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(54) ULTRASOUND IMAGING APPARATUS

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(52) **U.S. Cl.** **600/443**

(57) **ABSTRACT**

Ultrasound is sent and reflected waves are received, and an image is generated based on the reflected waves. Then, each umbilical cord present in the image is respectively specified, and the respective structures continuing into one end of the specified umbilical cords are specified. Each specified structure is identified and displayed on a monitor by color separation, screen division, display switching, etc.

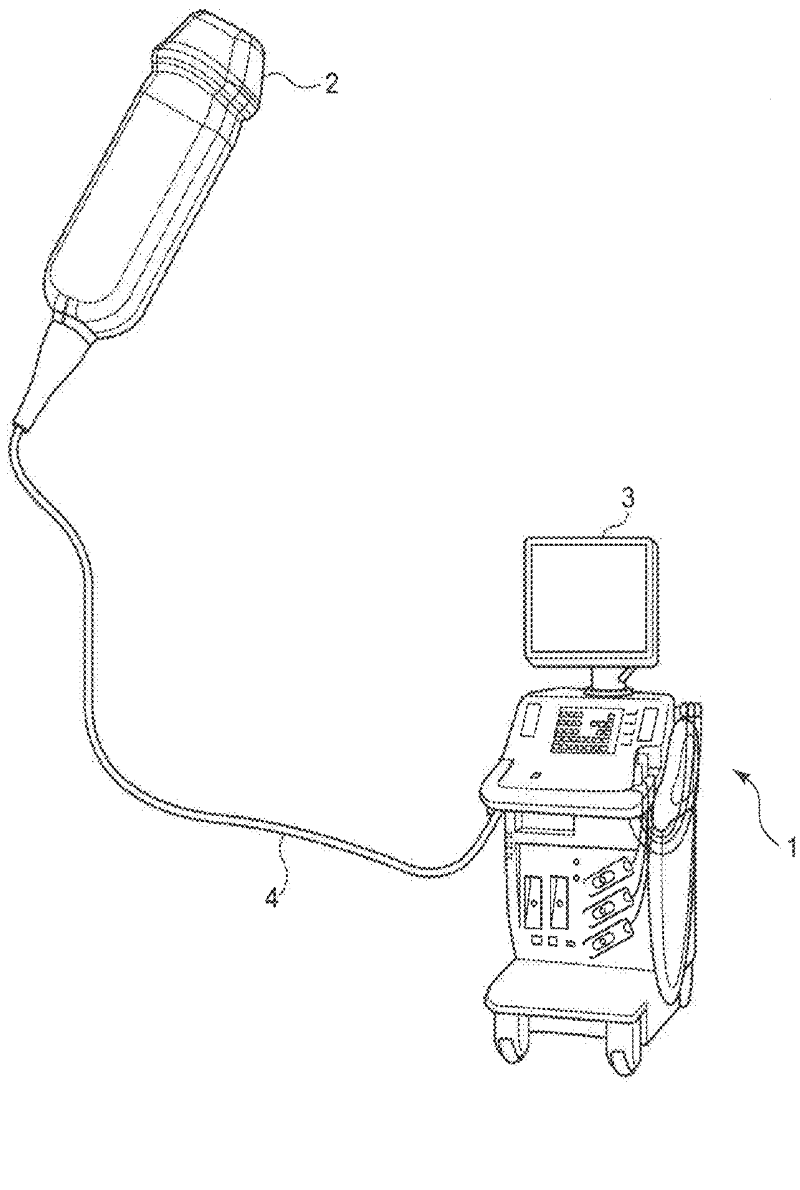


FIG. 1

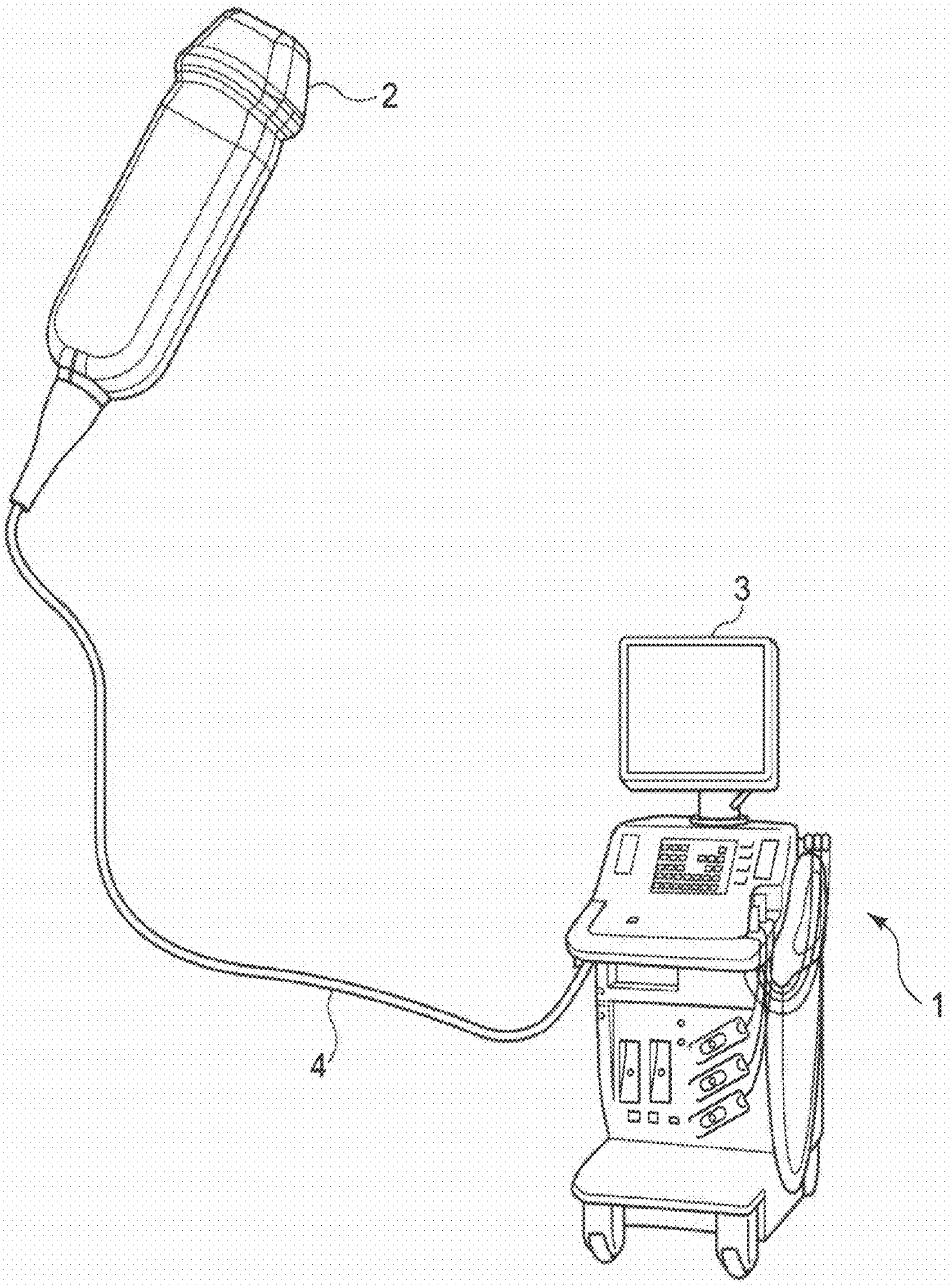


FIG. 2

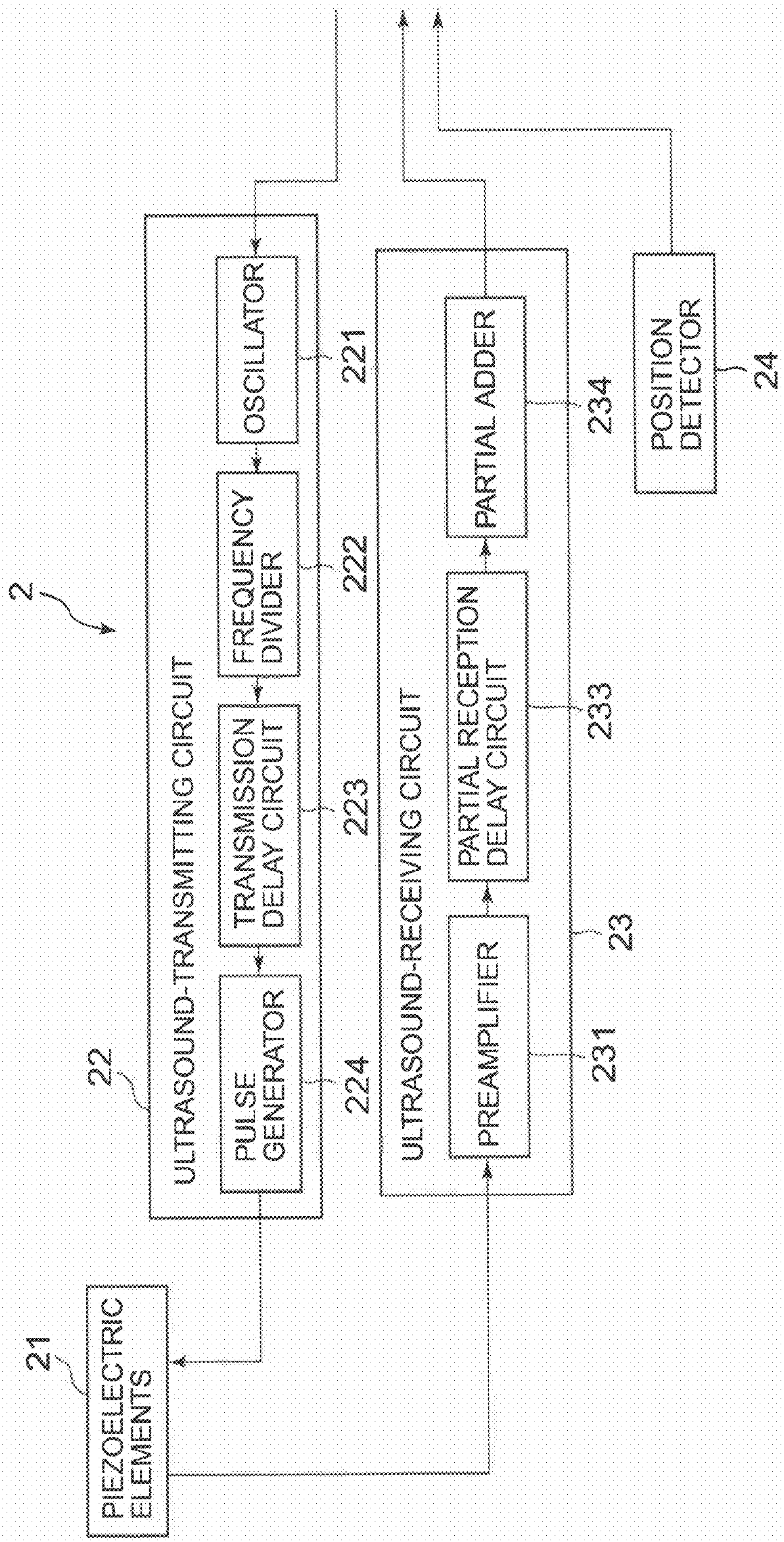

2
22
ULTRASOUND-TRANSMITTING CIRCUIT
OSCILLATOR
221
FREQUENCY DIVIDER
222
TRANSMISSION DELAY CIRCUIT
223
PULSE GENERATOR
224
ULTRASOUND-RECEIVING CIRCUIT
PARTIAL ADDER
234
PARTIAL RECEPTION DELAY CIRCUIT
233
PREAMPLIFIER
231
23
POSITION DETECTOR
24
PIEZOELECTRIC ELEMENTS
21

