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(54) ULTRASONIC DIAGNOSTIC IMAGING SYSTEM AND CONTROL METHOD THEREOF

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(57) **ABSTRACT**

An ultrasonic diagnostic imaging system not depending on an operator who operates the apparatus is provided. The system includes a measuring unit (coordinate calculation section **2034**) that measures a relative position and a relative posture of the ultrasonic probe with respect to an examinee using image information on the examinee acquired by the ultrasonic probe, a control amount calculation unit (**2035**) that calculates an amount of control of the position and posture of the ultrasonic probe based on the measurement result of the measuring unit and at least one of a probe control mechanism that controls the position and posture of the ultrasonic probe using the amount of control calculated by the control amount calculation unit and a guiding information presentation unit that presents information for guiding movement of the position and posture of the ultrasonic probe using the amount of control calculated by the control amount calculation unit.

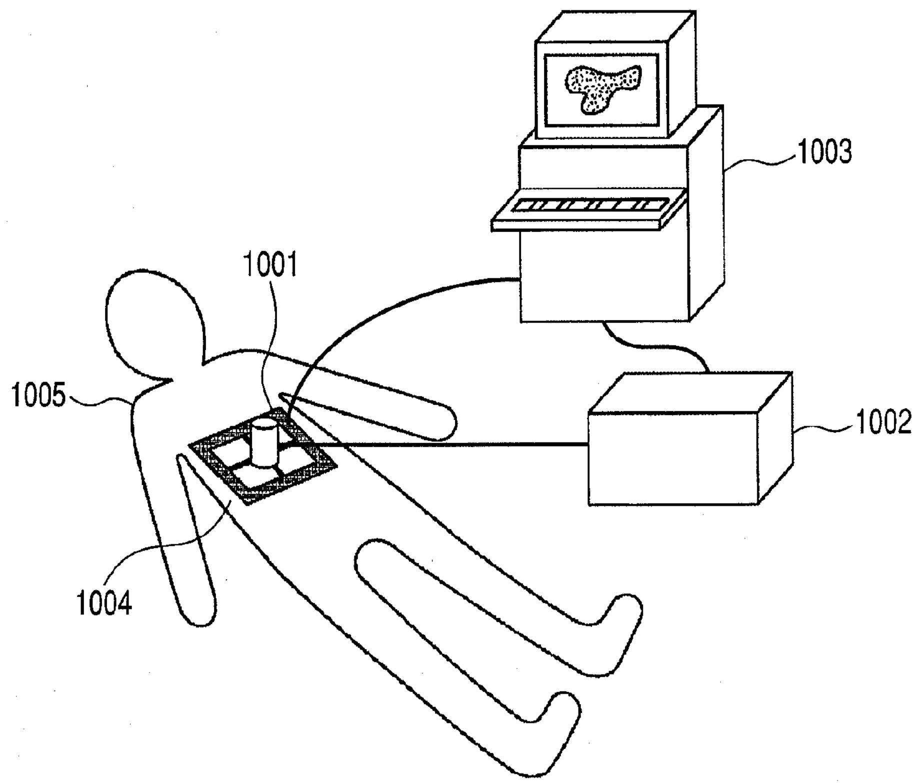


FIG. 1

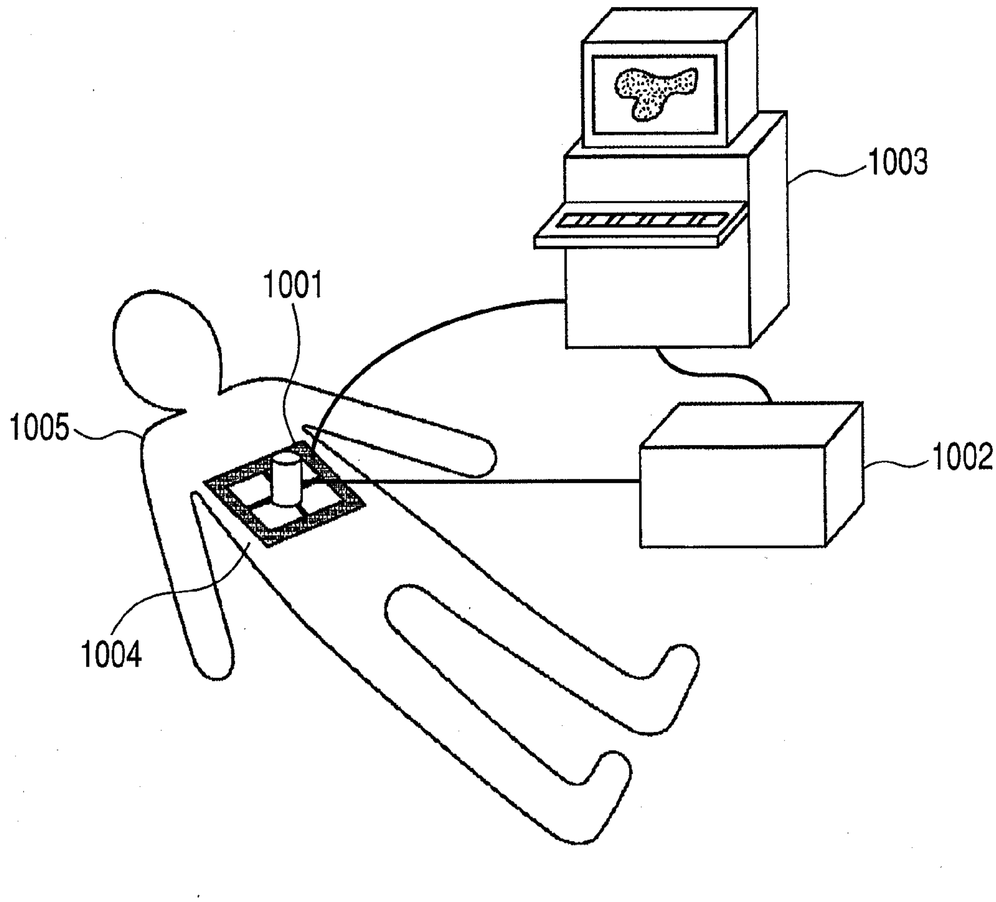


FIG. 2

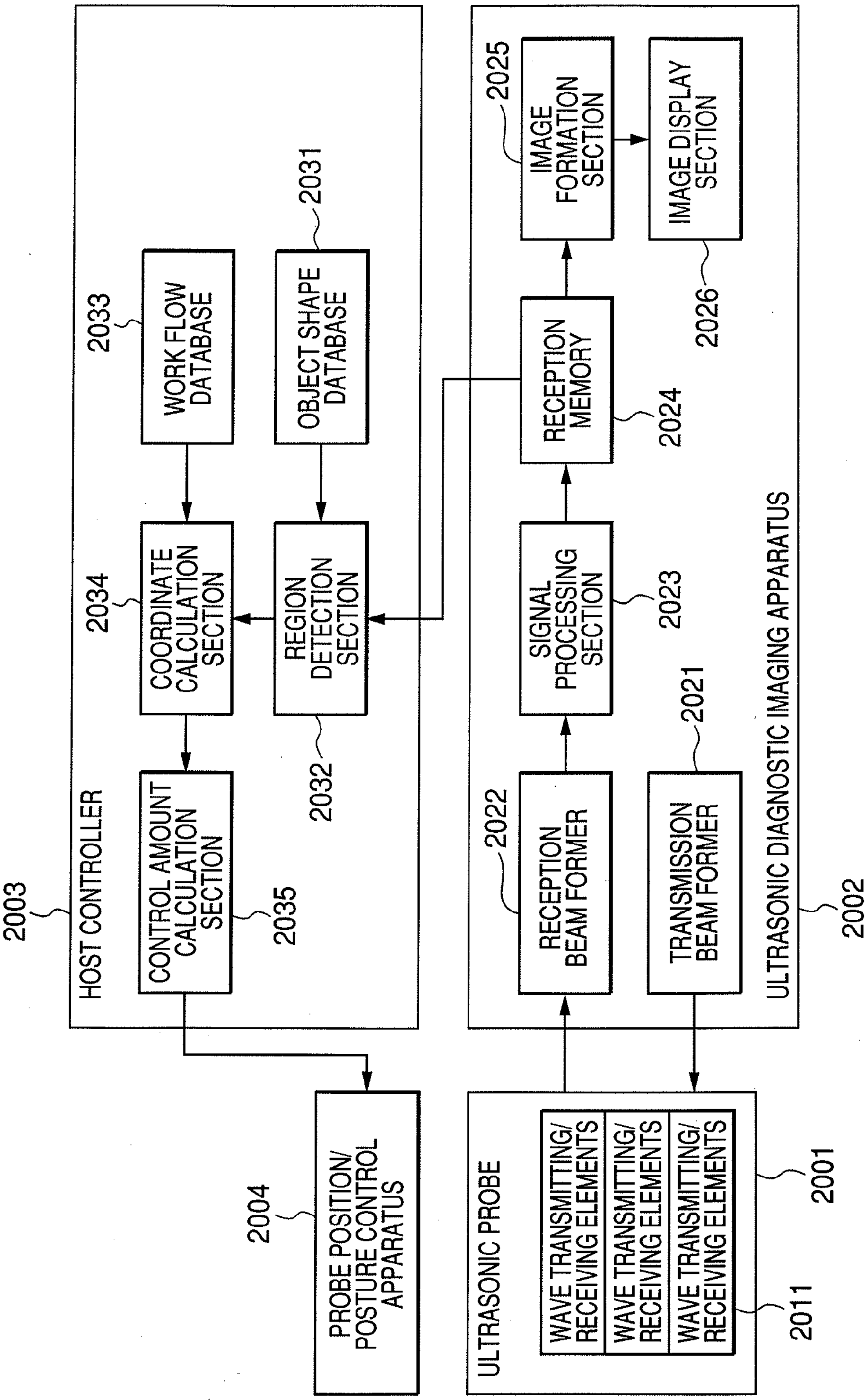

2003
HOST CONTROLLER
WORK FLOW DATABASE
2033
OBJECT SHAPE DATABASE
2031
COORDINATE CALCULATION SECTION
2034
REGION DETECTION SECTION
2032
CONTROL AMOUNT CALCULATION SECTION
2035
ULTRASONIC DIAGNOSTIC IMAGING APPARATUS
2002
IMAGE FORMATION SECTION
2025
IMAGE DISPLAY SECTION
2026
RECEPTION MEMORY
2024
SIGNAL PROCESSING SECTION
2023
RECEPTION BEAM FORMER
2022
TRANSMISSION BEAM FORMER
2021
PROBE POSITION/ POSTURE CONTROL APPARATUS
2004
ULTRASONIC PROBE
2001
WAVE TRANSMITTING/ RECEIVING ELEMENTS
WAVE TRANSMITTING/ RECEIVING ELEMENTS
WAVE TRANSMITTING/ RECEIVING ELEMENTS
2011

