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(54) ULTRASOUND DIAGNOSTIC APPARATUS

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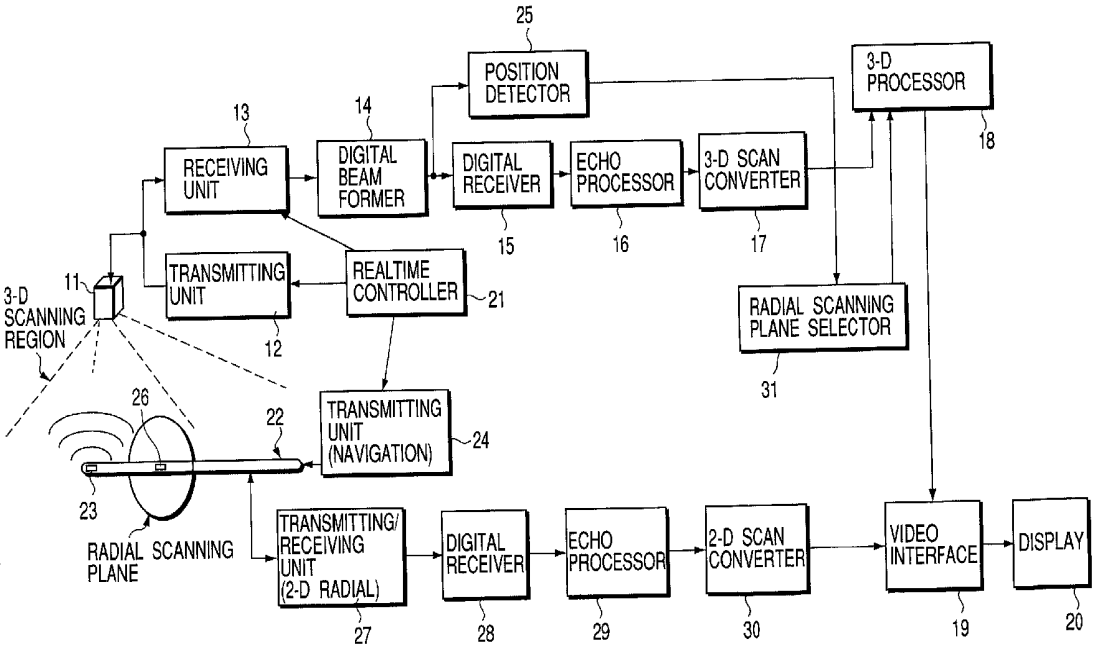
(57) **ABSTRACT**

An ultrasound diagnostic apparatus includes first and second probes. The inside of an object to be examined is scanned with a first ultrasound beam through the first probe to acquire first ultrasound image data associated with the object. The inside of the object is scanned with a second ultrasound beam through the second probe to acquire second ultrasound image data associated with the object. The second ultrasound image data is synthesized with the first ultrasound image data on the basis of the position of the first probe relative to the second probe, which is detected by a position detector.



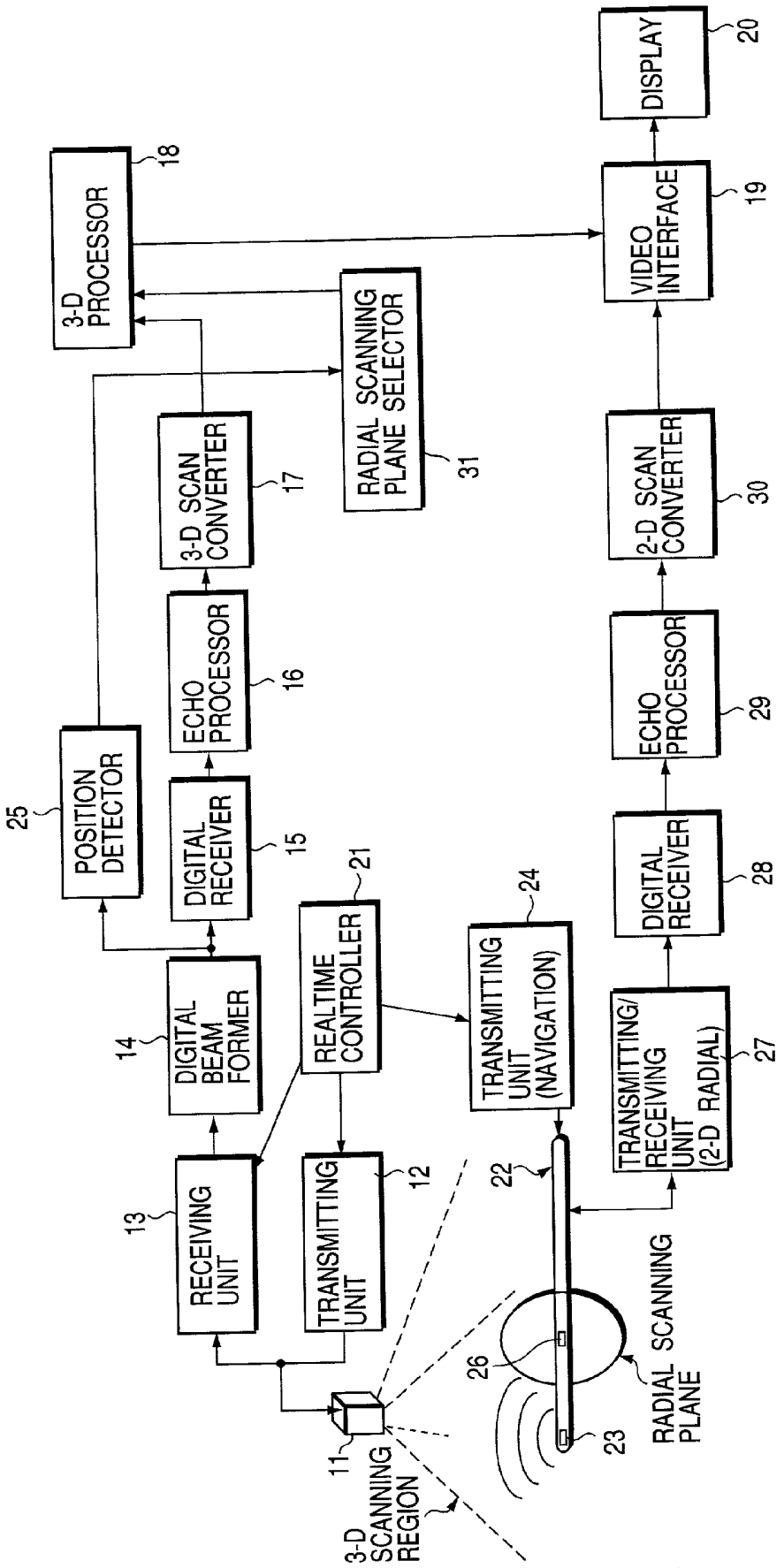

DISPLAY
20
VIDEO INTERFACE
19
3-D PROCESSOR
18
RADIAL SCANNING PLANE SELECTOR
31
3-D SCAN CONVERTER
17
2-D SCAN CONVERTER
30
ECHO PROCESSOR
16
ECHO PROCESSOR
29
POSITION DETECTOR
25
DIGITAL RECEIVER
15
DIGITAL RECEIVER
28
REALTIME CONTROLLER
21
TRANSMITTING UNIT (NAVIGATION)
24
DIGITAL BEAM FORMER
14
TRANSMITTING/ RECEIVING UNIT (2-D RADIAL)
27
RECEIVING UNIT
13
TRANSMITTING UNIT
12
22
26
23
RADIAL SCANNING PLANE
11
3-D SCANNING REGION

