnostic apparatus in the first embodiment related to the present invention, and FIG. **5** is a view for explaining a screen display example of the ultrasonic diagnostic apparatus in the first embodiment related to the present invention.

[0083] Display regions or display items of numeral references **501**~**515** in FIG. **5** will be described below since the flowchart shown in FIG. **4** will be described referring to a display example in FIG. **5**.

[0084] **501** shows a display screen. **502** is an image display region in the display screen **501**, in which an ultrasonic image of a carotid artery is displayed. **503** is a display region of IMT values, in which the average, maximum, the minimum, the left edge, the center, the right edge and the average of three points (the left edge, the center and the right edge) are displayed by numeral values. **504** is a display region of detection state of an ROI, and a term such as "good" or "bad" is displayed therein.

[0085] **505** is a display region of detection sensitivity, wherein the sensitivity is set as "high" when a lumen portion of a carotid artery or an outer region of a blood vessel wall is depicted clearly or as "middle" when a lumen portion of a carotid artery or an outer region of a blood vessel wall is depicted not very clearly due to the case of advanced arterial sclerosis. **506** is a display region of detection timing, and "every frame" is selected in FIG. **5**. **507** shows an ROI, **508** shows a lumen side boundary and **509** shows an outer-membrane side boundary respectively.

[0086] **510** shows a time passage curve of an IMT value, **511** shows a time passage curve of ECG and **512** shows a time phase marker for selecting a certain time phase of ECG respectively. **513** is a display region of the number of ROIs, and "1" is exemplified as the number of ROIs in FIG. **5**.

[0087] Next, an operation example of the ultrasonic diagnostic apparatus in the first embodiment related to the present invention will be described using FIG. **4**.

[0088] An examiner applies the ultrasonic probe **3** on a cervical region of an object **2**, and images an ultrasonic image of a carotid artery. The ultrasonic image is displayed on the image display region **502** (S**101**).

[0089] The examiner sets detection sensitivity, the number and the update timing of an ROI using the input unit **14**. The detection sensitivity, the number and the update timing of an

[0090] ROI are displayed on display regions **505**, **506** and **513**, and "High" is displayed on the display region **505**, "1" is displayed on the display region **506** and "every frame" is displayed on the display region **513** (S**102**).

[0091] The control unit **15** causes the ultrasonic image generation unit **6** to obtain a frame image of the update timing ("every frame" here) set in S**102** (S**103**).

[0092] The control unit **15** causes the ROI slate point detecting unit **8** to detect the ROI slate points on the ultrasonic image obtained in S013 (S**104**) . In concrete terms, the ROI slate point detecting unit **8** scans the pixel points in the ultrasonic image in the direction of **302** as shown in FIG. **3**, and searches a partial region of the ultrasonic image where plural sets of slate point data **301-1**~**301**-n are unevenly distributed which are plotted. As a result of search, the degree that slate point data **301-1 301**-n are concentrated in one region on the ultrasonic image (concentration ratio) is inspected.

[0093] The control unit **15** controls so that the position and the size of the ROI **507** are set using the ROI slate points detected in **5104** (S**105**) . Concretely, the position and the size of the ROI **507** is set in the direction parallel and vertical to the regression line **303** described in FIG. **3**.

[0094] The control unit **15** controls so that the ROI **507** set in S**105** is superimposed over the ultrasonic image of a carotid artery displayed on the image display region **502** in the display screen **501** of the output/display unit **13** (S**106**).

[0095] The control unit **15** determines whether or not setting of the ROI **507** in S**105** is executed properly. For example, assuming that the reference number of ROI slate points is **100**, when the ROI slate points wherein the number thereof is deviated from the range of plus and minus 10% of the reference number are measured, for example 89 or less or 111 or more, such condition is determined as non-detective state of an ROI.

[0096] Also, other than the number of ROI slate points stored in the ROI slate point storing unit **9**, the calculated reference values of the central position, extensity and gradient of the ROI can be used for the determination. Whether or not an ROI is properly set is displayed by coloring a frame border of the ROI **507** for distinction. For example, the color of the frame border of the ROI **507** is set as green when an ROI detection result is proper, and the color thereof is set as red when it is improper.