FIG. 3

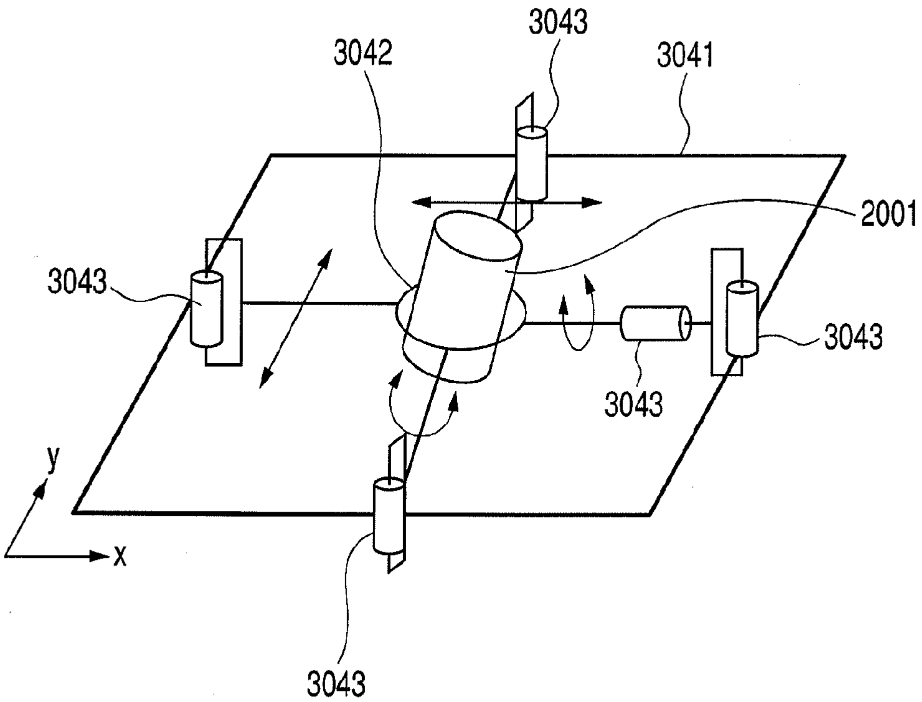
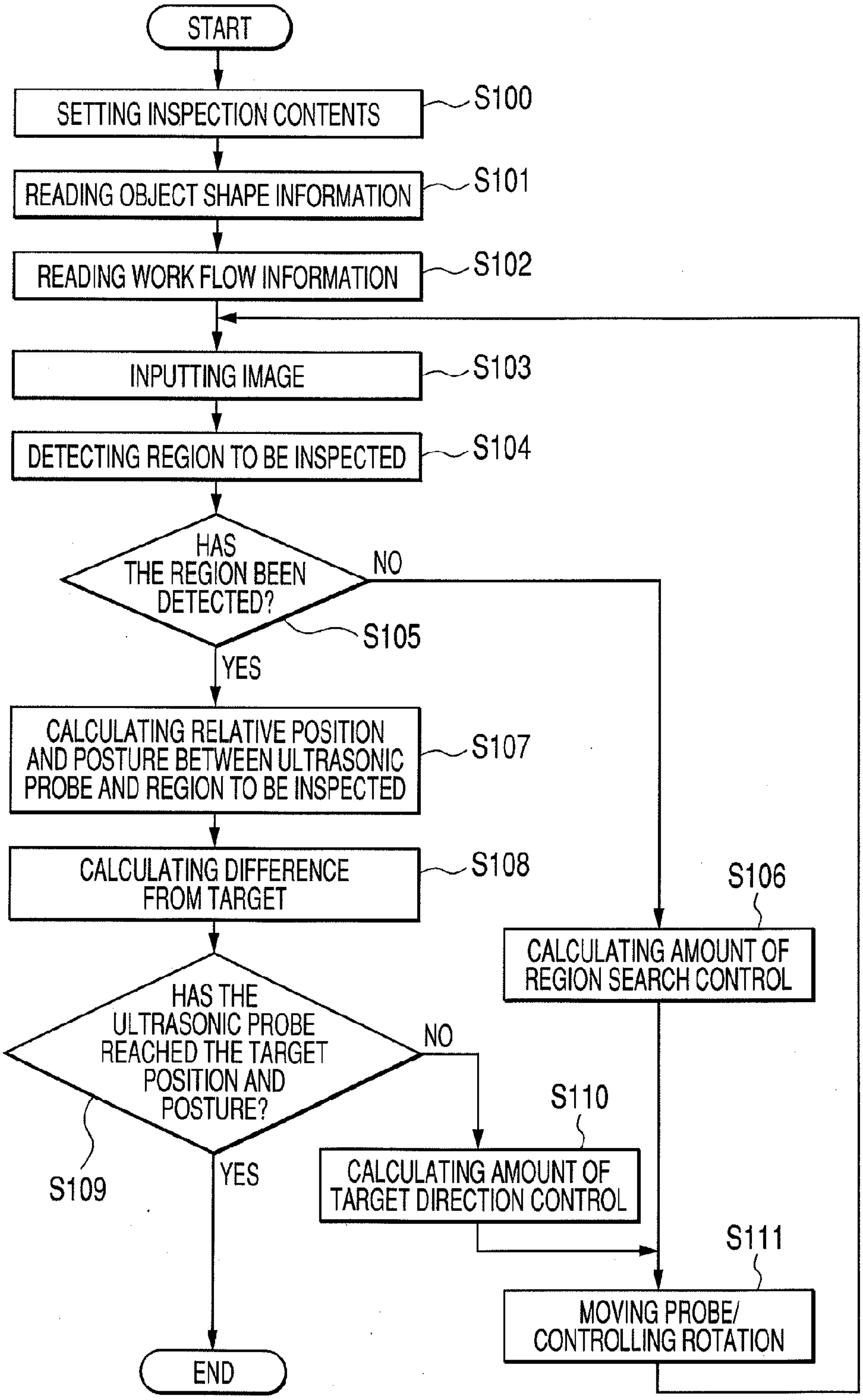


FIG. 4



START
SETTING INSPECTION CONTENTS
S100
READING OBJECT SHAPE INFORMATION
S101
READING WORK FLOW INFORMATION
S102
INPUTTING IMAGE
S103
DETECTING REGION TO BE INSPECTED
S104
HAS THE REGION BEEN DETECTED?
S105
NO
YES
CALCULATING RELATIVE POSITION AND POSTURE BETWEEN ULTRASONIC PROBE AND REGION TO BE INSPECTED
S107
CALCULATING DIFFERENCE FROM TARGET
S108
S106
CALCULATING AMOUNT OF REGION SEARCH CONTROL
HAS THE ULTRASONIC PROBE REACHED THE TARGET POSITION AND POSTURE?
S109
NO
YES
S110
CALCULATING AMOUNT OF TARGET DIRECTION CONTROL
S111
MOVING PROBE/ CONTROLLING ROTATION
END