FIG. 3

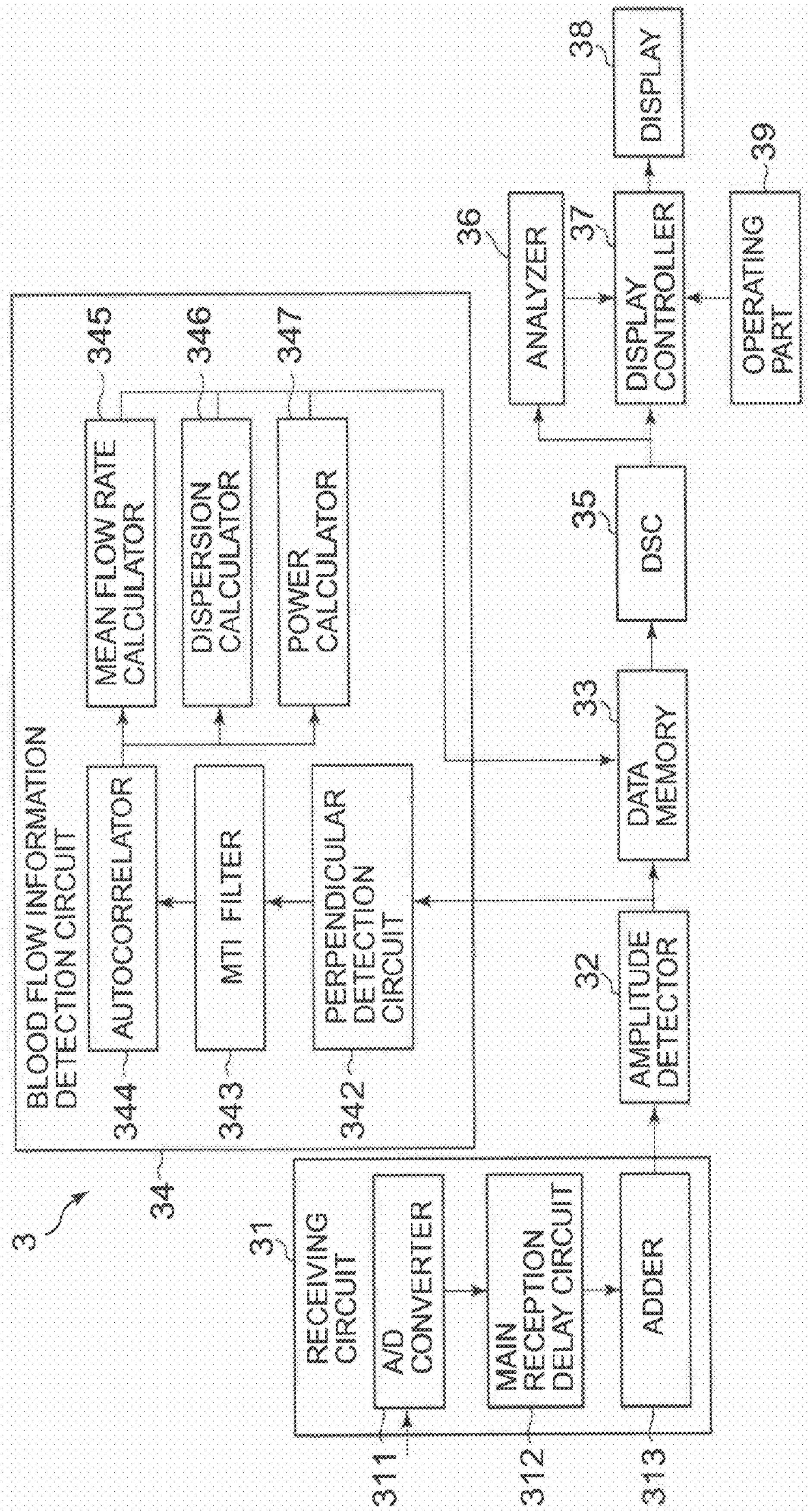

3
31
RECEIVING CIRCUIT
A/D CONVERTER
MAIN RECEPTION DELAY CIRCUIT
ADDER
311
312
313
34
BLOOD FLOW INFORMATION DETECTION CIRCUIT
344
AUTOCORRELATOR
343
MTI FILTER
342
PERPENDICULAR DETECTION CIRCUIT
345
MEAN FLOW RATE CALCULATOR
346
DISPERSION CALCULATOR
347
POWER CALCULATOR
32
AMPLITUDE DETECTOR
33
DATA MEMORY
35
DSC
36
ANALYZER
37
DISPLAY CONTROLLER
38
DISPLAY
39
OPERATING PART