[0097] Also by quantifying the ROI detection result using the numeric values of the central position, extensity and angle of the ROI **507**, the color of the frame border of ROI **507** may be consecutively changed from green color to red color according to the numeric values.

[0098] Also, besides changing the color in the frame border of the ROI **507**, the frame border may be depicted as a solid line when ROI detection is properly executed, and the frame border may be depicted as a dotted line or a blinking line when ROI detection is improperly executed. In this manner, it is easy to visibly confirm condition of the ROI detection. Also, detection state (information on whether proper or improper) can be displayed in the ROI detection state display **504** on the display screen **501** (S**107**).

[0099] The control unit **15** causes the intima-media boundary extracting unit **11** to extract a boundary of an intima-media complex with respect to the pixels included in the ROI **507** which is determined as proper in S**107** (S**108**).

[0100] The control unit **15** causes the IMT calculation unit **12** to calculate the IMT value from the boundary of the intima-media complex extracted in S**108** (S**109**).

[0101] The control unit **15** makes the IMT value calculated in S**109** to be displayed by numeric value on the IMT value display region **503** in the display screen **501** of the output/display unit **13**.

[0102] Also, the control unit **15** makes the IMT value calculated in S**109** to be displayed by the time passage curve **510** of the IMT value on the display screen **501** of the output/display unit **13** (S**110**).

[0103] The examiner inputs whether IMT measurement is completed or not using the input unit **14**. The control unit **15** receives the determination of completion of IMT measurement inputted by the input unit **14**, completes the program if the result indicates completion, ends the program if the IMT measurement is completed and executes the process of **5103** if the result indicates that IMT measurement is not completed (S**111**).

[0104] Next, in the case that detection is not proper in S**107**, the control unit **15** changes the display items and display pattern by changing the color or line pattern of the frame border in the ROI, and displays the message "bad" on the display region **504** of ROI detection state as a warning (S**112**).

[0105] There are cases that the control unit **15** determines the display region **504** of ROI detection state as "Bad" but it can be shifted to be used for IMT calculation by fine-adjusting the ROI position, as a result of image observation by the examiner. There are also cases that the detection sensitivity, quantity and the update timing of ROIs need to be reset by the examiner using the input unit **14**.

[0106] Given this factor, as an optional function for a case that shifting of an ROI to fine-adjustment is possible, the control unit **15** determines whether or not to freeze acquisition of the ultrasonic image. As a result of determination, S**114** is carried out when freezing of image acquisition is to be executed so as to fine-adjust the position or the size of an ROI, and S**115** is carried out when input for resetting to a carotid artery image is necessary (S**113**).

[0107] By the freezing process in S**113**, the examiner fine-adjusts the position or the size of an ROI using the input unit **14** and shifts to S**108** (S**114**).

[0108] On the other hand, the examiner does not execute freezing in S**113**, resets the detection sensitivity, the number and the update timing of an ROI using the input unit **14** (S**115**), and carries out the process of S**103**.

[0109] In accordance with the above-described present embodiment, an ROI is set referring to contour slate point, i.e. plural pixel points, whereby it is possible to improve accuracy of ROI setting. Also, the specific effect of the present embodiment is that an examiner can make fine adjustment of ROI by input setting even when the ROI setting is determined as no good, which leads to improvement of operationality.

Embodiment 2

[0110] The second embodiment exemplifies the case that there are two or more ROIs. Since the configuration and operation of the ultrasonic diagnostic apparatus **1** is the same as the first embodiment, the description thereof will be omitted and only different parts will be described.

[0111] The calculation step of the position and the size of an ROI will be described referring to FIG. **6**.

[0112] FIG. **6** is a view explaining the principle of ROI setting in the second embodiment of the present invention.

[0113] First, slate data **603** is plotted on the ultrasonic image in which the carotid artery to be displayed on the image display unit **502** in a screen is depicted. Then plural sets of the slate point data **603** are acquired by the same procedure, and plotted in the same manner on the ultrasonic image. The coordinate points of the plotted slate point data **603** on the ultrasonic image are stored to be read out in the subsequent process.