FIG. 5

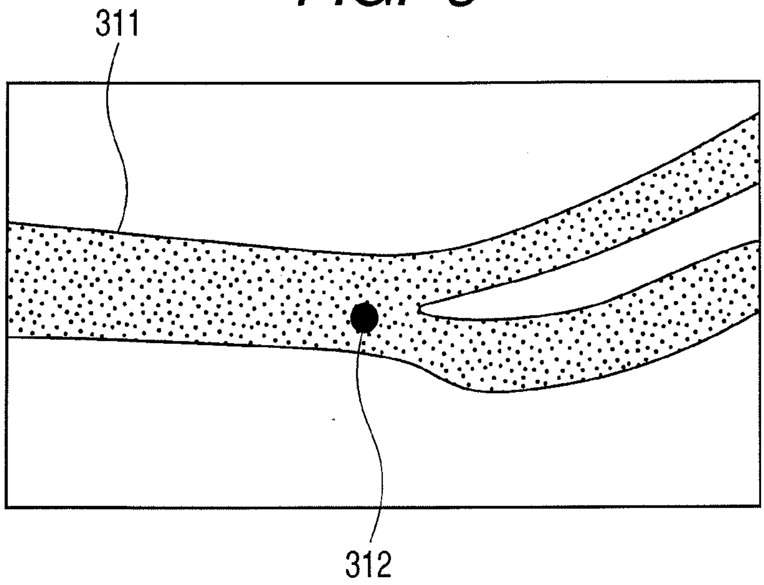


FIG. 6

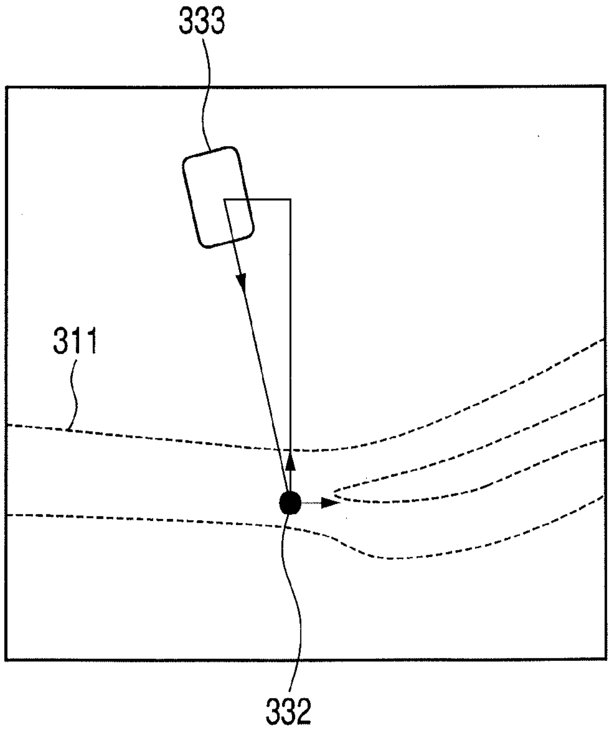


FIG. 7A

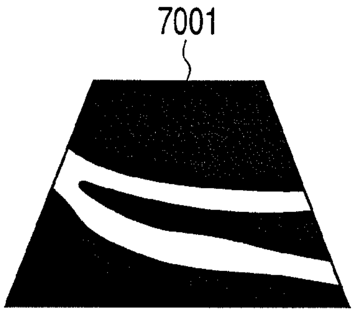


FIG. 7B

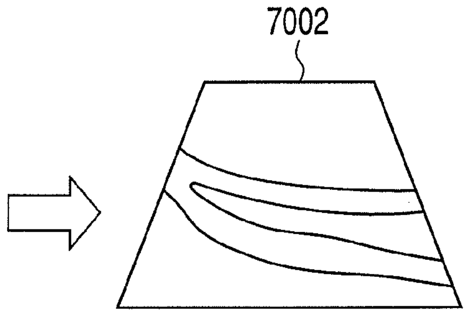


FIG. 7C

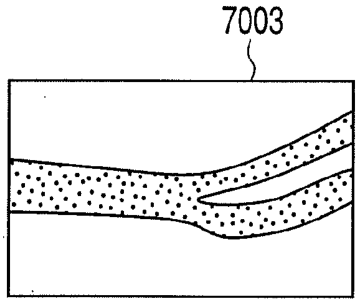


FIG. 7D

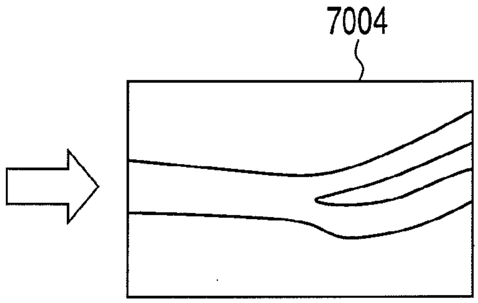
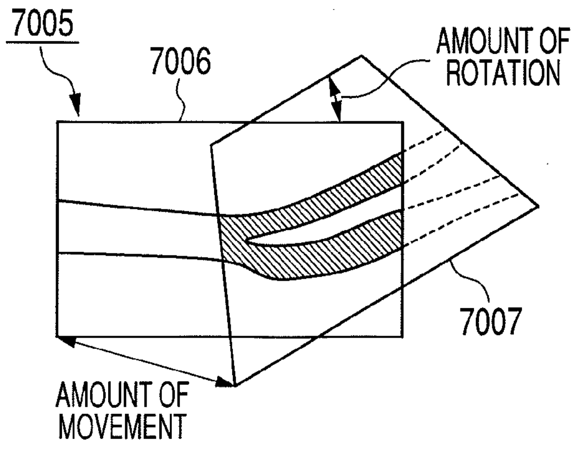