FIG. 4

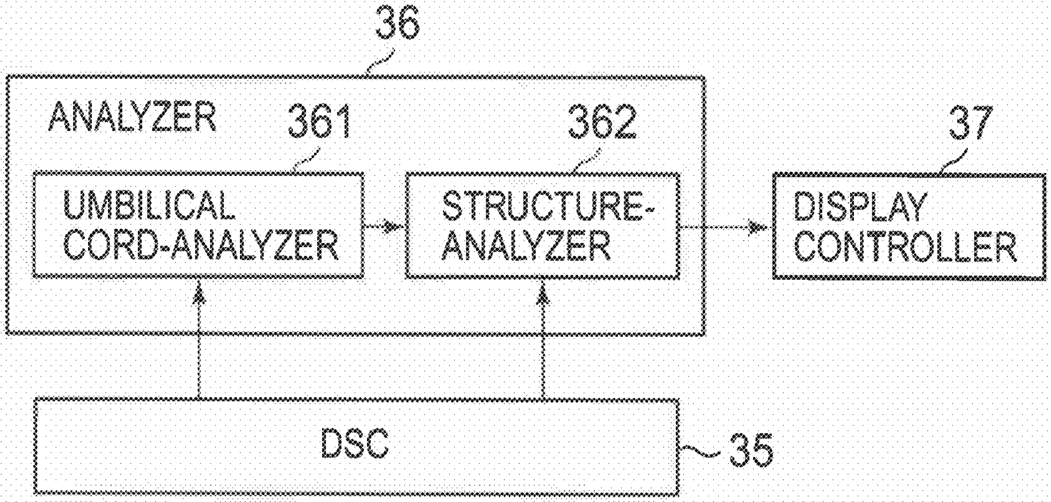

36
ANALYZER
361
362
37
UMBILICAL CORD-ANALYZER
STRUCTURE-ANALYZER
DISPLAY CONTROLLER
DSC
35

FIG. 5

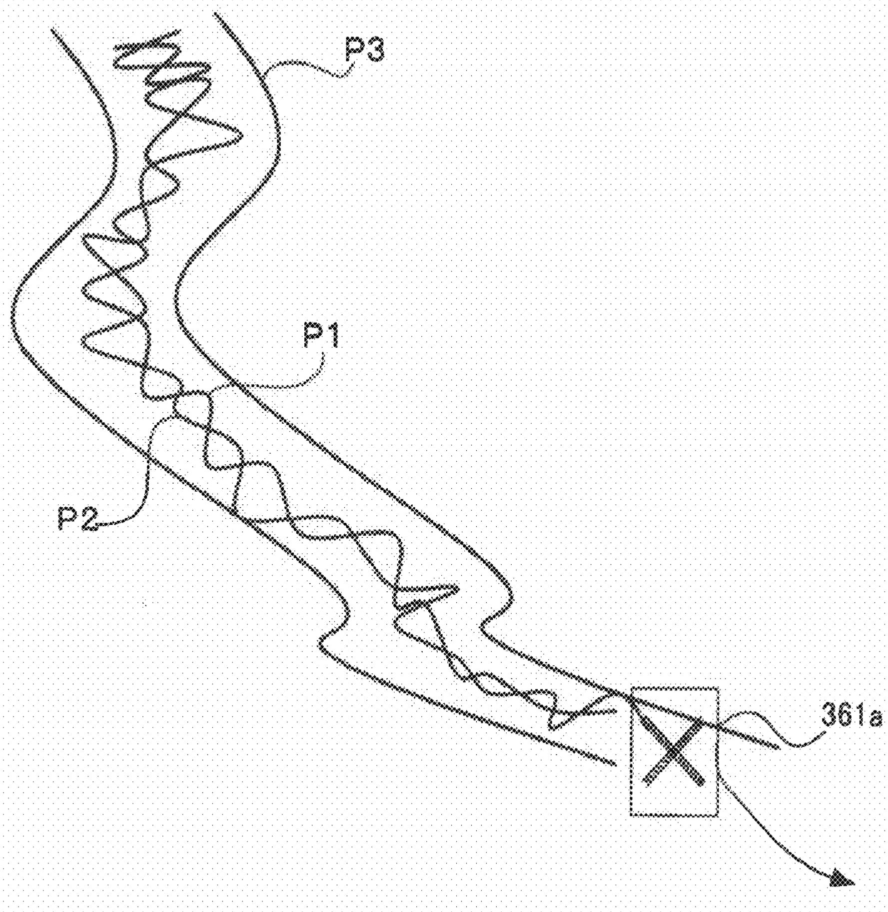


FIG. 6

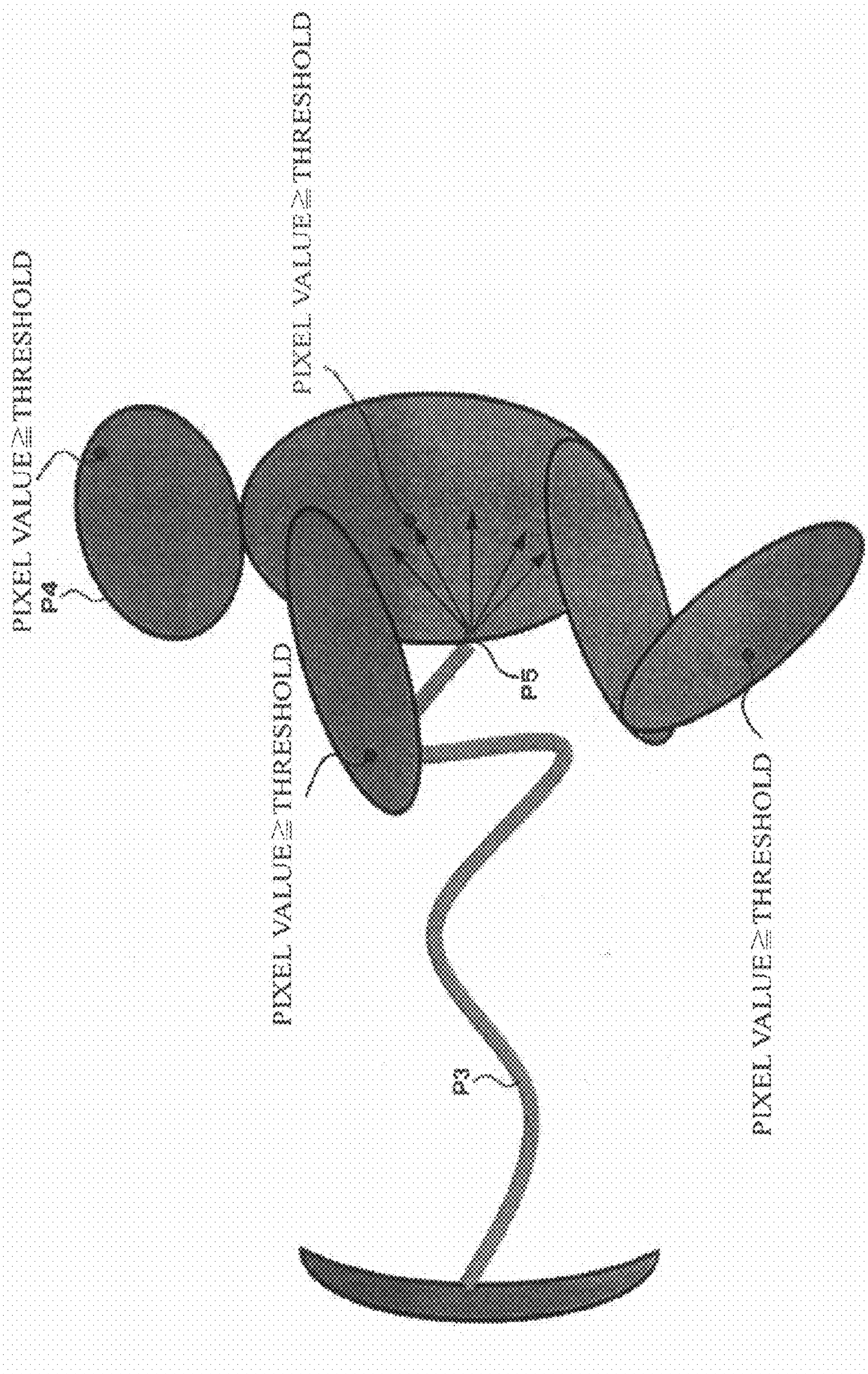

PIXEL VALUE ≧ THRESHOLD
P4
PIXEL VALUE ≧ THRESHOLD
PIXEL VALUE ≧ THRESHOLD
P5
PIXEL VALUE ≧ THRESHOLD
P3

FIG. 7

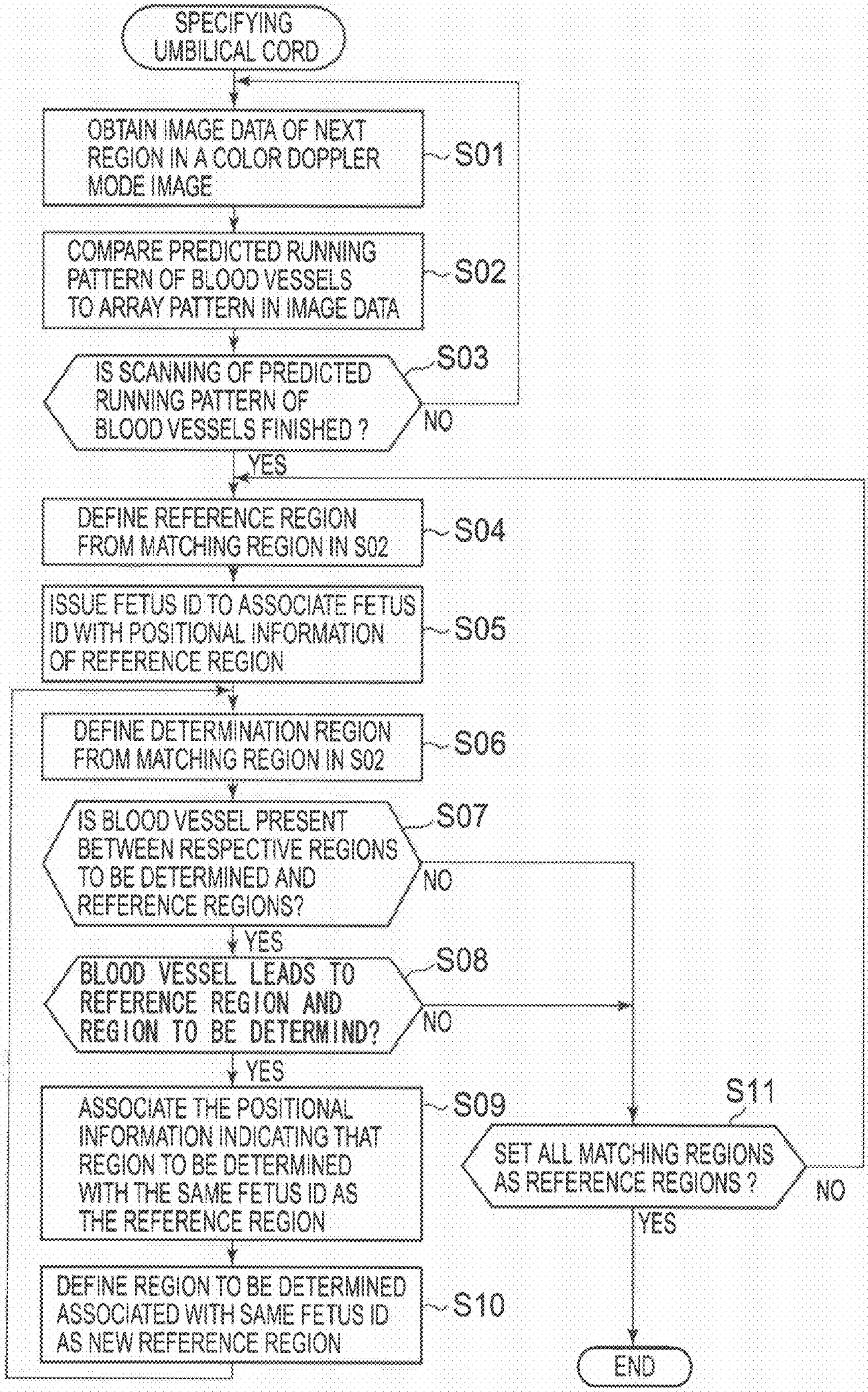

SPECIFYING UMBILICAL CORD
OBTAIN IMAGE DATA OF NEXT REGION IN A COLOR DOPPLER MODE IMAGE
S01
COMPARE PREDICTED RUNNING PATTERN OF BLOOD VESSELS TO ARRAY PATTERN IN IMAGE DATA
S02
IS SCANNING OF PREDICTED RUNNING PATTERN OF BLOOD VESSELS FINISHED ?
S03
NO
YES
DEFINE REFERENCE REGION FROM MATCHING REGION IN S02
S04
ISSUE FETUS ID TO ASSOCIATE FETUS ID WITH POSITIONAL INFORMATION OF REFERENCE REGION
S05
DEFINE DETERMINATION REGION FROM MATCHING REGION IN S02
S06
IS BLOOD VESSEL PRESENT BETWEEN RESPECTIVE REGIONS TO BE DETERMINED AND REFERENCE REGIONS?
S07
NO
YES
BLOOD VESSEL LEADS TO REFERENCE REGION AND REGION TO BE DETERMIND?
S08
NO
YES
ASSOCIATE THE POSITIONAL INFORMATION INDICATING THAT REGION TO BE DETERMINED WITH THE SAME FETUS ID AS THE REFERENCE REGION
S09
DEFINE REGION TO BE DETERMINED ASSOCIATED WITH SAME FETUS ID AS NEW REFERENCE REGION
S10
SET ALL MATCHING REGIONS AS REFERENCE REGIONS ?
S11
NO
YES
END