FIG. 1

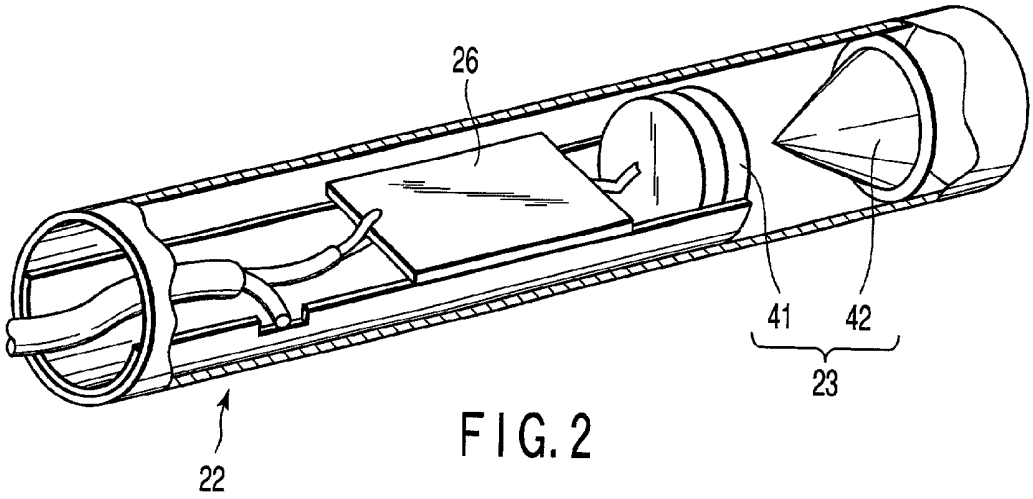


FIG. 2

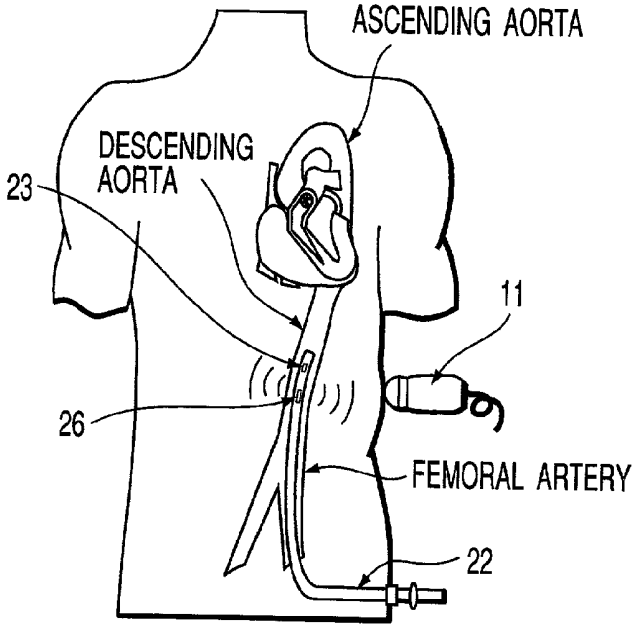


FIG. 3

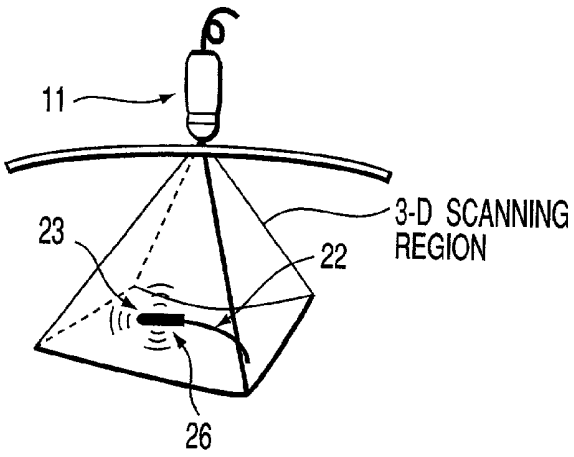


FIG. 4

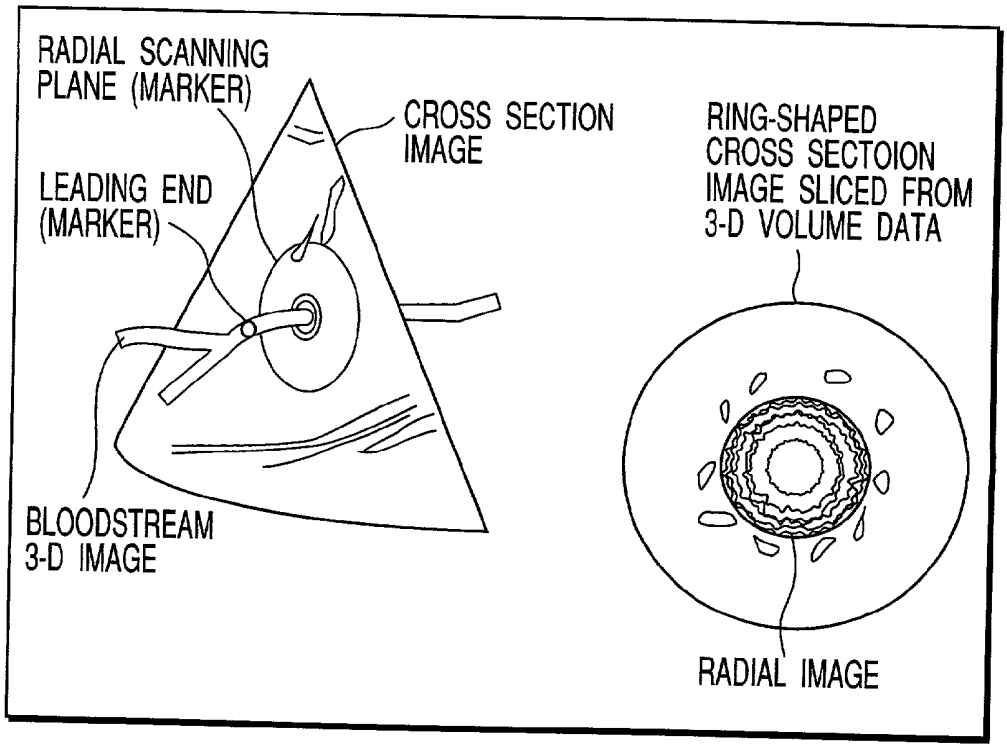


FIG. 5

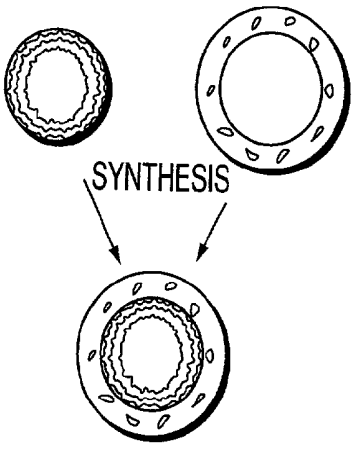