FIG. 7E



SUPERIMPOSITION

FIG. 8

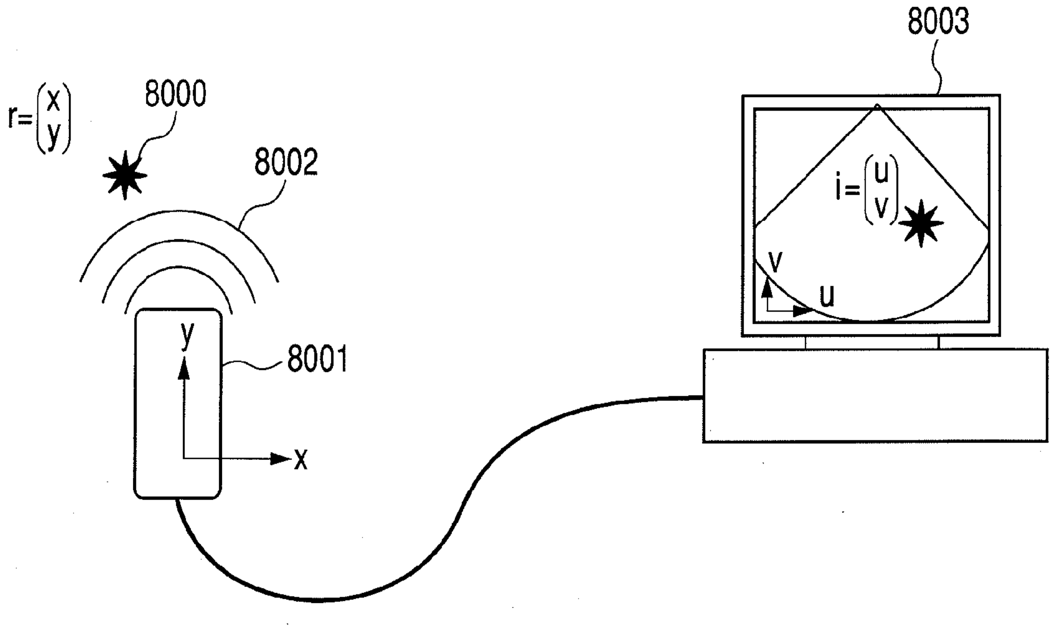


FIG. 9A

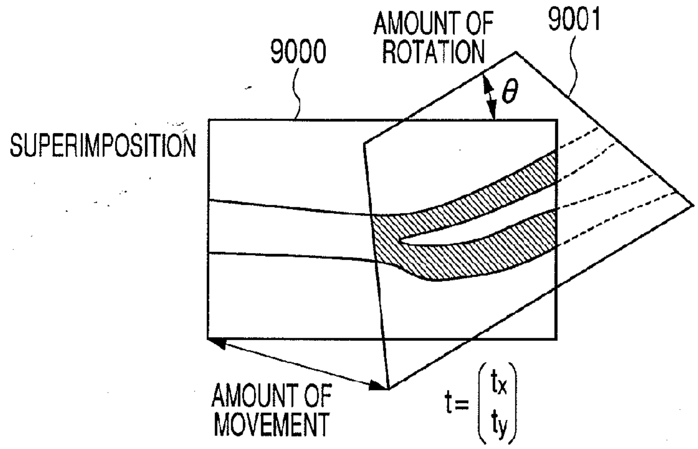


FIG. 9B

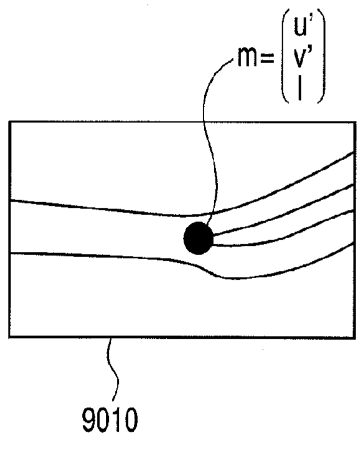


FIG. 9C

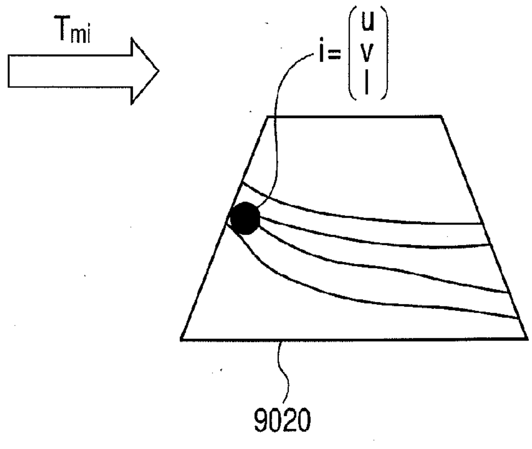


FIG. 10

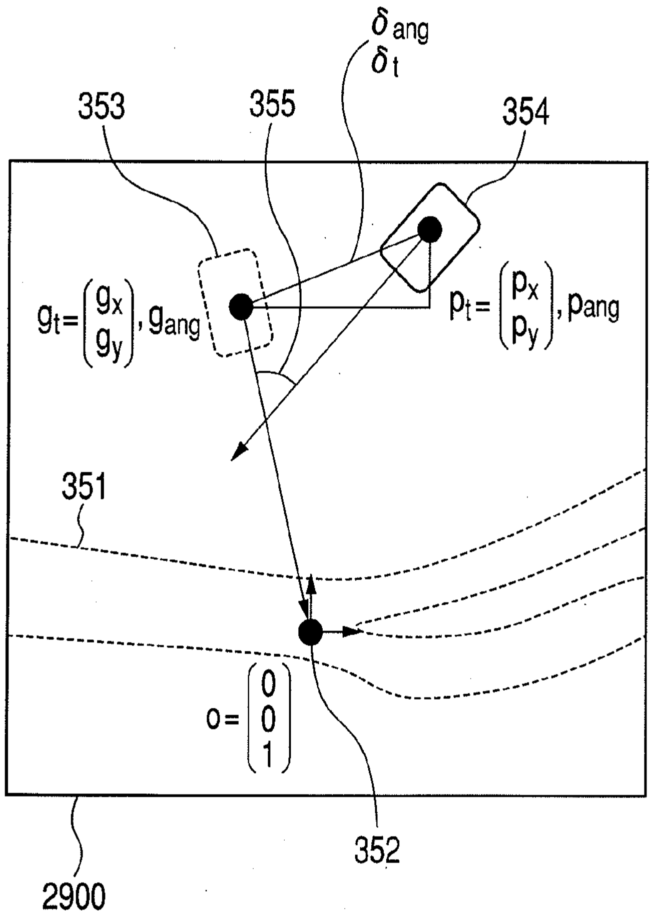
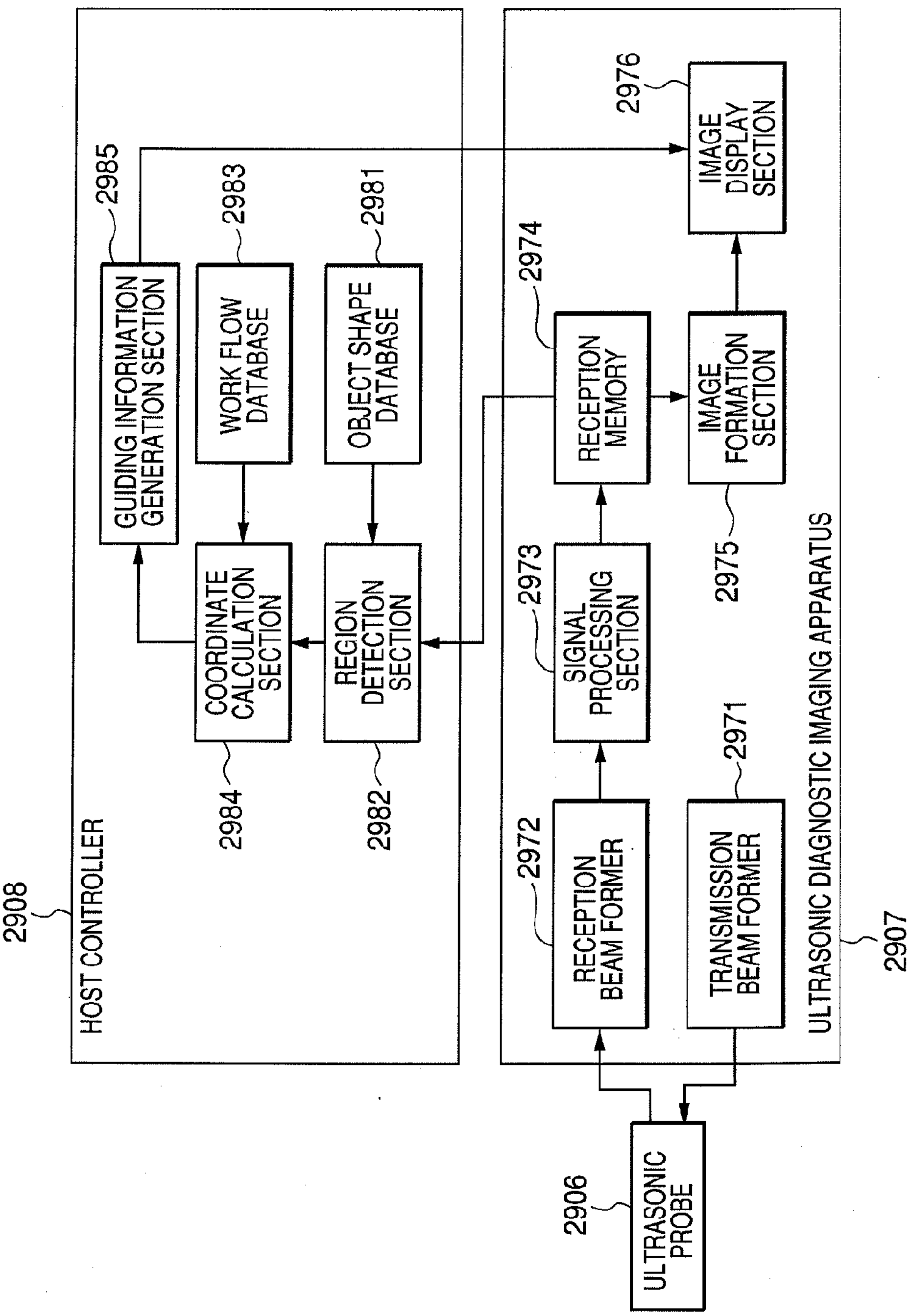


FIG. 11


2908
HOST CONTROLLER
GUIDING INFORMATION GENERATION SECTION
2985
WORK FLOW DATABASE
2983
OBJECT SHAPE DATABASE
2981
COORDINATE CALCULATION SECTION
2984
REGION DETECTION SECTION
2982
2906
ULTRASONIC PROBE
2907
ULTRASONIC DIAGNOSTIC IMAGING APPARATUS
RECEPTION BEAM FORMER
2972
TRANSMISSION BEAM FORMER
2971
SIGNAL PROCESSING SECTION
2973
RECEPTION MEMORY
2974
IMAGE FORMATION SECTION
2975
IMAGE DISPLAY SECTION
2976

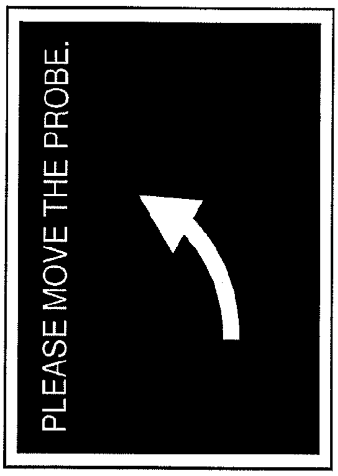


FIG. 12A

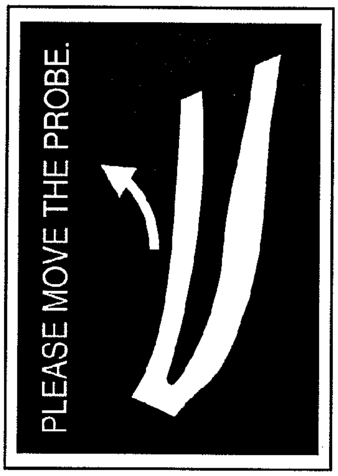


FIG. 12B

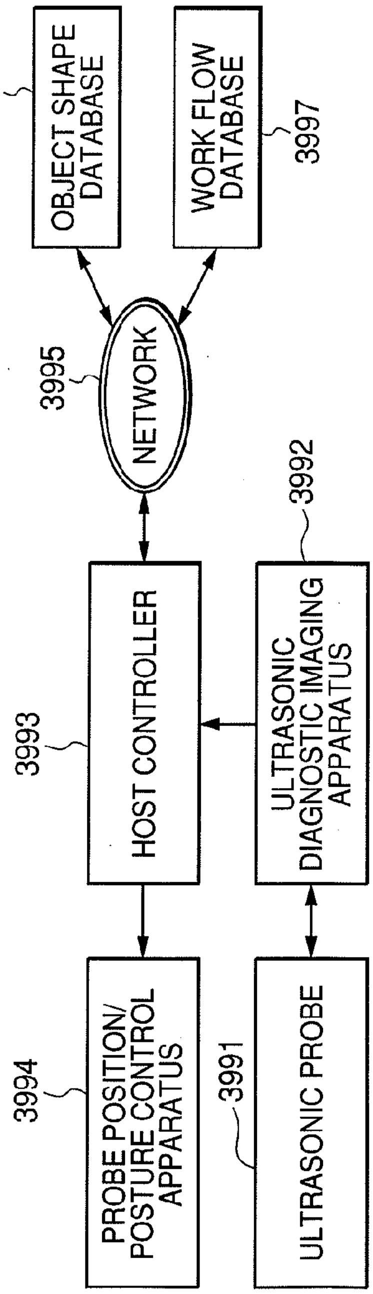


FIG. 13

ULTRASONIC DIAGNOSTIC IMAGING SYSTEM AND CONTROL METHOD THEREOF

TECHNICAL FIELD

[0001] The present invention relates to an ultrasonic diagnostic imaging system and a control method thereof.

BACKGROUND ART

[0002] An ultrasonic diagnostic imaging apparatus (echo) is a diagnostic apparatus that irradiate an examinee with ultrasound, receives ultrasound reflected inside the examinee using a probe and obtains image information from received data. Even when irradiated onto the human body, ultrasound is safe without any particular side effects, and is therefore widely used for diagnostics of various diseases on the medical front lines.

[0003] The ultrasound medical system disclosed in Japanese Patent Application Laid-Open No. 2004-499 discloses a medical system that combines a radiation system for radiological treatment with an ultrasonic diagnostic imaging apparatus. The ultrasonic diagnostic imaging apparatus provides positional information using the position of the radiation apparatus as the origin when providing the position of a tumor to be cured.

[0004] The ultrasound diagnostic apparatus is a simple diagnostic apparatus from the aspect that the ultrasound diagnostic apparatus can acquire image information by only pressing an ultrasonic probe on the human body. A doctor who operates the ultrasound diagnostic apparatus acquires an image by pressing the ultrasonic probe on a patient's body and moving the probe as appropriate. However, since there are many organs in the human body, obtaining image information on an organ to be diagnosed appropriately requires a certain degree of skill in moving the ultrasonic probe.

[0005] Japanese Patent Application Laid-Open No. H01-025576 describes a "scanner of ultrasonic probe." The position, posture and pressure at an end of an ultrasonic probe are measured and the ultrasonic probe is moved and controlled in such a way that the position, posture and pressure are kept constant.

[0006] The method of complementing the skill of the user regarding a scan technique, which is an operation technique, through such control is disclosed.

[0007] The above described method allows the state of the probe with respect to the surface of the human body to be kept adequately. However, keeping the ultrasonic probe in an appropriate state with respect to a region to be inspected in the examinee still requires the operator to have the corresponding skill and knowledge.

DISCLOSURE OF THE INVENTION

[0008] In view of the above described problems, it is an object of the present invention to provide an ultrasound diagnostic system and a control method thereof that enables image information on an examinee's tissue to be diagnosed to be appropriately obtained.

[0009] In order to solve the above described problems, one aspect of the present invention is an ultrasonic diagnostic imaging system provided with an ultrasonic probe and an image processing section that converts a signal generated when the ultrasonic probe receives ultrasound reflected from an examinee to image information, including a measuring unit that measures a relative position and a relative posture of the ultrasonic probe with respect to the examinee using image information on the examinee acquired by the ultrasonic probe, a control amount calculation unit that calculates an amount of control of the position and posture of the ultrasonic probe based on the measurement result of the measuring unit and at least one of a probe control mechanism that controls a position and posture of the ultrasonic probe using the amount of control calculated by the control amount calculation unit and a guiding information presentation unit that presents information for guiding movement of the position and posture of the ultrasonic probe using the amount of control calculated by the control amount calculation unit.