FIG. 8

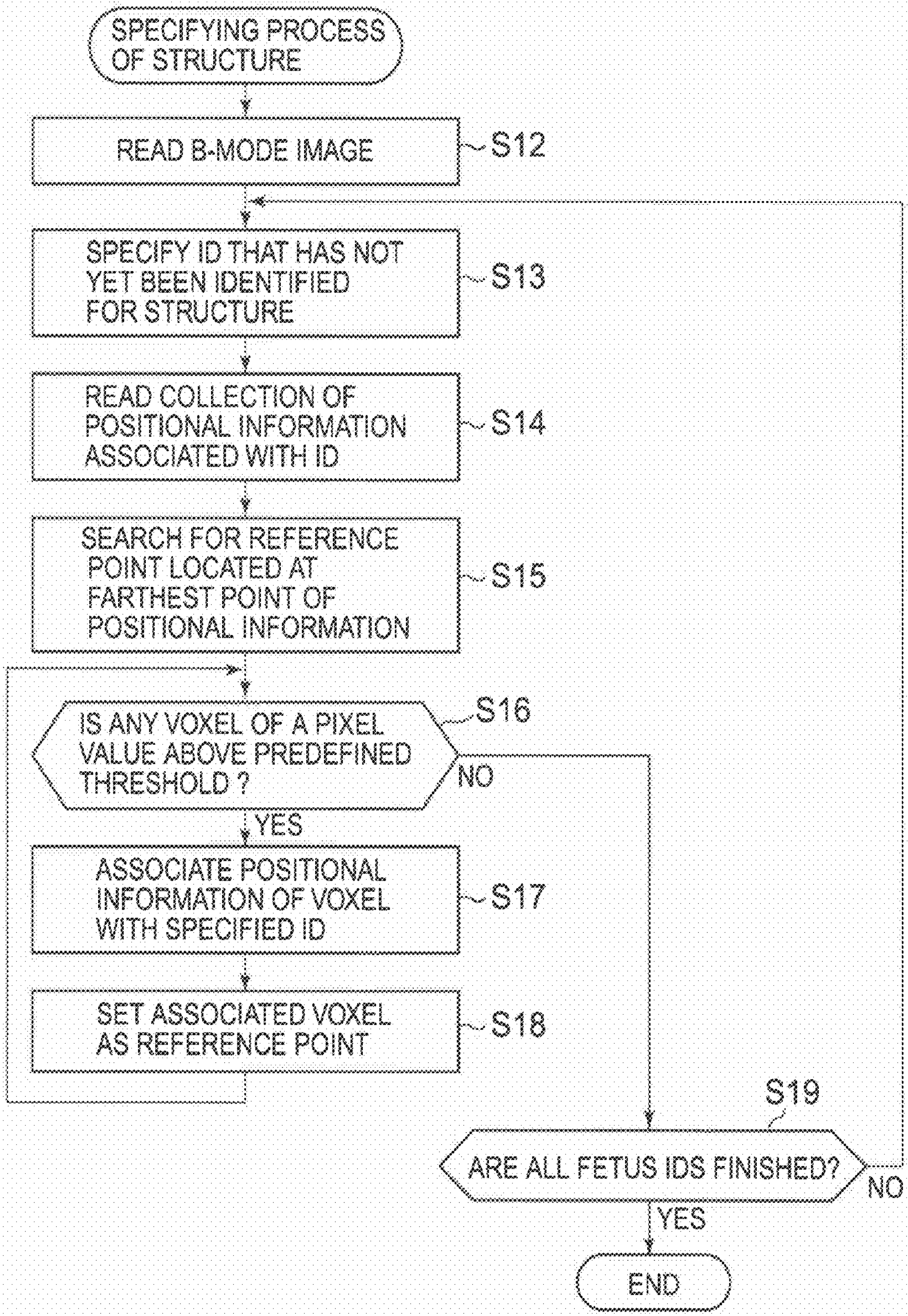

SPECIFYING PROCESS OF STRUCTURE
READ B-MODE IMAGE
S12
SPECIFY ID THAT HAS NOT YET BEEN IDENTIFIED FOR STRUCTURE
S13
READ COLLECTION OF POSITIONAL INFORMATION ASSOCIATED WITH ID
S14
SEARCH FOR REFERENCE POINT LOCATED AT FARTHEST POINT OF POSITIONAL INFORMATION
S15
IS ANY VOXEL OF A PIXEL VALUE ABOVE PREDEFINED THRESHOLD ?
S16
NO
YES
ASSOCIATE POSITIONAL INFORMATION OF VOXEL WITH SPECIFIED ID
S17
SET ASSOCIATED VOXEL AS REFERENCE POINT
S18
S19
ARE ALL FETUS IDS FINISHED?
NO
YES
END