FIG. 6A

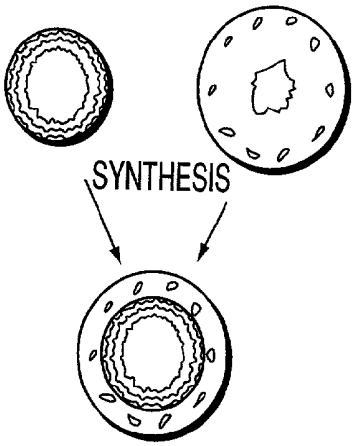


FIG. 6B

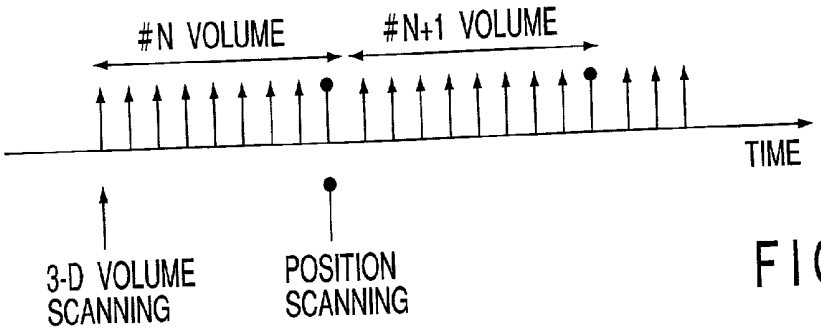


FIG. 7

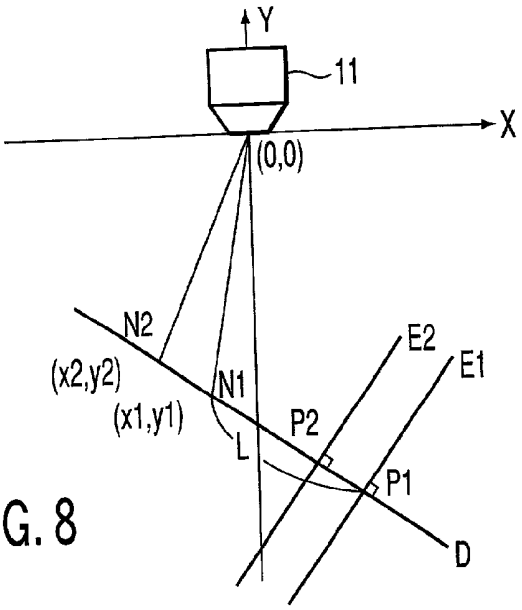


FIG. 8

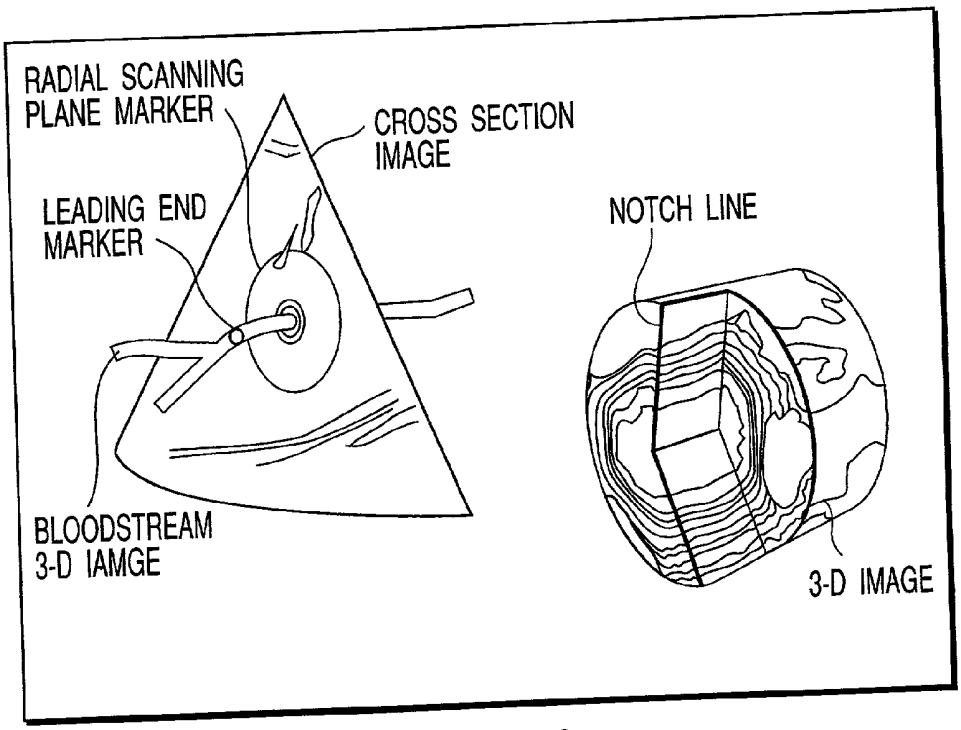
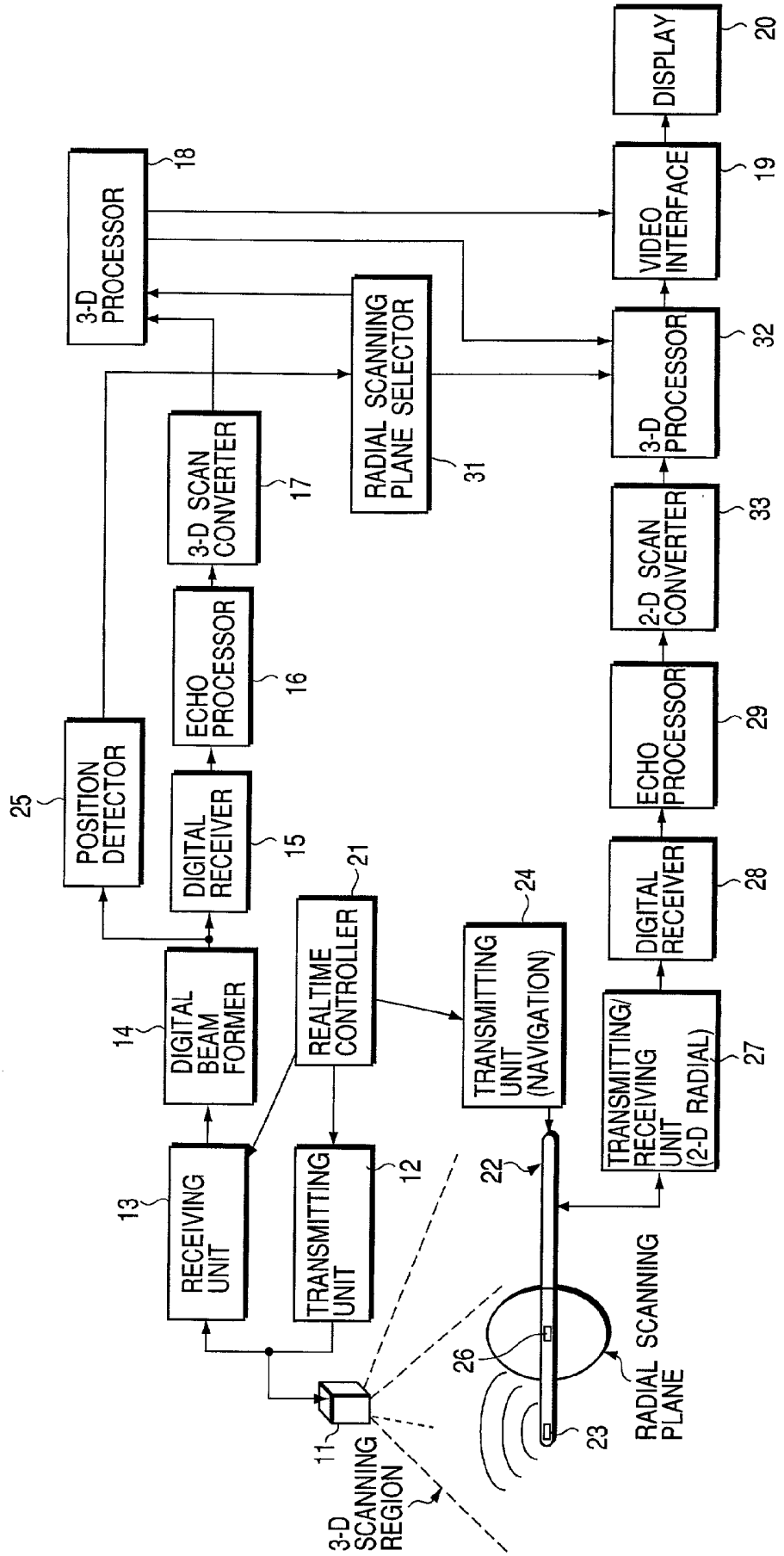