[0010] Furthermore, another aspect of the present invention is a control method for an ultrasonic diagnostic imaging system provided with an ultrasonic probe and an image processing section that converts a signal generated when the ultrasonic probe receives ultrasound reflected from an examinee to image information, measuring a relative position and relative posture of the ultrasonic probe with respect to the examinee using image information on the examinee acquired by the ultrasonic probe, calculating an amount of control of a position and posture of the ultrasonic probe based on the measurement result and at least one of controlling the position and posture of the ultrasonic probe using the calculated amount of control and presenting information for guiding movement of the position and posture of the ultrasonic probe using the amount of control calculated by the control amount calculation unit.

[0011] The present invention adopts a configuration capable of calculating an appropriate position and posture of an ultrasonic probe in an ultrasonic image diagnosis, and can thereby provide a system not depending on an operator who operates the apparatus.

[0012] Other features and advantages of the present invention will be apparent from the following description taken in conjunction with the accompanying drawings, in which like reference characters designate the same or similar parts throughout the figures thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. **1** illustrates a diagnostic method using an ultrasonic diagnostic imaging system according to the present invention.

[0014] FIG. **2** is a configuration diagram of the ultrasonic diagnostic imaging system according to the present invention.

[0015] FIG. **3** is an outside view of the probe position/posture control apparatus in the present invention.

[0016] FIG. **4** is a flowchart illustrating a procedure of the ultrasonic diagnostic imaging system according to the present invention.

[0017] FIG. **5** illustrates information stored in the object shape database in the present invention.

[0018] FIG. **6** illustrates information stored in the work flow database in the present invention.

[0019] FIGS. **7**A, **7**B, **7**C, **7**D and **7**E illustrate processing by the region detection section in the present invention.

[0020] FIG. **8** illustrates a relationship between the ultrasonic probe and an ultrasound image in the present invention.

[0021] FIGS. **9**A, **9**B and **9**C illustrate relationships between an ultrasound image and information on the object shape database in the present invention.

[0022] FIG. **10** illustrates processing by the coordinate calculation section in the present invention.

[0023] FIG. **11** is a configuration diagram of another ultrasonic diagnostic imaging system according to the present invention.

[0024] FIGS. **12**A and **12**B illustrate presentation examples of the guiding information in the present invention.

[0025] FIG. **13** is a configuration diagram of a further ultrasonic diagnostic imaging system according to the present invention.

BEST MODES FOR CARRYING OUT THE INVENTION

[0026] Preferred embodiments of the present invention will now be described in detail in accordance with the accompanying drawings.

[0027] Hereinafter, embodiments of an ultrasonic diagnostic imaging apparatus and a control method thereof according to the present invention will be described in detail according to the accompanying drawings. However, the scope of the invention is not limited to the illustrated embodiments.

First Embodiment

Ultrasonic Diagnostic Imaging System

[0028] The ultrasonic diagnostic imaging system according to this embodiment is an ultrasonic diagnostic imaging system provided with an ultrasonic probe and an image processing section that converts a signal generated when the ultrasonic probe receives ultrasound reflected from an examinee to image information.

[0029] The system includes the following components.

[0030] More specifically, the system includes a measuring unit (may also be referred to as a "coordinate calculation section" in exemplary embodiments which will be described later) that measures a relative position and relative posture of the ultrasonic probe with respect to the examinee using image information on the examinee acquired by the ultrasonic probe.

[0031] Furthermore, the system also includes a control amount calculation unit that calculates an amount of control of the position and posture of the ultrasonic probe based on the measurement result of the measuring unit.

[0032] The system also includes at least one of a probe control mechanism that controls a position and posture of the ultrasonic probe using the amount of control calculated by the control amount calculation unit and a guiding information presentation unit that presents information for guiding movement of the position and posture of the ultrasonic probe using the amount of control calculated by the control amount calculation unit.

[0033] Here, the measuring unit can measure the relative position and relative posture based on the detection result of the region detection section that detects a specific region of the examinee. The region detection section can detect a region from the correspondence between information on the shape of the region of the examinee and the image information.

[0034] Furthermore, the system can include a database that records the relative position and relative posture between the ultrasonic probe and the examinee beforehand and the control amount calculation unit can calculate the amount of control using information on the database.

[0035] Here, the information on the relative position and relative posture between the ultrasonic probe and the examinee recorded in the database can be information that records a suitable probe state (position and posture or the like) for carrying out an ultrasonic image diagnosis.

[0036] The ultrasonic probe can have a pressure measuring unit that measures a pressure between the ultrasonic probe and the examinee. In such a case, the database can record information on the pressure between the ultrasonic probe and the examinee.

Second Embodiment

Control Method

[0037] The control method according to this embodiment is a control method for an ultrasonic diagnostic imaging system provided with an ultrasonic probe and an image processing section that converts a signal generated when the ultrasonic probe receives ultrasound reflected from the examinee to image information. More specifically, the method includes the following steps.

a) A measuring step of measuring a relative position and relative posture of the ultrasonic probe with respect to the examinee using image information on the examinee acquired by the ultrasonic probe

b) A control amount calculation step of calculating an amount of control of the position and posture of the ultrasonic probe based on the measurement result of the measuring step

[0038] Furthermore, the method includes at least one of e) and f) below.

e) A probe control step of controlling the position and posture of the ultrasonic probe using the amount of control calculated in the control amount calculation step

f) A guiding information presentation step of presenting information for guiding movement of the position and posture of the ultrasonic probe using the amount of control calculated by the control amount calculation unit

[0039] Furthermore, it is also an exemplary embodiment that the method includes a region detection step of detecting a specific region of the examinee, and in the measurement step, the relative position and relative posture are measured using the detection result in the region detection step.

[0040] In the region detection step, information on the shape of the examinee is included beforehand and the region can be detected through the correspondence with the image converted by the image processing section.

[0041] The method includes a database that records the relative position and relative posture between the ultrasonic probe and the examinee beforehand, and in the control amount calculation step, the amount of control can be calculated using the information on the database.

[0042] The information on the relative position and relative posture between the ultrasonic probe and the examinee recorded in the database can be information that records a state of the ultrasonic probe for carrying out an ultrasonic image diagnosis.

[0043] The ultrasonic probe may also be provided with a pressure sensor and a pressure measurement step of measuring a pressure between the ultrasonic probe and the examinee can further be added to the steps of the control method. In such a case, the database can record information on the pressure between the ultrasonic probe and the examinee.

[0044] Furthermore, the present invention includes a program to realize the aforementioned control method and a recording medium that records the program to realize the control method.

[0045] Hereinafter, the invention according to the above described embodiments will be described more specifically using exemplary embodiments.

EXEMPLARY EMBODIMENTS

Exemplary Embodiment 1

A: Overall Configuration

[0046] FIG. **1** illustrates an overview of an ultrasonic diagnostic imaging system, which is one of the embodiments of the present invention. The ultrasonic diagnostic imaging system of this exemplary embodiment includes an ultrasonic probe **1001**, an ultrasonic diagnostic imaging apparatus **1002**, a host controller **1003** and a probe position/posture control apparatus **1004**. The ultrasonic probe **1001** is used so as to contact an examinee **1005** such as a human body. Furthermore, the ultrasonic probe **1001** is held by the probe position/posture control apparatus **1004**. These apparatuses are mutually connected and operate by exchanging a control signal or the like through the connection. The probe position/posture control apparatus **1004** is necessary when automating the operation of the ultrasonic probe **1001** and is not indispensable to the aforementioned present invention. The exemplary embodiments which will be described later illustrate the configuration in the case where this probe position/posture control apparatus is not used. FIG. **1** describes the ultrasonic diagnostic imaging apparatus **1002** and the host controller **1003** as separate apparatuses, but it goes without saying that a configuration in which one is incorporated in the other may also be acceptable.

[0047] Next, the function and configuration of the ultrasonic diagnostic imaging system of this exemplary embodiment will be described using FIG. **2**.

B: Ultrasound Probe

[0048] An ultrasonic probe **2001** is made up of a plurality of wave transmitting/receiving elements **2011** (ultrasonic resonators) that transmit ultrasonic pulses to the examinee **1005** and also receive signals reflected from the examinee.

[0049] The wave transmitting/receiving element **2011** can be made up of a piezoelectric element including a polymer piezoelectric element such as piezoelectric ceramic represented by PZT (lead zirconium titanate) and PVDF (polyvinyl difluoride). In this case, ultrasonic pulses can be generated by converting a time-varying electric signal to mechanical vibration through a piezoelectric element.

[0050] The ultrasonic probe **2001** can be configured by arranging the plurality of wave transmitting/receiving elements **2011** in a one-dimensional array. In this case, the ultrasonic probe **2001** can form a two-dimensional scanning plane in the space and can take cross-sectional images of the examinee. Furthermore, the ultrasonic probe **2001** can be configured by arranging the plurality of wave transmitting/receiving elements **2011** in a two-dimensional array. In this case, the ultrasonic probe **2001** can take images of three-dimensional voxel data of the examinee through three-dimensional and electronic scanning in the space.

C: Ultrasonic Diagnostic Imaging Apparatus

[0051] An ultrasonic diagnostic imaging apparatus **2002** is made up of a transmission beam former **2021**, a reception beam former **2022**, a signal processing section **2023**, a reception memory **2024**, an image formation section **2025** and an image display section **2026**.

[0052] The transmission beam former **2021** forms ultrasound to be transmitted through the ultrasonic probe **2001** by controlling a transmission drive signal supplied to the plurality of wave transmitting/receiving elements **2011** of the ultrasonic probe **2001**.

[0053] The reception beam former **2022** collects received wave data output by the wave transmitting/receiving element **2011** and forms echo data.

[0054] The signal processing section **2023** generates brightness data, blood flow velocity data and displacement data or the like based on the echo data formed by the reception beam former **2022**.

[0055] The brightness data, blood flow velocity data and displacement data or the like formed by the signal processing section **2023** are written into the reception memory **2024**. The written data is output to a host controller **2003**. Furthermore, the data written into the reception memory data **2024** is also output to the image formation section **2025** in the ultrasonic diagnostic imaging apparatus **2002**, the image formation section **2025** forms an ultrasound image and the image display section **2026** displays the ultrasound image.

D: Host Controller

[0056] The host controller **2003** is made up of an object shape database **2031**, a region detection section **2032**, a work flow database **2033**, a coordinate calculation section (measuring unit) **2034** and a control amount calculation section **2035**. However, all or some of the components of the host controller **2003** may also be incorporated in the ultrasonic diagnostic imaging apparatus **2002**.