[0114] Next, the control unit **15** scans the pixel points of the ultrasonic image in the direction of, for example **602** and searches the region where plural sets of the plotted slate point data **603** are unevenly distributed on the ultrasonic image.

[0115] In the present embodiment, the case that there are two searched regions that are not consolidated. In addition, the process can be performed in the same manner even when there are three or more searched regions.

[0116] First, the control unit **15** extracts a contour **601** of the blood vessel wall in a carotid artery and stores the position of the contour **601** in the blood vessel wall on the ultrasonic image. Then the control unit **15** calculates and outputs the segment wherein more than a predetermined number (five here) of the slate point data **603** are detected on the stored contour **601** of a blood vessel as the ROI **604** and the ROI **605**. The position and the size of the ROI **604** and the ROI **605** in the direction along the contour **601** are determined by the above-described process. Another method, in the case that the contour **601** is not extracted, sets an ROI in the same manner as the first embodiment by calculating the regression line of the slate point data **603** included in the segment in which more slate point data **603** than a predetermined number is detected.

[0117] Next, the control unit **15** acquires the position and the size of the contour **601**, the ROI **604** and the ROI **605** in the normal line direction by, for example drawing a vertical line at the respective midpoints of the ROI **604** and the ROI **605** in the direction along the contour **601**, acquiring the maximum range between the slate point data passing through the respective vertical lines, and further acquiring integral multiplication (double here) of the acquired maximum range. The contour **601** and the normal line direction are also determined by the above-described process, thus the position and the size of the ROI **604** and the ROI **605** are determined.

[0118] In IMT value calculation, an IMT value maybe calculated using plural ROIs or the average value of the IMT values of plural ROIs may be calculated. The IMT value and the ultrasonic image are outputted and displayed on the output/display unit **13** as in the first embodiment.

[0119] Also, it is easier for the examiner to distinguish between ROIs and the regions that are not an ROI by changing the display pattern of a region **606** between the ROI **604** and the ROI **605** which is not recognized as an ROI by changing the color or gradation thereof from that of the other regions.

[0120] Also, there are cases that the ROI **604**, the ROI **605** and the region **606** are observed by the examiner and they can be combined as one ROI **507** as shown in the first embodiment. When the case can be determined as appropriate combine the regions, the examiner inputs the command to the input unit **14** to consolidate the ROI **604**, the ROI **605** and the region **606** into one region as ROI **507**. The control unit **15** receives the input of command for making one ROI, consolidates the ROI **604**, the ROI **605** and the region **606** to generate one ROI such as the ROI **507** in the first embodiment.

[0121] In accordance with the above-described present embodiment, an ROI is set referring to contour slate points, i.e. plural pixel points, thus accuracy of ROI setting can be improved.

[0122] Also, the specific effect of the present embodiment is that, even when an intima-media complex is depicted while being discontinued, the measurement values can be calculated by setting plural ROIs and executing boundary extraction only in the positions where boundary extraction can be executed.

[0123] Since the region where an ROI is not extracted avoids the region where error can be easily caused upon boundary extraction of an intima-media complex, not only improvement of boundary extraction but also improvement of accuracy in IMT value measurement can be expected.

[0124] Also even when plural ROIs are recognized, calculation of the position and the size of the respective ROIs can be more simplified compared to the first embodiment.

[0125] Even when there are separate plural ROIs, since it is possible to consolidate them into one ROI by an examiner's observation, the effect in the first embodiment can be exerted after the consolidation.

Embodiment 3

[0126] The third embodiment explains an example that the ROI setting executed on the blood vessel wall of a carotid artery which is closer to an ultrasonic probe (one side) is reflected on the ROI setting of the blood vessel which is farther from the probe (the other side).

[0127] Since the configuration and operation of the ultrasonic diagnostic apparatus **1** is the same as the first embodiment, the description thereof will be omitted and only the parts different from the first embodiment will be described.

[0128] The calculation step of the position and the size of an ROI in the present embodiment will be described using FIG. **7**.