FIG. 10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POSITION DETECTOR
25
DIGITAL BEAM FORMER
14
REALTIME CONTROLLER
21
TRANSMITTING UNIT (NAVIGATION)
24
TRANSMITTING/ RECEIVING UNIT (2-D RADIAL)
27
RECEIVING UNIT
13
TRANSMITTING UNIT
12
22
26
23
RADIAL SCANNING PLANE
11
3-D SCANNING REGION

FIG. 9

ULTRASOUND DIAGNOSTIC APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is based upon and claims the benefit of priority from the prior Japanese Patent Application No. 2001-126242, filed Apr. 24, 2001, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to an ultrasound diagnostic apparatus equipped with an internal probe that can be inserted into a body cavity such as a blood vessel or bile duct.

[0004] 2. Description of the Related Art

[0005] Recently, operation of directly inserting an internal probe, for example a small diameter probe inserted into a human body cavity, e.g., a blood vessel or bile duct of a patient, diagnosing a lesion, stricture, and the degree of invasion of a cancer in a tube wall, and determining a surgical operation plan and postoperative therapeutic effect has been done, together with various medical treatments such as TAE (Transcatheter Arterial Embolization), PTCA (Percutaneous Transluminal Coronary Angioplasty), and PTCR (Percutaneous Transluminal Coronary Recanalization). An operator must therefore comprehend the entrance position of a catheter or internal probe and check whether the distal end portion has reached a region to be diagnosed or treated.

[0006] Conventionally, a region which a catheter or internal probe enters is imaged by using an X-ray fluoroscopic apparatus, and the operator monitors the position of the distal end of the catheter or internal probe while watching the X-ray image displayed on a monitor. In monitoring by X-ray fluoroscopy, however, the operator is inevitably exposed to X-rays as well as the patient.

[0007] For this reason, a method of checking the position of the distal end of a catheter or internal probe by using an ultrasound diagnostic apparatus instead of an X-ray fluoroscopic apparatus has been proposed. The ultrasound diagnostic apparatus is designed to apply ultrasound beams from the body surface to the inside of the body using an external probe, receive an echo signal reflected by a region where acoustic impedance varies, and reconstruct an image. A catheter or internal probe has a smooth surface and is bent inside the body in general. For this reason, ultrasound beams incident from the body surface are regularly reflected by the surface of the catheter or internal probe, and do not return to the body surface probe in many instances. This makes it very difficult to detect a position and form an image. Under the circumstances, a method is disclosed in Jpn. Pat. Appln. KOKAI Publication No. 4-129543, in which a transducer is mounted on the distal end of a catheter or internal probe, and position information is obtained by receiving the ultrasound beam transmitted from an external probe.

[0008] A conventional ultrasound diagnostic apparatus is generally designed as a system to reconstruct and display a cross section image by performing scanning within a plane by transmitting ultrasound beams from a one-dimensional array ultrasound transducer. For this reason, attempts have been actively made to obtain 3-D information by acquiring diagnostic images while moving a probe as an ultrasound beam transmitting/receiving unit, and new diagnostic possibility is expected from display of a 3-D image in an ultrasound diagnostic apparatus. In practice, researches have been made by, for example, manually or mechanically moving an abdominal convex probe or linear array probe and using a transesophageal multi-plane probe having a mechanism of rotating an electronic sector probe. However, it takes a considerably long period of time to obtain 3-D information by using the above technique, as compared with the conventional cross section image scanning technique. Hence, movement information cannot be obtained from a target that moves quickly, such as the heart. In addition, if a probe cannot be satisfactorily fixed, even an image of an abdominal portion, which does not move so quickly as the heart, greatly deforms.

[0009] Under the circumstances, a 3-D ultrasound diagnostic apparatus is under study, which includes an ultrasound probe having 2-D phased array ultrasound transducers and a function of stereoscopically scanning an ultrasound beam, and can scan and display a 3-D volume image with a corresponding frame.

[0010] Conventionally, importance is attached to the resolution of images in an intravascular ultrasound (IVUS) apparatus/intraductal ultrasound (IDUS) apparatus/endoscopic ultrasonography (EUS) apparatus having a internal probe. However, the walls of a blood vessel and body cavity cannot be observed sufficiently deep because of lack of penetration.

BRIEF SUMMARY OF THE INVENTION

[0011] It is an object of the present invention to solve the problem associated with the lack of penetration of an ultrasound diagnostic apparatus using an internal probe.