[0057] The object shape database **2031** is a unit that records information such as shape information on the inspection object. For example, data of a standard human body internal structure called a "human body atlas" can be used as the information to be stored in the object shape database.

[0058] The region detection section **2032** references the information stored in the object shape database **2031** and detects a region to be inspected from among ultrasound images input from the ultrasonic diagnostic imaging apparatus **2002**. Various detection methods are available. Examples of the detection method include template matching and contour shape matching. More specific processing contents will be described in the procedure which will be described later.

[0059] The work flow database **2033** is a unit that stores information on the ultrasonic probe operation in an ultrasonic image diagnosis. The information to be stored in the work flow database can be, for example, data having information on a relationship of the relative position and posture between an appropriate region and the ultrasonic probe when the region is imaged using ultrasound for each region to be inspected.

[0060] The coordinate calculation section **2034** calculates the relationship of the relative position and posture between the region to be inspected and the ultrasonic probe **2001** based on the detection result of the region detection section **2032**. This calculation can be performed as follows. For example, the relationship between the spatial coordinates relative to the ultrasonic probe **2001** and the image coordinates of the ultrasound image taken by the ultrasonic probe is determined beforehand. Determining the relationship beforehand in this way allows the relationship of the relative position and posture between the region to be inspected and the ultrasonic probe **2001** to be determined from the image coordinates in the ultrasound image of the region to be inspected detected by the region detection section **2032**.

[0061] The control amount calculation section **2035** calculates the amount of control on the position and posture of the ultrasonic probe **2001**. More specifically, the control amount calculation section **2035** uses information on the ultrasonic probe operation stored in the work flow database **2033** and the relationship of the relative position and posture between the ultrasonic probe **2001** and the region to be inspected calculated by the coordinate calculation section **2034**.

E: Probe Position/Posture Control Apparatus

[0062] A probe position/posture control apparatus **2004** holds the ultrasonic probe **2001** using a mechanism that can move/rotate the ultrasonic probe **2001** and performs operation to move/rotate the ultrasonic probe **2001** according to the input from the host controller **2003**. The probe position/posture control apparatus **2004** can be configured using a base frame **3041**, a probe holder **3042** and a plurality of actuators **3043** as shown in FIG. **3** to realize this operation. In this case, the plurality of actuators **3043** are driven according to the input from the host controller **2003**. As a result of changing the relationship of the relative position and posture between the base frame **3041** and probe holder **3042**, the position and posture of the ultrasonic probe **2001** held by the probe holder **3042** is controlled. Of course, the probe position/posture control apparatus **2004** includes not only an apparatus that controls both the position and posture of the probe but also an apparatus that controls any one of the position and posture.

[0063] FIG. **3** illustrates the mechanism capable of carrying out operation with a total of four degrees of freedom; movement in each axial direction and rotation around each axis on the x-y plane of the base frame **3041** as an example, but in addition to this, a mechanism that also allows movement and rotation with respect to the z axis in the direction perpendicular to x-y can be adopted. This case results in the mechanism capable of carrying out operation with a total of 6 degrees of freedom. Furthermore, a mechanism having any number of degrees of freedom other than 4 and 6 degrees of freedom shown as examples can also be an embodiment of the present invention.

F: Description of Processing Flow

[0064] Next, a more specific procedure executed by the ultrasonic diagnostic imaging apparatus **2002** according to this embodiment will be described with reference to FIG. **4** and FIG. **2**.

f1: Setting of Inspection Contents (Step **S100**)

[0065] First, the user sets inspection contents as step **S100**. For example, a plurality of buttons are arranged on an operation panel (not shown) provided on the host controller **2003** and inspection items are assigned to the buttons. Pressing each button allows the corresponding inspection contents to be set. In addition to this, for example, a list of inspection items may be shown on the image display section **2026** of the ultrasonic diagnostic imaging apparatus **2002** so as to allow the user to select an inspection item by operating the operation panel (not shown).

f2: Reading Object Shape Information (Shape DB) (Step **S101**)

[0066] Next, the information on the shape of the region to be inspected corresponding to the inspection item set in step **S100** is read from the object shape database **2031** into the region detection section **2032**. In this case, by recording various types of shape information which vary depending on the attributes such as age, sex, height and weight in the object shape database **2031** and also setting those attributes on the examinee to be inspected, it is possible to read shape information more suited to the examinee.

[0067] This exemplary embodiment will describe a case where "inspection on arterial sclerosis of carotid artery" is set as an inspection item as an example. FIG. **5** shows an example of the information on the shape of the region to be inspected, which is read in this case. In this figure, a region to be inspected **311** shows the shape of the region to be inspected corresponding to the inspection contents set in step **S100**. Here, the case where the region to be inspected **311** has two-dimensional image information is described as an example, but the present invention is not limited to this and, for example, three-dimensional voxel data or the like may also be used. Furthermore, a reference point **312** is reference information on the position and posture added to the region to be inspected and referenced in the next and subsequent steps. When reading the above described information recorded in the object shape database **2031**, the region detection section **2032** can read the information on the object shape database **2031** in the same format or also read the information after extracting the contour plane and contour lines of the region. Furthermore, information on the contour plane or contour lines of the region to be inspected can also be stored in the shape information database from the beginning.

f3: Reading Work Flow Database (Step **S102**)

[0068] Next, target values of the probe position and posture corresponding to the inspection items set in step **S100** are read from the work flow database **2033**. FIG. **6** shows an example of target values, which are read in this case. Here, a case where the work flow database stores the range of the relative position of the region to be inspected relative to the reference point and the range of the relative angle as target values of the probe position and posture is shown as an example.

[0069] In this figure, a region to be inspected **331** indicates the region to be inspected set in step **S100**. A reference point **332** indicates the position which becomes a base point of the target values of the probe position and posture. Furthermore, as indicated by the arrow in the figure, the reference point **332** also has information on the direction to be a reference. A probe target position/target posture **333** indicates the position state and posture state that should be taken by the ultrasonic probe **2001** when an ultrasound image is taken. All these states are read as numerical information using the reference point **332** as a reference.

f4: Image Input (Step **S103**)

[0070] Next, an ultrasound image is taken and the image is input. To take an ultrasound image, the transmission beam former **2021** of the ultrasonic diagnostic imaging apparatus **2002** forms and sends an electric signal to drive the wave transmitting/receiving element **2011** of the ultrasonic probe **2001**.

[0071] The wave transmitting/receiving element **11** of the ultrasonic probe **2001** receives the ultrasound reflected and returned from within the examinee and the signal is input to the reception beam former **2022** of the ultrasonic diagnostic imaging apparatus **2002**. The reception beam former **2022** performs processing such as superimposition on the received signal and inputs the signal to the reception memory **2024**. The data input to the reception memory **2024** is displayed on the image display section **2026** through the image formation section **2025** and also input to the region detection section **2032** of the host controller **2003**.

f5: Region Detection (Step S**104**)

[0072] Next, the region detection section **2032** detects the region to be inspected read from the object shape database **2031** from among the ultrasound images input from the ultrasonic diagnostic imaging apparatus **2002**.

[0073] There are various methods of detecting the region to be inspected. Here, a method of applying contour extraction of an object to be imaged to the information on the ultrasound image and region shape database **2031** and detecting the region to be inspected based on matching between the contours will be described using FIGS. **7**A, **7**B, **7**C, **7**D and **7**E.

[0074] In FIGS. **7**A to **7**E, FIG. **7**A shows an input ultrasound image **7001**. Contour information **7002** as shown in FIG. **7**B is obtained by applying contour extraction processing to this image. Furthermore, an image **7003** in FIG. **7**C is information on the object shape database **2031** and contour information **7004** as shown in FIG. **7**D is obtained by applying contour extraction to the image **7003**.

[0075] Here, the contour information **7004** in FIG. **7**D is superimposed on the contour information **7002** in FIG. **7**B and the amount of movement/amount of rotation of FIG. **7**D that corresponds to the maximum superimposition between the two pieces of information is searched (of course, the amount of movement/amount of rotation of the image FIG. **7**B may also be searched).

[0076] As a result, the amount of movement/amount of rotation corresponding to the maximum superimposition can be calculated as shown in **7005** in FIG. **7**E. Here, the image **7006** corresponds to the image **7004** in FIG. **7**D and the image **7007** corresponds to the image **7002** in FIG. **7**B. Here, the procedure for detecting a region by applying contour extraction processing to both pieces of information on the ultrasound image and the region shape database and comparing the two contour shapes has been described.

[0077] However, the procedure for region detection in step S**104** is not limited to this method.

[0078] For example, there can also be a procedure that detects a plurality of characteristic corners instead of carrying out contour extraction processing and detects the region through matching among those characteristic corners. Furthermore, there can also be a procedure for detecting the region by directly comparing pixel values between the ultrasound image and the object shape database **2031**. In this case, the similarity among pixel values can be evaluated by indices such as correlation coefficients and mutual information content. Furthermore, more robust region detection can also be performed in consideration of deformation of the shape of the region.

[0079] With the above described procedure, the region similar to the shape information stored in the object shape database **2031** can be detected from the ultrasound image. Furthermore, the detection intensity using the similarity of both shapes as a reference and a relationship between positions where both shapes closely resemble each other can also be obtained simultaneously.

[0080] Here, the case where both the ultrasound image and the shape information stored in the object shape database **2031** are two-dimensional image data has been described, but the present invention is not limited to this. For example, at least one of the ultrasound image and the shape information stored in the object shape database **2031** may be three-dimensional voxel data. In such a case, the target region can be detected through matching between three-dimensional voxel data or matching between two-dimensional image data and three-dimensional voxel data.

f6: Determining Detection Result (Step S**105**)

[0081] In step S**105**, it is determined whether or not the region has been detected based on the result of the region detection carried out in step S**104**.

[0082] This determination can be made assuming, for example, that when the maximum value of the detection intensity obtained as a result of the region detection is greater than a preset threshold, the region to be inspected has been detected, whereas when smaller than the threshold, the region to be inspected has not been detected. In addition to this, when the detection intensity exceeds the threshold for several frames consecutively, it is also possible to determine that the region has been detected. In this case, there is an advantage that a determination can be made with higher reliability. Furthermore, a value that differs from one region to be inspected to another can also be set as the threshold. In this case, an appropriate threshold can be set in consideration of the difference between regions with and without large individual differences in shape.