FIG. 9

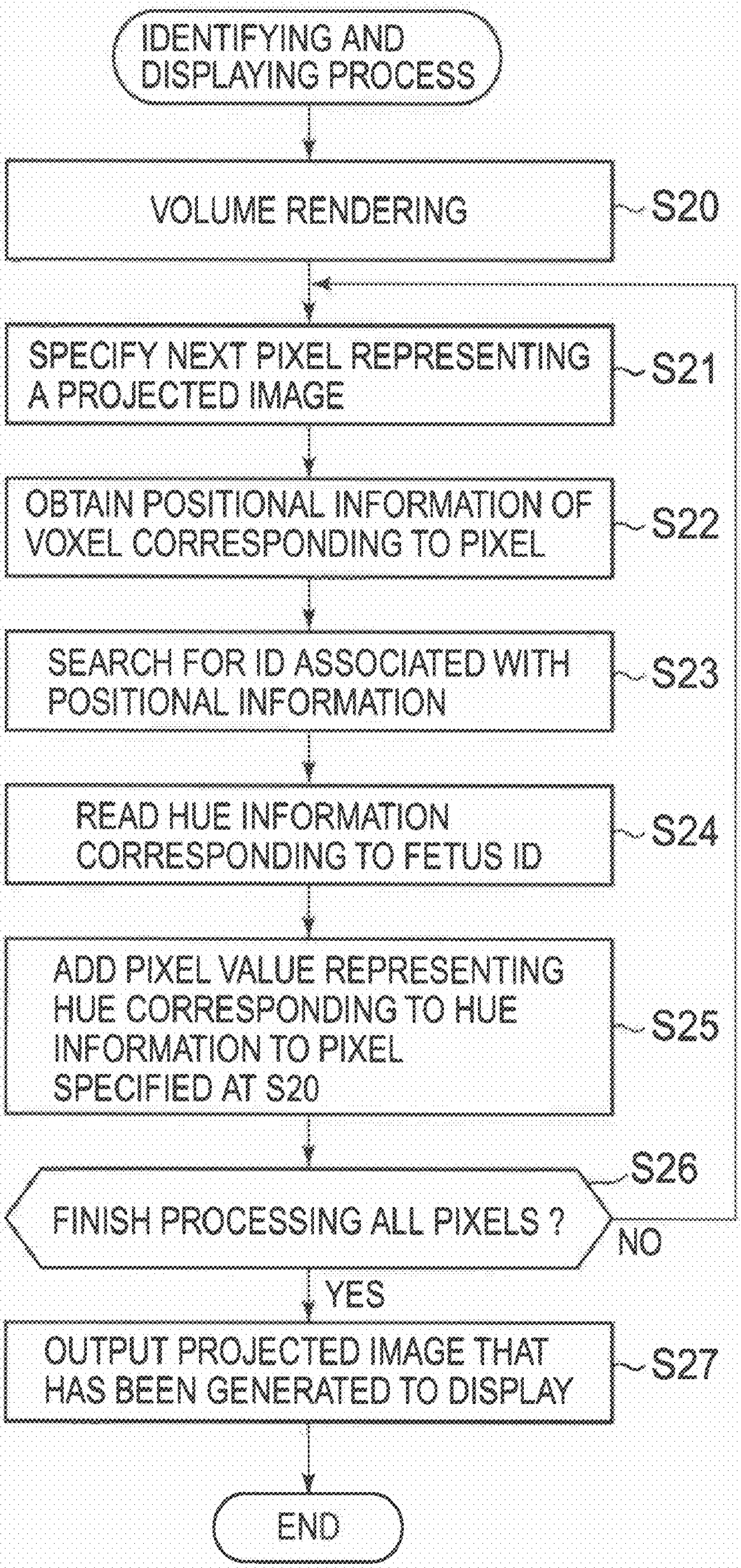

IDENTIFYING AND DISPLAYING PROCESS
VOLUME RENDERING
S20
SPECIFY NEXT PIXEL REPRESENTING A PROJECTED IMAGE
S21
OBTAIN POSITIONAL INFORMATION OF VOXEL CORRESPONDING TO PIXEL
S22
SEARCH FOR ID ASSOCIATED WITH POSITIONAL INFORMATION
S23
READ HUE INFORMATION CORRESPONDING TO FETUS ID
S24
ADD PIXEL VALUE REPRESENTING HUE CORRESPONDING TO HUE INFORMATION TO PIXEL SPECIFIED AT S20
S25
S26
FINISH PROCESSING ALL PIXELS ?
NO
YES
OUTPUT PROJECTED IMAGE THAT HAS BEEN GENERATED TO DISPLAY
S27
END