[0012] An ultrasound diagnostic apparatus according to the present invention includes first and second probes. The inside of an object to be examined is scanned with a first ultrasound beam through the first probe to acquire first ultrasound image data associated with the object. The inside of the object is scanned with a second ultrasound beam through the second probe to acquire second ultrasound image data associated with the object. The second ultrasound image data is synthesized with the first ultrasound image data on the basis of the position of the first probe relative to the second probe, which is detected by a position detector.

[0013] Additional objects and advantages of the present invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the present invention. The objects and advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out hereinafter.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0014] The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the present invention and, together with the

general description given above and the detailed description of the embodiments given below, serve to explain the principles of the present invention.

[0015] **FIG. 1** is a block diagram showing the arrangement of a small-diameter ultrasound diagnostic apparatus according to an embodiment of the present invention;

[0016] **FIG. 2** is a perspective view showing the internal structure of a internal probe in **FIG. 1**;

[0017] **FIG. 3** is a schematic view showing an example of how the internal probe and an external probe in **FIG. 1** are used;

[0018] **FIG. 4** is a view showing a scanning region for the external probe in **FIG. 1**;

[0019] **FIG. 5** is a view showing a display example of a display in **FIG. 1**;

[0020] **FIG. 6A** is a view showing the first method of synthesizing a radial image with an image sliced from volume data;

[0021] **FIG. 6B** is a view showing the second method of synthesizing a radial image with an image sliced from volume data;

[0022] **FIG. 7** is a view showing a sequence of 3-D volume scanning and position scanning;

[0023] **FIG. 8** is a view for explaining a method of computing the position and direction of the internal probe relative to the external probe by using a position detector in **FIG. 1**;

[0024] **FIG. 9** is a bock diagram showing another example of the arrangement of the internal probe type ultrasound diagnostic apparatus according to the embodiment of the present invention; and

[0025] **FIG. 10** is a view showing a display example of a display corresponding to the arrangement shown in **FIG. 9**.

DETAILED DESCRIPTION OF THE INVENTION

[0026] First Embodiment

[0027] The present invention relates to an ultrasound diagnostic apparatus with an internal probe. There are an ultrasound catheter for the blood vessel to use for IVUS (Intravascular Ultrasound), a small-diameter ultrasound probe for the intradermal duct such as a bile duct and a pancreatic duct to use for IDUS (Intraductal Ultrasound), an ultrasound endoscope to use for a cervical esophagus inspection and so on in the internal probe. It is named as a internal probe including the ultrasound catheter for the blood vessel and the small-diameter ultrasound probe for the intradermal duct.

[0028] A internal probe is designed to improve resolution using high frequencies at the sacrifice of penetration (depth of field). The field of view of the internal probe is therefore very narrow. The lack of penetration of the internal probe is compensated by the intracorporeal tissue form information acquired through the external probe placed on the body surface.

[0029] **FIG. 1** shows the arrangement of an ultrasound diagnostic apparatus with a internal probe according to an embodiment of the present invention. This apparatus includes a navigation portion (position detecting unit) for detecting the position of the distal end portion of a internal probe, an external realtime 3-D ultrasound visualizing portion, and an image synthesizing portion as characteristic features in addition to the basic functional portion of the internal probe type ultrasound diagnostic apparatus, i.e., a radial 2-D scanning portion for acquiring a circular tissue form image (to be simply referred to as a radial image hereinafter) by radially (circularly) scanning around the probe through a small transducer (micro-transducer) **26** for 2-D imaging which is mounted in the distal end portion of the internal probe.

[0030] (Radial 2-D Scanning Portion)

[0031] The small transducer **26** for 2-D imaging is placed near the distal end of a internal probe (first ultrasound probe) **22**, and more specifically, behind a navigation transducer **23** at a predetermined distance therefrom. The radial 2-D scanning portion is a unit which is typically designed to obtain a radial 2-D image representing a tissue form by scanning around the probe with a transmitting/receiving unit **27** through the transducer **26** while mechanically and axially rotating the transducer **26**. Note that as the center frequency of ultrasound waves for radial 2-D scanning, a frequency is selected from the band of 20 to 50 MHz to obtain relatively high resolution. As the center frequency of ultrasound waves for 3-D scanning by an external probe (second ultrasound probe), a frequency is selected from the band of 1 to 10 MHz to obtain relatively deep penetration. The difference between these center frequencies makes it possible to concurrently execute 3-D scanning and 2-D scanning.

[0032] The ultrasound wave generated by the mechanical vibration of the transducer **26** on the basis of a driving signal (high-frequency voltage signal) propagates through an object to be examined, is reflected by a discontinuous surface of acoustic impedance on the way, and returns as an echo to the transducer **26**. This echo mechanically vibrates the transducer **26**. A weak electrical signal generated by this vibration is amplified by the preamplifier of the transmitting/receiving unit **27** and digitized. The resultant data is subjected to quadrature detection in a digital receiver **28**, and is also subjected to envelope detection in an echo processor **29**. The ultrasound vector data generated by this operation is converted into circular pixel data by a 2-D scan converter **30**. This data is then sent to a video interface **19**.

[0033] (Navigation Portion)

[0034] This apparatus is equipped with a navigation portion to detect the position of the distal end of the internal probe **22**. As shown in **FIG. 2**, the transducer **23** for navigation is mounted at the distal end of the internal probe **22**. A transmitting unit **24** applies a driving signal to the navigation ultrasound wave source **23** in synchronism with the navigation pulse generation signal generated by the realtime controller **21**. With this operation, an nondirectional ultrasound pulse is generated from the navigation ultrasound wave source **23**. Note that the center frequency of this nondirectional ultrasound pulse is set to a frequency equal or approximate to that of ultrasound waves from an external probe **11** to allow the external probe **11** to detect this nondirectional ultrasound pulse with high sensitivity.

[0035] **FIG. 2** shows the internal structure of the internal probe **22**. A conical reflector **42** is placed in a reversed state

inside the distal end portion of the internal probe **22**. A transducer **41** is placed to squarely face the reflector **42**. The ultrasound wave generated by this transducer **41** is reflected in all directions by the conical reflector **42**.

[**0036**] This nondirectional ultrasound pulse propagates in the object to be examined and is received by the external probe **11**. A position detector **25** estimates the position of the navigation ultrasound wave source **23**, i.e., the position of the distal end of the internal probe **22**, on the basis of the reception signal. Obviously, this position is the position of the distal end of the internal probe **22** relative to the external probe **11**, and is expressed in a coordinate system unique to the external probe **11** or the XYZ coordinate system with the center of the external probe **11** being set as the origin.

[**0037**] Typical position estimating methods are the GPS scheme and maximum energy pulse detecting scheme. This scheme can use either of these schemes or may selectively use both of them. Alternatively, the two schemes are simultaneously used, and the final position may be determined from the two results (estimated positions).