[0083] When it is determined in step S**105** that the region to be inspected has been detected, the process moves to step S**107** or moves to step S**106** otherwise.

f7: Calculating Amount of Region Search Control (Step S**106**)

[0084] In step S**105**, when the region to be inspected has not been detected from among the ultrasound images, control over the movement/rotation is performed so as to change the position and posture of the ultrasonic probe **2001** so that the inspection object falls within the imaging range. In this case, the simplest method for moving/rotating the ultrasonic probe **2001** may be the method of thoroughly scanning the movable range of the probe position/posture control apparatus **2004**. For example, the ultrasonic probe **2001** is moved to the position of the farthest end of the probe position/posture control apparatus **2004** and a control signal is sent to the probe position/posture control apparatus so as to gradually move the ultrasonic probe **2001** while taking ultrasound images. If the region to be inspected is detected in the process, scanning of the position and posture of the ultrasonic probe is finished according to the determination result in step S**105** and the process moves to step S**107**.

[0085] Furthermore, as another method, not only the region to be inspected but also the shapes of regions existing around and their relative positional relationship with the region to be inspected can be stored in the region shape database. Such storage allows the ultrasonic probe **1** to be moved or rotated according to the detection results of the peripheral regions even when the region to be inspected cannot be directly detected.

[0086] The more specific operation of the probe position/posture control apparatus **2004** will be described in detail in the description of step S**111**.

f8: Coordinate Calculation (Step S**107**)

[0087] Next, the coordinate calculation section **2034** (FIG. **2**) calculates the relative position and posture between the ultrasonic probe **2001** and a reference point in the object shape database **2031**.

[0088] This calculation is performed based on the following first and second relationships. The first relationship is a relationship between the spatial coordinates using the ultrasonic probe **2001** as a reference and the image coordinates of the ultrasound image taken. The second relationship is a correlation between the position and posture information on the image of the region to be inspected detected in step S**104** and the reference coordinates stored in the object shape database **2031**.

[0089] This processing will be described in detail using FIG. **8** and FIGS. **9**A, **9**B and **9**C.

[0090] For simplicity of description here, suppose that all the real space, ultrasound image and shape information of the object shape database **2031** occupy a two-dimensional space. However, the present invention is not limited to this and when, for example, all or part of the information occupies a three-dimensional space, the present invention can be implemented by a simple extension in the following description.

[0091] FIG. **8** illustrates a relationship between coordinates of the real space in which an imaging object exists and those of an ultrasound image generated through ultrasonic imaging. Reference numeral **8001** schematically denotes an ultrasonic probe, **8002** denotes ultrasound, **8003** denotes a host controller and **8000** denotes a measurement target.

[0092] In this figure, coordinates on an image are expressed by vector $i=(u\ v)^t$, coordinates in the real space are expressed by vector $r=(x\ y)^t$. Here, "t" added at the shoulder of the vector represents transposition. Suppose the coordinate vector i represents a pixel point on an image located at the uth position in the rightward direction and with position in the downward direction on the screen relative to the origin assuming the left top end point of the image as the origin $(0\ 0)^t$. Furthermore, the coordinate vector r has the origin $(0\ 0)^t$ inside the ultrasonic probe **8001** and expresses a point in the real space which is moved by x[mm] and y[mm] respectively relative to the origin with respect to two mutually orthogonal axes that form an imaging plane.

[0093] The ultrasonic diagnostic imaging apparatus **2002** (FIG. **2**) generates ultrasound from the ultrasonic probe **2001** (FIG. **1**) and determines a brightness value at a point i on the ultrasound image based on the observed value of the reflected signal from a point r in the real space. Here, the correspondence between the point r in the real space and point i on the ultrasound image is expressed by the following expression using a function T_{ri}.

$$i=T_{ri}(r) \quad \text{(Expression 1)}$$

Here, assuming that the coordinate vector i has a linear relationship with respect to the coordinate vector r, i can be expressed as:

$$i=T_{ri}r \quad \text{(Expression 2)}$$

where T_{ri} represents a matrix expressing the linear relationship between i and r, and i and r are redefined as extended vectors $i=(u\ v\ 1)^t$ and $r=(x\ y\ 1)^t$ respectively. Normally, the assumption of the above described linear relationship sufficiently holds in a calibrated ultrasonic diagnostic imaging apparatus. Furthermore, on the contrary, transformation from the point i on the image to the point r in the real space can be expressed using an inverse matrix T_{ri}^{-1} of the matrix T_{ri} as:

$$r=T_{ri}^{-1}i \quad \text{(Expression 3)}$$

Since the matrix T_{ri} is a regular matrix except special cases, the inverse matrix T_{ri}^{-1} can be calculated.

[0094] On the other hand, the correspondence between the point i on the ultrasound image and the point of the object shape database **2031** is obtained from the processing result in step S**104**. This will be described using FIGS. **9**A, **9**B and **9**C. **9000** and **9001** in FIG. **9**A correspond to **7006** and **7007** in FIGS. **7**A, **7**B, **7**C, **7**D and **7**E respectively. First, suppose the point in the object shape database **2031** with respect to the point i on the ultrasound image is vector $m=(u'\ v'\ 1)^t$. On the assumption that vector m (FIG. **9**B **9010**) and vector i (FIG. **9**C **9020**) have a linear relationship, i can be expressed using a linear transformation matrix T_{mi} as:

$$i=T_{mi}m \quad \text{(Expression 4)}$$

[0095] Furthermore, the relationship with the point r in the real space corresponding to an arbitrary point m in the object shape database **2031** can be expressed using Expression 3 and Expression 4 as:

$$r=T_{ri}^{-1}T_{mi}m \quad \text{(Expression 5)}$$

Here, assuming that the point m represents coordinates of a region reference point of the object shape database **2031**, the corresponding point in the real space can be determined as a coordinate r using the ultrasonic probe **2001** as a reference.

[0096] Here, the example has been described where the position of the region reference point of the object shape database **2031** is determined in a coordinate system using the ultrasonic probe **2001** as a reference, but to the contrary, the position and posture of the ultrasonic probe may also be determined using the region reference point of the object shape database **2031** as a reference.

f9: Calculating Difference from Target (Step S**108**)

[0097] As the next step, the coordinate calculation section **2034** further calculates a correspondence between the position and posture of the ultrasonic probe **2001** and the target position and posture read from the work flow database **2033**. To calculate this correspondence, a correspondence between the position and posture of the reference point of the region to be inspected in the coordinate system using the ultrasonic probe **2001** obtained in step S**107** as a reference and the target position and posture of the work flow database **2033** is determined. This processing will be described in detail using FIG. **10**.

[0098] FIG. **10** illustrates the target position and posture of the ultrasonic probe stored in the work flow database and the current position and posture of the ultrasonic probe. Here, a region to be inspected **351**, a reference point **352**, a probe target position and posture **353** are the information read in step S**102**. Furthermore, the region to be inspected **351** and reference point **352** can be assumed to express the same contents as the region to be inspected **311** and reference point **312** out of the information stored in the region shape database **2031** read in step S**101**.

[0099] In FIG. **10**, the probe target position and posture **353** means the target values of the position and posture of the probe in the coordinate system whose origin is the reference point **352** of the region to be inspected. Here, the probe target position and posture **353** are divided into components of translational motion and rotation, and expressed as g_t and g_{ang} respectively. Similarly, the probe current position and posture **354** can also be expressed as p_t and p_{ang} respectively based on the relative position and posture with respect to the reference point of the ultrasonic probe and region to be inspected already determined in S**107**. From the information, the difference in position δ_t between the current ultrasonic probe and the target, and difference in posture δ_{ang} can be calculated from the following expressions respectively.

$$\delta_t = p_t - g_t \quad \text{(Expression 6)}$$

$$\delta_{ang} = p_{ang} - g_{ang} \quad \text{(Expression 7)}$$

Through the above described processing, the degree of deviation in position/angle of the ultrasonic probe **2001** from the target position and posture at the present moment can be calculated.

f11: Determining Reach of Target (Step S**109**)

[0100] Next, it is determined whether or not the ultrasonic probe has reached the target position and posture based on the relative difference of the current position and posture of the ultrasonic probe from the target value calculated in step S**108**. As the method for determining this, the ultrasonic probe may be determined as having reached the target when the difference between the current position/posture of the ultrasonic probe **1** calculated in step S**108** and the target value is smaller than a predetermined threshold and determined as not having reached the target otherwise.

[0101] Furthermore, a value that varies depending on the setting of the region to be inspected may also be automatically set for this threshold. In this case, the target range of the position/posture of the ultrasonic probe can be changed for each inspection object.

f12: Calculating Amount of Target Direction Control (step S**110**)

[0102] When the determination result in step S**109** shows that the probe position/posture falls short of the target value, step S**110** is carried out. In step S**110**, the control amount calculation section **2035** calculates the amount of control to be sent to the probe position/posture control apparatus so as to make the probe position/posture closer to the target value. Calculation of the amount of control can take various modes depending on the characteristic of the control apparatus. When, for example, the direction of movement/rotation is specified for the probe position/posture control apparatus and constant-speed drive is performed, the direction can be determined based on the positive/negative sign of each component value of the position difference δ_t and the posture difference δ_{ang} from the target value calculated in step S**108**.

[0103] As another method, the amount of control can also be calculated using both the signs and absolute values of the differences δ_t and δ_{ang} from the target value. In this case, there can be a method of determining the direction of control based on, for example, the signs of the difference values and determining the speed based on the absolute values.

f13: Probe Movement/Rotation Control (Step S**111**)

[0104] In step S**111**, the amount of control calculated in step S**106** or step S**110** is input to the ultrasonic probe position/posture control apparatus **2004** (FIG. **2**) and the position and posture of the ultrasonic probe are driven so as to approximate to the target values. For example, based on the amount of control over the position and posture of the probe calculated in step S**110**, a voltage proportional, for example, to the amount of control is applied to the corresponding actuators **3043** (FIG. **3**). In this way, the actuators **3043** are driven in the direction approximating to the target position and posture recorded in the work flow database **2033**, and as a result, the ultrasonic probe **2001** held approximates to the target state.