[0129] FIG. **7** is a view for explaining the principle of ROI setting in the third embodiment of the present invention.

[0130] First, data processing is executed on one side of the carotid artery which is an outer wall part in the lower side of the diagram, as in FIG. **3**.

[0131] Next, the following data processing is executed on the other side of the carotid artery which is the outer wall part in the upper side of the diagram.

[0132] Slate point data **702** is plotted on the ultrasonic image in which a carotid artery to be displayed on the image display region **502** of a screen is depicted. Then plural sets of slate point data **702** are acquired in the same procedure and plotted in the same manner on the ultrasonic image. The coordinate points of the plotted slate point data **702** on the ultrasonic image are stored to be read out in the subsequence process.

[0133] Next, the pixel points on the ultrasonic image are scanned, for example in the direction of **701**, and a partial region of the ultrasonic image where the plotted plural sets of slate point data **702** are unevenly distributed is searched. From the result of search, the degree that the plural sets of slate point data **702** are concentrated (concentration ratio) is searched.

[0134] The concentration ratio is acquired, for example by first defining the regression line **703** which passes through the maximum number of the slate point data **702**. The start point and the end point are set as the ends of the distributed slate point data **702** in the horizontal direction. In other words, the position where there is the regression line **703** is the position where the plural sets of slate point data **702** are concentrated, which is the index of the concentration ratio.

[0135] Then the profile of the ROI **707** is set as a rectangle, and the position and the size of the ROI **707** is determined on the regression line **703** as described in the first embodiment.

[0136] While a rectangle is exemplified as the ROI profile of an intima-media complex in the present embodiment, an arbitrary profile besides a rectangle may be used.

[0137] The position and the size of an ROI of the outer wall part on one side and an ROI of the outer wall part on the other side of a carotid artery can be set by the above-described procedure. However, it is difficult to execute quantitative IMT measurement if the position and the size of the set ROIs are different.

[0138] Given this factor, if the position and the size of an ROI of the outer wall part on one side of a carotid artery are different from an ROI of the outer wall part on the other side, the position and the size of the ROI on one side of the carotid artery is matched to those of the ROI on the other side.

[0139] For example, the area ratio between the area of one ROI and the area of the other ROI is acquired, and if the area ratio is within plus or minus 10%, the IMT value is calculated as usual from one ROI and the other ROI.

[0140] In the case that the area ratio deviates from the range of plus or minus 10%, one ROI is recalculated in accordance with the area of the other ROI, and the IMT value is calculated from the recalculated respective ROIs.

[0141] In concrete terms, if the area of one ROI is 200 cm^2, the IMT value can be calculated as usual when the area of the other ROI is 180~220 cm^2.

[0142] However, when the area of the other ROI is deviated from 180~220 cm^2, the area of the other ROI is adjusted to make the area of the other ROI to fall in the range of 180~220 cm^2. Here, selection to match the areas of ROIs can be executed by an examiner by inputting the information to input unit **14** and by the control unit **15** which receives the inputted information.

[0143] Also, there is a simpler method which can be described referring to FIG. **8**.

[0144] FIG. **8** is a view for explaining another example which differs from the example shown in FIG. **7**.

[0145] In FIG. **8**, the frame border of the ROI **507** set on the outer wall part of a carotid artery shown in the lower part of the diagram is copied on the frame border of an ROI **807** of the outer wall part in the carotid artery shown in the upper part of the diagram.

[0146] The contour of the outer wall part in the carotid artery shown in the upper part of the diagram is extracted in advance, and the frame border of the ROI **807** is shifted on the contour of the outer wall part of the carotid artery shown in the upper part of the diagram. In the case of not extracting a contour, the frame border may be manually shifted using the input unit **14**.

[0147] In accordance with the above-described copying process, there is no need to adjust the areas of the ROI **507** and the ROI **807** since the areas of the ROI **507** and the ROI **807** are the same.

[0148] In accordance with the above-described present embodiment, ROI setting can be improved since an ROI is set referring to contour slate points, i.e. plural pixel points.