[**0038**] a) GPS Scheme

[**0039**] The position of the navigation ultrasound wave source **23** seen from the center point of the external probe **11** is estimated by triangulation on the basis of the intensity ratios among three reception signals of navigation ultrasound pulses received at three discrete points on the array surface of the external probe **11**, i.e., three discrete transducers or three discrete groups each constituted by a predetermined number of transducers. Theoretically, a position can be estimated by one reception. If, however, the S/N ratio is low, transmission/reception and position estimation may be repeated several times to determine the barycentric position of a plurality of estimated positions as the final position.

[**0040**] b) Maximum Energy Pulse Detection Scheme

[**0041**] The navigation ultrasound pulse received by the external probe **11** is beam-formed in many directions by a digital beam former **14**, and the position detector **25** extracts the position of a point on the beam, of these beams, at which the maximum energy (maximum wave height) is obtained. That is, the maximum energy point obtained by scanning the overall volume is the position of the navigation ultrasound pulse source, i.e., the position of the navigation ultrasound wave source **23**. This scheme attains a high S/N ratio as compared with the GPS scheme described above. However, since beam forming processing is repeatedly executed in many directions, a long period of time is required for estimation.

[**0042**] (External Realtime 3-D Ultrasound Visualizing Portion)

[**0043**] The realtime 3-D external probe **11** is a probe of a type that is brought into contact with the body surface of an object to be examined, as shown in **FIG. 3**, unlike the internal probe **22** inserted into the object. The external probe **11** has a plurality of two-dimensionally arranged transducers to scan a 3-D region inside the object with an ultrasound beam at high speed. A transmitting unit **12** is connected to the external probe **11** at the time of transmission. A receiving unit **13** is connected to the external probe **11** at the time of reception. The transmitting unit **12** has pulsers, transmission delay circuits, and pulse generators respectively connected to a plurality of transducers. Each pulser applies a driving signal (high-frequency voltage signal) to a corresponding transducer in response to a pulse signal, as a trigger, which is generated from a corresponding pulse generator at a predetermined period and delayed by the transmission delay circuit to beam-form an ultrasound sound and give directivity. As the center frequency of this ultrasound wave, for example, a frequency in the band of 1 to 10 MHz, preferably 2.5 MHz or nearby frequency, is selected to obtain relatively deep penetration. The thickness of the piezoelectric element of each transducer is designed accordingly.

[**0044**] The ultrasound wave generated by the mechanical vibration of the transducer **26** to which a driving signal is applied propagates through an object to be examined, is reflected by a discontinuous surface of acoustic impedance on the way, and returns as an echo to the probe **11**. This echo mechanically vibrates the transducers of the probe **11**. A weak electrical signal generated by the vibration is amplified by the preamplifier of the receiving unit **13** and digitized. The resultant data is then subjected to phased addition processing in the digital beam former **14**. As a consequence, a reception signal with directivity is generated. As shown in **FIG. 4**, the transmitting unit **12** and receiving unit **13** change the directivities of transmission and reception for each transmission/reception under the control of the realtime controller **21**, thereby scanning a 3-D region in the object with an ultrasound beam. In actual examination, the position of the external probe **11** is adjusted such that a portion near the distal end of the internal probe **22** is included in this 3-D scanning range.

[**0045**] The reception signal generated by the receiving unit **13** is subjected to quadrature detection in a digital receiver **15** and supplied to an echo processor **16**. The echo processor **16** performs envelope detection of the reception signal to generate data representing a tissue form. The echo processor **16** also generates bloodstream data from the reception signal through MTI filtering and autocorrelation processing. The bloodstream data contains movement velocity information of bloodstreams and/or power information of bloodstreams. The tissue form data form and The bloodstream data are converted into the volume data of the 3-D region by a 3-D scan converter **17**. This data is supplied to a 3-D processor **18**.

[**0046**] A radial scanning plane selector **31** calculates the central position and direction of a radial scanning plane on the basis of the axial direction of the internal probe **22** which is specified by the position of the navigation ultrasound wave source **23** detected by the position detector **25** and the axial direction of the internal probe **22** and the temporal displacement of the position, i.e., the traveling direction of the internal probe **22**. The radial scanning plane selector **31** then outputs the position and direction data to the 3-D processor **18**. The central position of the radial scanning plane is apart from the position of the navigation ultrasound wave source **23**, which is detected by the position detector **25**, in a direction opposite to the traveling direction by a predetermined distance, i.e., the physical distance between the navigation ultrasound wave source **23** and the transducer **26**. The radial scanning plane is perpendicular to the traveling direction with respect to the position of the navigation ultrasound wave source **23**.

[0047] The 3-D processor **18** reconstructs image data (to be referred to as cross-sectional conversion image data) typically associated with a ring-shaped cross section corresponding to the position and direction of the radial scanning plane. This reconstructed image data is sent to the video interface **19** to be synthesized with radial image data into one frame, which is displayed on the display **20**.

[0048] The bloodstream data generated by the echo processor **16** is converted into bloodstream 3-D image data by the 3-D processor **18** using a technique such as volume rendering and surface rendering. The 3-D processor **18** adds a marker indicating the position of the navigation ultrasound wave source **23** to this bloodstream 3-D image data in accordance with the position where it is detected.

[0049] (Image Synthesizing Portion)

[0050] As described above, the video interface **19** synthesizes the radial image from the 2-D scan converter **30** and the ring-shaped image data (cross-sectional conversion image data) representing the tissue form on a cross section flush with the radial scanning plane from the 3-D processor **18**, and forms the display window shown in **FIG. 5**, together with the bloodstream 3-D image data from the 3-D processor **18**.

[0051] For example, the bloodstream 3-D image is displayed in the left region in the display window. The cross-sectional conversion image data of the radial scanning plane acquired through the external probe **11**, a circular marker representing the radial scanning plane, and a marker indicating the position of the navigation ultrasound wave source **23** of the internal probe **22** are synthesized with this bloodstream 3-D image.

[0052] In addition, in the right region in the display window, the radial image representing the tissue form obtained through the 2-D imaging transducer **26** of the internal probe **22** is displayed. the cross-sectional conversion image data reconstructed by the 3-D processor **18** is synthesized with this radial image to compensate for the lack of penetration. Thereby the image that the ultrasound image by the internal probe **22** is superimposed on the ultrasound image by the external probe **11** is obtained.

[0053] The cross-sectional conversion image to be synthesized with this radial image may be a ring-shaped range in contact with the outer circumference of the radial scanning plane of the internal probe **22** as shown in **FIG. 6A** or a range which includes the radial scanning surface of the internal probe **22** is concentric therewith as shown in **FIG. 6B**. The operator can arbitrarily select one of them.

[0054] By synthesizing the radial image of the internal probe **22** with the form image (cross-sectional conversion image) acquired from a surrounding image through the external probe **11** in this manner, the lack of penetration of the internal probe **22** can be compensated to allow the operator to see a sufficiently deep portion in a blood vessel wall.