[0105] Performing the processing from step S**100** to step S**111** described above can keep the ultrasonic probe **2001** in an appropriate position and posture with respect to the region to be inspected. By so doing, it is possible to provide an ultrasonic diagnostic imaging apparatus that allows even a user who has not special skill about ultrasonic imaging to take an ultrasound image suitable for a diagnosis.

[0106] This exemplary embodiment has described the case where the probe position/posture control apparatus **2004** mechanically moves/rotates the position and posture of the ultrasonic probe **2001** to realize ultrasonic imaging of a region to be inspected from the appropriate position/angle as an example. However, the embodiment of the present invention is not limited to this. When, for example, an ultrasonic probe having a plurality of wave transmitters/receivers capable of electronically changing the position/direction of transmission/reception of an ultrasound signal is used, making the wave transmission/reception position and direction of the ultrasound signal the control targets can produce the effects similar to those of the above described embodiment. Moreover, a configuration combining both mechanical control and electronic control also becomes one embodiment of the present invention.

Exemplary Embodiment 2

[0107] Exemplary Embodiment 1 has described the example where the ultrasonic probe is moved/rotated so as to guide the ultrasonic probe to an appropriate position and posture with respect to an object of ultrasound inspection, but the embodiment of the present invention is not limited to this.

[0108] For example, there can also be an embodiment of presenting navigation to urge the user to move/rotate the ultrasonic probe instead of providing an apparatus for moving/rotating the ultrasonic probe. An example of adopting such an embodiment will be described.

A: Overall Configuration

[0109] FIG. **11** illustrates the configuration of the exemplary embodiment presenting navigation to move/rotate the ultrasonic probe to the user.

[0110] The ultrasonic diagnostic imaging system of this embodiment is made up of an ultrasonic probe **2906**, an ultrasonic diagnostic imaging apparatus **2907** and a host controller **2908**.

B: Ultrasound Probe

[0111] Since the ultrasonic probe **2906** is similar to that in Exemplary Embodiment 1, descriptions thereof will be omitted.

C: Ultrasonic Diagnostic Imaging Apparatus

[0112] The ultrasonic diagnostic imaging apparatus **2907** is made up of a transmission beam former **2971**, a reception beam former **2972**, a signal processing section **2973**, a reception memory **2974**, an image formation section **2975** and an image display section **2976**.

[0113] The image display section **2976** presents ultrasound image and navigation information based on signals from the image formation section **2975** and host controller **2908**. Since the rest of the configuration included in the ultrasonic diagnostic imaging apparatus **2907** is similar to that described in Exemplary Embodiment 1, descriptions thereof will be omitted.

D: Host Controller

[0114] The host controller **2908** is made up of an object shape database **2981**, a region detection section **2982**, a work flow database **2983**, a coordinate calculation section **2984** and a guiding information generation section **2985**.

[0115] However, all or some of the components of the host controller **2908** can also be incorporated in the ultrasonic diagnostic imaging apparatus **2907**. The guiding information generation section **2985** generates guiding information on the movement/rotation of the probe to be carried out by the user based on the difference from the target value of the probe calculated by the coordinate calculation section **2984**. The guiding information generated is sent to the image display section **2976** of the ultrasonic diagnostic imaging apparatus **2907** and presented to the user using a display or the like. The rest of the configuration included in the host controller **2908** is the same as that described in Exemplary Embodiment 1, and therefore descriptions thereof will be omitted.

E: Guiding Information Generation Section

[0116] The guiding information generated by the guiding information generation section **2985** and presented by the image display section **2976** can be presented using symbols like an arrow as shown, for example, in FIG. **12**A. Furthermore, as shown in FIG. **12**B, the image display section **2976** may be enabled to present an ultrasound image and present guiding information simultaneously.

[0117] Furthermore, the presentation of the guiding information is not limited to the presentation by the image display section **2976** of the ultrasonic diagnostic imaging apparatus **2907**. For example, the ultrasonic probe **2906** may be newly provided with a display section for presenting guiding information on the position and posture to enable guiding information to be presented. In this case, the user has the merit of being able to intuitively recognize the probe moving direction without referencing the ultrasonic diagnostic imaging apparatus **2907**.

[0118] Furthermore, the guiding information of this exemplary embodiment is not limited to presentation with an image. As another configuration example, the host controller **2908** or ultrasonic diagnostic imaging apparatus **2907** or ultrasonic probe **2906** may be newly provided with a sound presentation section such as a speaker and the navigation generation section **2985** may be enabled to create guiding information with speech. In this case, the user can obtain the guiding information without viewing the screen.

Exemplary Embodiment 3

[0119] Exemplary Embodiment 1 and Exemplary Embodiment 2 have described the case where the host controller includes the database that stores information on the region to be inspected and the ultrasound inspection work flow as an example. However, the present invention is not limited to this embodiment.

[0120] Exemplary Embodiment 3 will describe an example of an ultrasound diagnostic system that acquires information on the region to be inspected and the ultrasound inspection work flow with reference to an external database.

[0121] FIG. **13** is a configuration diagram of an ultrasonic diagnostic imaging system according to this exemplary embodiment that acquires information from an external database via a network. The ultrasonic diagnostic imaging system according to this exemplary embodiment is made up of the following components. More specifically, the ultrasonic diagnostic imaging system is made up of an ultrasonic probe **3991**, an ultrasonic diagnostic imaging apparatus **3992**, a host controller **3993**, a probe position/posture control apparatus **3994**, an object shape database **3996** and a work flow database **3997**.

[0122] Furthermore, the host controller **3993** is connected to the object shape database **3996** and the work flow database **3997** via a network **3995**.

[0123] Here, a case where both the object shape database **3996** and work flow database **3997** are connected to the host controller **3993** via the network is described as an example, but the embodiment of the present invention is not limited to this.

[0124] For example, such a configuration may also be adopted that only one of the object shape database **3996** and the work flow database **3997** is connected via the network and the other is located inside the host controller **3993**. Moreover, a connection via the network **3995** is shown as an example of connection, but the mode of connection may also be a so-called LAN connection or other connection modes such as USB connection, serial connection or parallel connection. Furthermore, the object shape database **3996** or work flow database **3997** and host controller **3993** need not always be paired. For example, depending on the embodiment, such a mode may also be adopted that the host controllers **3993** of a plurality of ultrasonic diagnostic imaging systems share the object shape database **3996** or the work flow database **3997**.

[0125] Adopting the above described configuration eliminates the necessity for the ultrasound diagnostic system of the present invention to store necessary region shape information or work flow information in the host controller **3993** and enables a database supplied to the system to be flexibly expanded or changed.

[0126] Moreover, the host controller may also be configured so that the information stored in the object shape database **3996** and work flow database **3997** can be added, changed or deleted through an external operation. In this case, it is possible to flexibly update the database associated with expansion of the corresponding inspection items and revision of the inspection method or the like.

Other Embodiments

[0127] Furthermore, it goes without saying that the object of the present invention can also be attained by supplying a recording medium that records software program code to realize the functions of the aforementioned embodiments and exemplary embodiments to the system or apparatus. More specifically, a computer (or CPU or MPU) of the system or the apparatus reads and executes the program code stored in the recording medium. In this case, the program code itself read from the recording medium realizes the functions of the aforementioned embodiments and the recording medium storing the program code constitutes the present invention.

[0128] The functions of the aforementioned embodiments are realized by the computer executing the read program code, but the present invention does not include only such a case. It goes without saying that the present invention also includes a case where based on instructions of the program code, the operating system (OS) operating on the computer performs part or whole of actual processing and realizes the functions of the aforementioned embodiments.

[0129] Furthermore, it goes without saying that the present invention also includes a case where the functions of the aforementioned embodiments are realized through the processing performed in A) and B) below.

[0130] A) The program code read from the recording medium is written into a memory provided for a feature expansion card inserted in the computer or a feature expansion unit connected to the computer.

[0131] B) Based on instructions of the program code, a CPU provided for the feature expansion card or feature expansion unit then performs part or whole of the actual processing.

[0132] When the present invention is applied to the above described recording medium, the recording medium stores the program code corresponding to the flowchart described above.

[0133] The descriptions in the aforementioned embodiments are only examples of the preferred ultrasonic diagnostic imaging apparatus according to the present invention and the present invention is not limited to these examples.

[0134] The present invention is not limited to the above embodiments and various changes and modifications can be made within the spirit and scope of the present invention. Therefore to apprise the public of the scope of the present invention, the following claims are made.

[0135] This application claims the benefit of Japanese Patent Application No. 2007-226340, filed Aug. 31, 2007, which is hereby incorporated by reference in its entirety.

1. An ultrasonic diagnostic imaging system provided with an ultrasonic probe and an image processing section that converts a signal generated when the ultrasonic probe receives ultrasound reflected from an examinee to image information, comprising:

a measuring unit that measures a relative position and a relative posture of the ultrasonic probe with respect to the examinee using image information on the examinee acquired by the ultrasonic probe;

a control amount calculation unit that calculates an amount of control of the position and posture of the ultrasonic probe based on the measurement result of the measuring unit; and

at least one of a probe control mechanism that controls a position and posture of the ultrasonic probe using the amount of control calculated by the control amount calculation unit and a guiding information presentation unit that presents information for guiding movement of the position and posture of the ultrasonic probe using the amount of control calculated by the control amount calculation unit.

2.-**16**. (canceled)

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摘要(译)

提供了一种不依赖于操作该装置的操作者的超声波诊断成像系统。该系统包括测量单元（坐标计算部分 2034 ），其使用关于由超声波探头获取的被检者的图像信息来测量超声波探头相对于被检者的相对位置和相对姿势，控制量计算单元（ 2035 ），其基于测量单元的测量结果和控制该控制单元的探针控制机构中的至少一个来计算超声波探头的位置和姿势的控制量。使用由控制量计算单元和引导信息呈现单元计算的控制量的超声波探头的位置和姿势，该引导信息呈现单元使用由控制量计算的控制量来呈现用于引导超声波探头的位置和姿势的移动的信息计算单位。