[0149] Also, the specific effect of the present embodiment is that ROIs of the outer wall part of a carotid artery in the lower part of the diagram and the outer wall part in the upper part in the diagram can be set at the same time, whereby improving operationality in ROI setting for an examiner.

[0150] Also, the present embodiment can eliminate the process of adjusting the size of each ROI by copying the ROI of the outer wall part in a carotid artery shown in the lower part of the diagram to the ROI of the outer wall part shown in the upper part of the diagram, it is possible to improve operationality in ROI setting for an examiner.

Embodiment 4

[0151] The fourth embodiment describes an example of displaying the maximum value or the minimum value of an IMT measurement value while being associated with the set ROI.

[0152] Since the configuration and operation of the ultrasonic diagnostic apparatus **1** is the same as the first embodiment, the description thereof will be omitted and only different parts from the first embodiment will be described.

[0153] The step of displaying the maximum value or the minimum value of an IMT value in the present embodiment will be described using FIG. **9**.

[0154] FIG. **9** is a view for explaining a screen display example of the ultrasonic diagnostic apparatus in the fourth embodiment related to the present invention. Only the reference numerals besides those described in FIG. **5** will be described in FIG. **9**.

[0155] **901** shows the minimum value of an IMT in the ROI **507**, **902** shows the maximum value of IMT in the ROI **507**, **903** shows the minimum value of the time passage curve in an IMT and **904** shows the maximum value of the time passage curve in IMT.

[0156] While a maximum value **902** of IMT is indicated by ▼, a minimum value **901** of IMT is indicated by ∇, a maximum value **904** of the time passage curve in IMT is indicated by ● and the minimum value of the time passage curve in IMT is indicated by O, colors or profiles do not have to be limited for indicating the position of the maximum values and the minimum values.

[0157] Further, in the case that the maximum value of the measured IMT is greater than the standardized IMT value for healthy subjects, the mark may be, for example a triangle colored in red to make it distinctive.

[0158] In this manner, it is easier to visually recognize the position of the maximum value and the minimum value of IMT or abnormality thereof.

[0159] In accordance with the above-described present embodiment, accuracy in ROI setting can be improved since an ROI is set referring to contour slate points, i.e. plural pixel points.

[0160] Also, the specific effect of the present embodiment is that the maximum value and the minimum value of IMT or abnormality thereof are easy to confirm, which leads to improvement in diagnosis performance by an examiner.

[0161] The preferable embodiments of the ultrasonic diagnostic apparatus, etc. according to the present invention have been described referring to the attached diagrams. However, the present invention is not limited to these embodiments. It is obvious that persons skilled in the art can make various kinds of alterations or modifications within the scope of the technical idea disclosed in this application, and it is understandable that they belong to the technical scope of the present invention.

DESCRIPTION OF REFERENCE NUMERALS

[0162] **1**: ultrasonic diagnostic apparatus
[0163] **2**: object
[0164] **3**: ultrasonic probe
[0165] **4**: ultrasonic transmission/reception unit
[0166] **5**: ultrasonic signal generation unit
[0167] **6**: ultrasonic image generation unit
[0168] **7**: biosignal detection unit
[0169] **8**: ROI slate point detecting unit
[0170] **9**: ROI slate point storing unit
[0171] **10**: ROI calculation unit
[0172] **11**: intima-media boundary extracting unit
[0173] **12**: IMT calculation unit
[0174] **13**: output/display unit
[0175] **14**: input unit
[0176] **15**: control unit

1. An ultrasonic diagnostic apparatus that images an ultrasonic image by transmitting/receiving ultrasonic waves to/from a region in an object to be examined including a carotid artery portion, having a thickness measuring unit configured to measure thickness of an intima-media complex from the ultrasonic image, which comprises a region-of-interest setting unit configured to scan the ultrasonic image and set a region of interest including the intima-media complex based on the concentration degree of contour slate points in the carotid artery on the ultrasonic image, wherein the thickness measuring unit measures thickness of the intima-media complex based on the boundary in the set region of interest.

2. The ultrasonic diagnostic apparatus according to claim **1**, wherein the region-of-interest setting unit calculates position of the region of interest by performing derivation on a first brightness change in an outer-membrane and an intima-media of the intima-media complex and on a second brightness change in an intima-media and a lumen respectively.