[0055] **FIG. 7** shows a sequence of 3-D volume scanning by the external probe **11** and position scanning, in which an nondirectional ultrasound wave is transmitted from the transducer **23** and is received by the external probe **11** to detect the position of the source **23** of the internal probe **22** (the position of the distal end of the catheter), in this embodiment. As described above, since ultrasound waves in the same frequency band are used in these operations, the operations must be performed time-divisionally. In this case, position scanning is executed once every time volume scanning is repeated a predetermined number of times, e.g., eight times.

[0056] **FIG. 8** is a view for explaining detection of the position of the transducer **23** of the internal probe **22** (the position of the distal end of the catheter) by the position detector **25**. The central position of the external realtime 3-D ultrasound probe **11** is set as the origin (**0**, **0**) on the X- and Y-axes. Let N**1** be the position (x**1**, y**1**) of the navigation ultrasound wave source **23** mounted on the distal end of the catheter at time t1, P**1** be the position of the radial scanning transducer **26** mounted at the central portion of the catheter at time t1, L be the fixed distance between the navigation ultrasound wave source **23** and the radial scanning transducer **26**, N**2** be the position (x**2**, y**2**) of the position of the navigation ultrasound wave source **23** at time t2 after the lapse of a position scanning period from time t1, and P**2** be the position of the radial scanning transducer **26**. The catheter therefore travels from N**1** to N**2** (from P**1** to P**2**). Letting D be a line connecting N**1** and N**2** (P**1** and P**2**), a line E**1** perpendicular to the line D corresponds to a plane in which a cross section (radial scanning plane) of the image obtained by the radial scanning transducer **26** of the catheter is contained. Likewise, let E**2** be a cross section after a given period of time.

[0057] Information on the cross sections E**1** and E**2** must be sliced from the volume data acquired by the external realtime 3-D probe **11**, and the position and direction of each cross section are computed by the radial scanning plane selector **31** in **FIG. 1**. The computation result or volume data on the corresponding cross section represented by the computation result is sent to the video interface **19**.

[0058] An example of the computation method will be described below.

[0059] The slope of the straight line D is given by (y**2**−y**1**)/(x**2**, x**1**). The slopes of the straight lines E**1** and E**2** are perpendicular to the straight line D, and hence are given by (x**2**−x**1**)/(y**2**−y**1**).

[0060] If the straight line E**2** is given by

$$y - \frac{x_2 - x_1}{y_2 - y_1} x + b$$

[0061] since the straight line E**2** passes through the point P**2**, the coordinates of the point P**2** are given by

$$\left(x_2 + \frac{(x_2 - x_1)L}{\sqrt{(y_2 - y_1)^2 + (x_2 - x_1)^2}}, y_2 + \frac{(y_2 - y_1)L}{\sqrt{(y_2 - y_1)^2 + (x_2 - x_1)^2}} \right)$$

[0062] In addition, according to

$$b = -\frac{x_2 - x_1}{y_2 - y_1} \cdot \left(x_2 + \frac{(x_2 - x_1)L}{\sqrt{(y_2 - y_1)^2 + (x_2 - x_1)^2}} \right) + y^2 + \frac{(y_2 - y_1)L}{\sqrt{(y_2 - y_1)^2 + (x_2 - x_1)^2}}$$

[0063] the straight line E2 is expressed by

$$y = \frac{x_2 - x_1}{y_2 - y_1} x - \frac{x_2 - x_1}{y_2 - y_1} \cdot \left(x_2 + \frac{(x_2 - x_1)L}{\sqrt{(y_2 - y_1)^2 + (x_2 - x_1)^2}} \right) + y^2 + \frac{(y_2 - y_1)L}{\sqrt{(y_2 - y_1)^2 + (x_2 - x_1)^2}}$$

[0064] According to this relational expression, position data on the straight line E2 can be read.

[0065] According to this embodiment, as described above, the radial image obtained by the internal probe **22** is synthesized with a surrounding image sliced from the 3-D volume data acquired through the external probe **11**. This compensates for the lack of penetration of the internal probe **22** and allows the operator to see a sufficiently deep portion of a blood vessel wall.

[0066] Second Embodiment

[0067] In the second embodiment, cylindrical 3-D volume data is generated from the radial image acquired by a internal probe **22**, and the data acquired by an external realtime 3-D probe **11** is synthesized with the outer circumference of this cylindrical region. The 3-D volume data of a large cylindrical region can be generated by synthesizing the data acquired by the internal probe **22** and the data acquired by the external probe **11**.

[0068] **FIG. 9** shows an arrangement of this embodiment. **FIG. 10** shows a display example. A 3-D processor **32** has a 3-D volume memory and generates cylindrical 3-D volume data by writing the data output from a 2-D scan converter **29** and 3-D processor **18** in this 3-D volume memory.

[0069] More specifically, the 2-D scan converter **29** and a radial scanning plane selector **31** respectively send a radial image and the position information of a cross section to the 3-D processor **18**. The 3-D processor **18** slices the data of the cross section from the 3-D volume data obtained by the external probe **11**, and sends the data to the 3-D processor **32**. The 3-D processor **32** writes the data of the radial image at an address corresponding to the position of the cross section in the 3-D volume memory. At this time, the 3-D processor **32** writes the data sent from the 3-D processor **18** in the outer circumference of the radial image. With this operation, the circular data obtained by synthesizing the data, acquired by the external probe **11**, with the outer circumference of the radial image is written in the 3-D volume memory.

[0070] This operation is performed for each frame sequentially output from the 2-D scan converter **29**. With this operation, the above synthesized circular data are sequentially written at the positions of the corresponding cross sections, thereby generating the 3-D volume data of a cylindrical ultrasound image.

[0071] The 3-D processor **32** obtains a 3-D image to be displayed from the above cylindrical 3-D volume data by performing processing such as volume rendering and surface rendering. In this case, it is preferable that an arbitrary portion of the cylindrical 3-D volume data be cut away to allow observation of the state of the inside of the cylinder.

[0072] This display image is sent from the 3-D processor **32** to a video interface **19** to be synthesized with the surface image data originated from the external probe and generated by the 3-D processor **18**.

[0073] **FIG. 10** shows an example of the image displayed on a display monitor **20** at this time. The image obtained by synthesizing the cross section image corresponding to a radial scanning plane, generated on the basis of the data acquired from the external probe **11**, a bloodstream 3-D image, a circular maker indicating the radial scanning plane, and a marker indicating the position of a navigation transducer **23** of the internal probe **22** is displayed on, for example, the left area on the display screen.

[0074] In addition, the image obtained by synthesizing the cylindrical 3-D form image data acquired by the external probe **11** with the outer circumference of the cylindrical 3-D radial image data representing a tissue form, acquired by a 2-D imaging transducer **26** of the internal probe **22** is displayed on the right area on the display screen. The 3-D image obtained by cutting away a portion of this cylindrical 3-D form image data is displayed.

[0075] With this operation, high-resolution 3-D image data is obtained by the internal probe **22** to allow proper observation of the state of the tissue. The lack of penetration of the internal probe **22** is compensated by the data obtained by the external probe **11** to generate 3-D image data in a wide range, thereby allowing the operator to properly grasp the relationship between the tissue positions. In addition, since the 3-D image obtained by cutting away an arbitrary portion of this 3-D image data can be displayed, the operator can properly observe a desired portion inside a blood vessel by changing this cut portion.

[0076] As described above, an image originated from the external probe may be synthesized with an image originated from the internal probe on three dimensions, and the resultant image may be displayed.

[0077] Note that the present invention is not limited to the above embodiment, and can be variously modified and practiced within the sprit and scope of the invention. The above embodiments include inventions of various stages, and various inventions can be extracted by proper combinations of a plurality of disclosed constituent elements. For example, several constituent elements can be omitted from the all the constituent elements in the embodiment.

[0078] Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be

made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

What is claimed is:

1. An ultrasound diagnostic apparatus comprising:

a first probe;

a second probe;

a first transmitter/receiver configured to scan the inside of an object to be examined with a first ultrasound beam through said first probe to acquire first ultrasound image data associated with the object;

a second transmitter/receiver configured to scan the inside of the object with a second ultrasound beam through said second probe to acquire second ultrasound image data associated with the object;

a position detector configured to detect a position of said first probe relative to said second probe;

an image processor configured to synthesize the second ultrasound image data with the first ultrasound image data on the basis of the detected position to generate a synthetic image data; and

a display configured to display an image on the basis of the synthetic image data.

2. An apparatus according to claim 1, wherein said first probe is placed inside the object, and said second probe is placed outside the object.

3. An apparatus according to claim 1, wherein said first probe is of a radial scanning type, and said second probe is of a 3-D scanning type.

4. An apparatus according to claim 1, wherein said second transmitter/receiver scans a 3-D region inside the object through said second probe to acquire volume data.

5. An apparatus according to claim 4, wherein said image processor generates cross section image data of a cross section corresponding to the position of said first probe from the volume data, and synthesizes the cross section image data with the first ultrasound image data.

6. An apparatus according to claim 1, wherein said image processor superimposes the first ultrasound image data on the second ultrasound image data upon position matching on the basis of the detected position.

7. An apparatus according to claim 1, wherein said image processor generates image data of a cross section corresponding to the detected position from the second ultrasound image data.

8. An apparatus according to claim 1, wherein a center frequency of the first ultrasound beam differs from a center frequency of the second ultrasound beam.

9. An apparatus according to claim 1, wherein a center frequency of the first ultrasound beam is higher than a center frequency of the second ultrasound beam.

10. An apparatus according to claim 1, wherein scanning of the first ultrasound beam is executed concurrently with scanning of the second ultrasound beam.

11. An apparatus according to claim 1, wherein said position detector includes an nondirectional vibrator mounted on said first probe, and a position calculator which calculates the position of said first probe on the basis of a reception signal transmitted from said nondirectional vibrator and received by said second probe.

12. An apparatus according to claim 11, wherein said position calculator calculates a traveling direction of said first probe on the basis of a change in the position of said first probe.

13. An apparatus according to claim 1, wherein a center frequency of an nondirectional ultrasound wave transmitted from said nondirectional vibrator is substantially equal to a center frequency of the second ultrasound beam transmitted from said second probe.

14. An apparatus according to claim 1, further comprising a unit configured to acquire volume data associated with a bloodstream inside the object through said second probe, and a unit configured to generate 3-D image data associated with a bloodstream from the volume data.

15. An apparatus according to claim 14, wherein said display unit displays the synthesized ultrasound image data, together with the 3-D image data.

16. An apparatus according to claim 15, wherein a marker representing the position of said first probe is displayed together with the 3-D image data.

17. An ultrasound diagnostic apparatus comprising:

a internal probe which is inserted into the body of an object to be examined;

an external probe which is brought into contact with a body surface of the object;

a unit configured to acquire radial cross section image data by radial scanning around said internal probe with the first ultrasound through said internal probe;

a unit configured to acquire volume data by scanning a 3-D region inside the object with the second ultrasound beam through said external probe;

an image processor configured to generate cross section image data of a cross section corresponding to the position of said internal probe from the volume data and performing synthesis of the cross section image data with the radial cross section image data; and

a display configured to display an image on the basis of the image data obtained by the synthesis.

18. An apparatus according to claim 17, wherein said image processor generates cross section image data associated with a ring-shaped cross section from the volume data.

19. An apparatus according to claim 17, wherein said image processor generates cross section image data associated with a circular cross section from the volume data.

20. An apparatus according to claim 17, further comprising a position detector configured to detect a position of said internal probe relative to said external probe.

21. An apparatus according to claim 20, wherein said position detector includes an nondirectional vibrator mounted on said internal probe, and a unit which calculates the position of said internal probe on the basis of a reception signal transmitted from said nondirectional vibrator and received by said external probe.

22. An ultrasound diagnostic apparatus comprising:

a plurality of ultrasound probes;

a transmitter/receiver configured to scan the inside of an object to be examined with said plurality of probes so as to acquire a plurality of ultrasound images corresponding to said plurality of probes;

an image processor configured to synthesize the plurality of ultrasound images to generate a synthetic image data; and

a display configured to display an image on the basis of the synthetic image data.

23. An image generating method for an ultrasound diagnosis comprising:

generating first ultrasound image data on the basis of outputs of an internal probe;

generating second ultrasound image data on the basis of outputs of an external probe;

detecting a position of said internal probe relative to said external probe; and

synthesizing the second ultrasound image data with the first ultrasound image data on the basis of the detected position to generate a display image data.

24. A method according to claim 23, wherein the display image data is generated from 3-D volume data formed by a composition with the first ultrasound image and the second ultrasound image.

* * * * *

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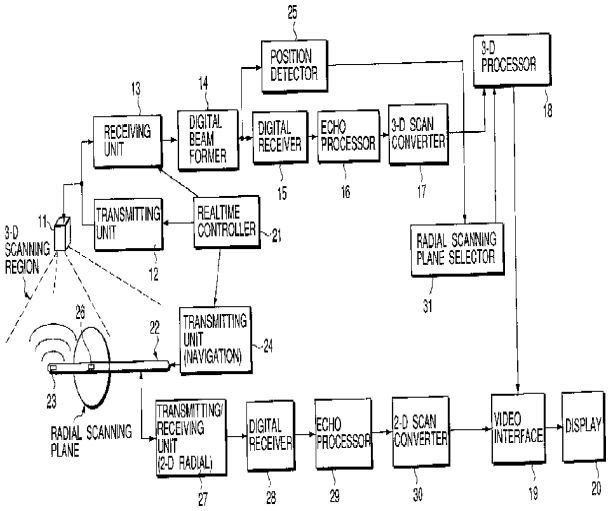
超声诊断设备包括第一和第二探针。利用第一超声波束通过第一探头扫描待检查对象的内部，以获取与该对象相关联的第一超声图像数据。利用第二超声波束通过第二探头扫描物体的内部，以获取与物体相关联的第二超声图像数据。基于第一探针相对于第二探针的位置，利用第一超声图像数据合成第二超声图像数据，其由位置检测器检测。