3. The ultrasonic diagnostic apparatus according to claim **1**, wherein the region-of-interest setting unit calculates position of the region of interest based on the brightness of a bloodstream part in the carotid artery.

4. The ultrasonic diagnostic apparatus according to claim **1**, wherein the region-of-interest setting unit, in the case that there are plural aggregations of pixels, calculates position of the region of interest for each of the aggregation using the degree of concentration.

5. The ultrasonic diagnostic apparatus according to claim **4**, wherein the region-of-interest setting unit consolidates the region of interests that are calculated for the respective aggregations, and calculates position of one region of interest.

6. The ultrasonic diagnostic apparatus according to claim **1**, comprising a display unit configured to display regions in which the position of a region of interest can not be calculated by the region-of-interest setting unit, by changing the display pattern thereof from that of the other regions.

7. The ultrasonic diagnostic apparatus according to claim **1**, wherein the region-of-interest setting unit calculates position of a region of interest in a blood vessel wall on one side of the carotid artery based on the position of a region of interest in a blood vessel wall on the other side of the carotid artery.

8. The ultrasonic diagnostic apparatus according to claim **7**, wherein the region-of-interest setting unit calculates position of a region of interest in the blood vessel wall on the other side of the carotid artery referring to the concentration degree of contour slate points of the blood vessel wall on the other side of the carotid artery.

9. The ultrasonic diagnostic apparatus according to claim **7**, wherein the region-of-interest setting unit calculates position of a region of interest in the blood vessel wall on the other side of the carotid artery by copying the information on a region of interest in the blood vessel wall on one side of the carotid artery.

10. The ultrasonic diagnostic apparatus according to claim **1** comprising:

a thickness calculating unit configured to calculate the maximum value or the minimum value in the thickness of the intima-media complex;

a marker generating unit configured to generate a marker which indicates the thickness of the maximum value or the minimum value; and

a display unit configured to display the mark, the intima-media thickness and the ultrasonic image.

11. A region-of-interest setting method of the ultrasonic diagnostic apparatus which images an ultrasonic image by transmitting/receiving ultrasonic waves to/from a region in an object to be examined including a carotid artery portion, including a first step of measuring thickness of an intima-media complex on the ultrasonic image by a thickness measuring unit, comprising a second step of scanning the ultrasonic image and setting a region of interest including the intima-media complex on the ultrasonic image based on the concentration degree of contour slate points of the carotid artery by the region-of-interest setting unit, wherein the first step measures thickness of the intima-media complex by the thickness measuring unit based on the boundary in the set region of interest.

12. The region-of-interest setting method according to claim **11**, including a third step of displaying regions in which position of the region of interest can not be calculated by the display unit, by changing the display pattern thereof from that of other regions.

13. The region-of-interest setting method according to claim **11**, including a fourth step of calculating position of a region of interest in a blood vessel wall on one side of the carotid artery based on the position of a region of interest in a blood vessel on the other side of the carotid artery by the region-of-interest setting unit.

14. The region-of-interest setting method according to claim **11**, comprising:

a fifth step of calculating the maximum value or the minimum value in the intima-media thickness by a thickness calculating unit;

a sixth step of generating a marker which indicates the maximum value or the minimum value by a marker generating unit; and

a seventh step of displaying the mark, the intima-media thickness and the ultrasonic image by a display unit.

* * * * *

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摘要(译)

公开了一种超声波诊断装置，其向/从包括物体的颈动脉的区域发送/接收超声波，对超声波图像进行成像，并且包括厚度测量单元，该厚度测量单元被配置为测量来自所述内膜 - 中层复合体的厚度。超声波图像，超声波诊断装置具有关注区域设定单元，该关注区域设定单元被构造成扫描超声波图像，并基于轮廓的集中程度在超声波图像上设定包括内膜 - 介质复合体的关注区域颈动脉的平板点，其中厚度测量单元基于所设定的感兴趣区域内的边界测量内膜 - 中层复合体的厚度。