FIG. 10

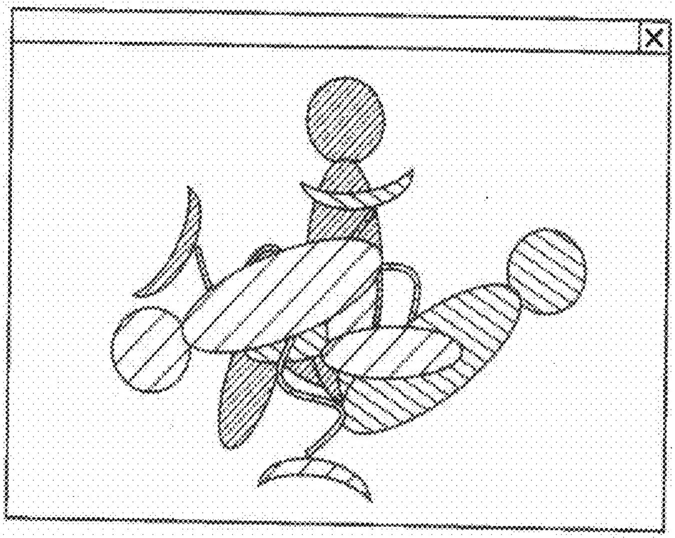


FIG. 11

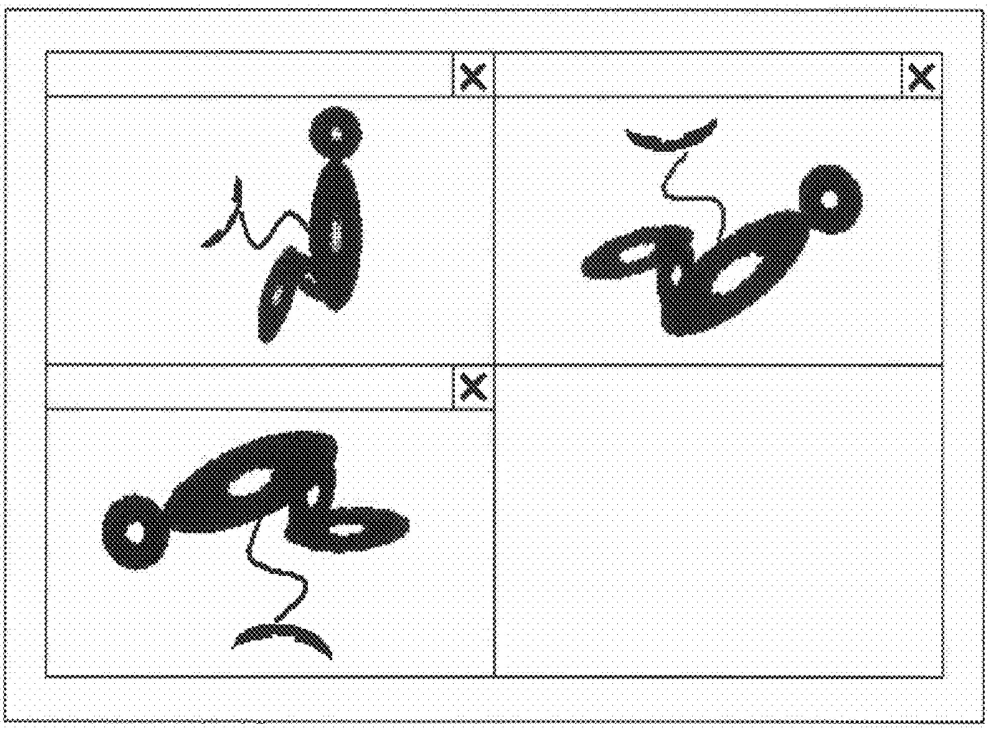


FIG. 12

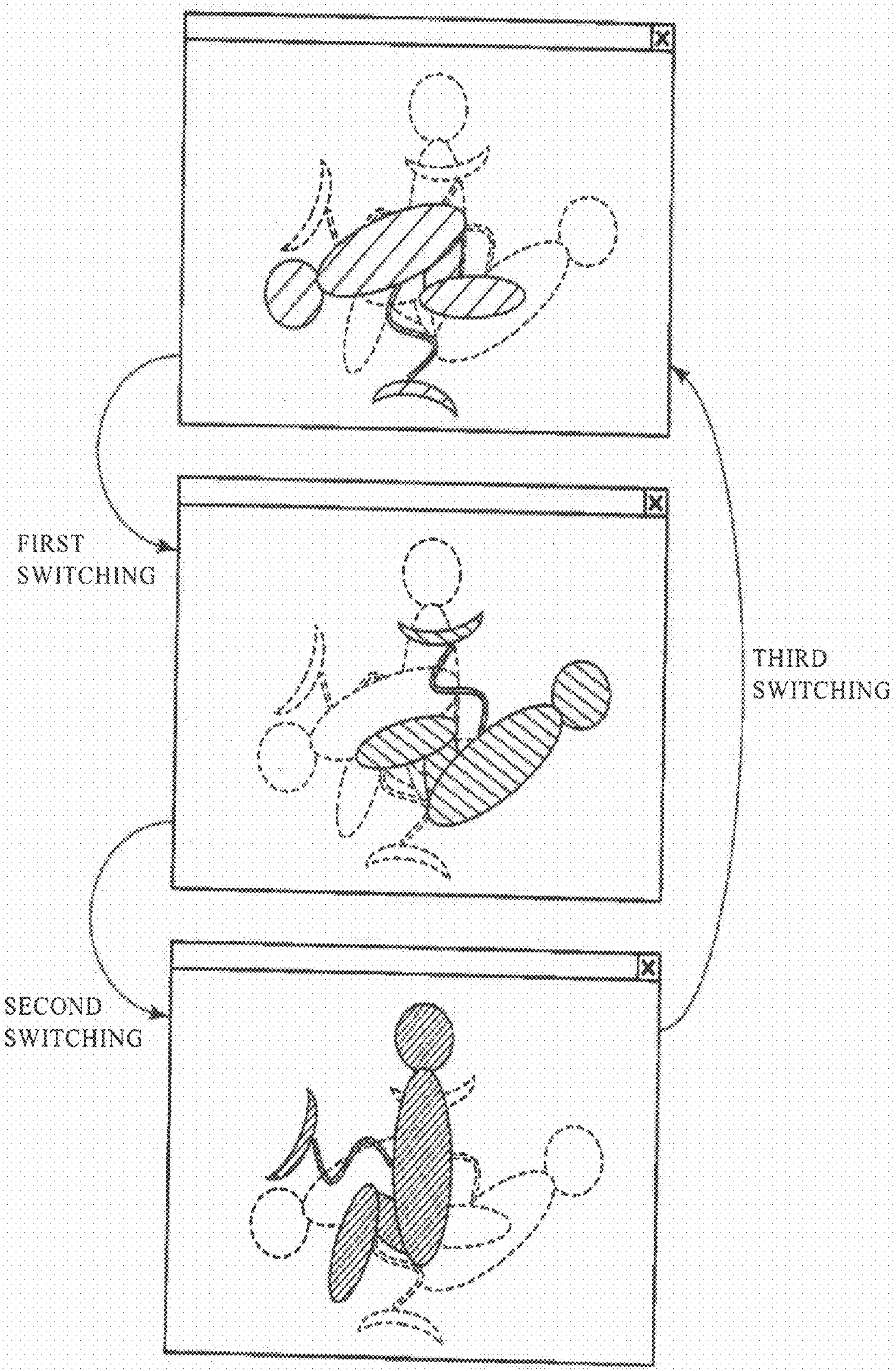


FIG. 13

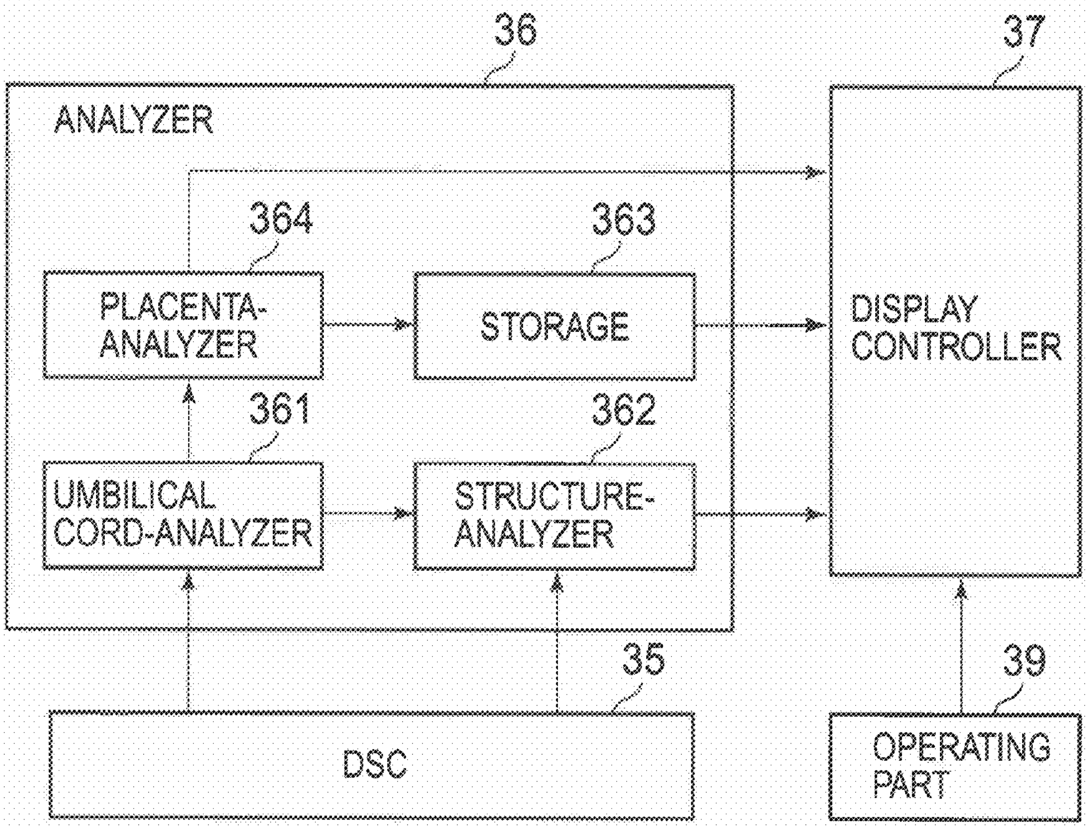

36
37
ANALYZER
364
363
PLACENTA-ANALYZER
STORAGE
DISPLAY CONTROLLER
361
362
UMBILICAL CORD-ANALYZER
STRUCTURE-ANALYZER
35
39
DSC
OPERATING PART

FIG. 14

PATIENT ID	
PLACENTA POSITIONAL INFORMATION A	FETUS ID-A
PLACENTA POSITIONAL INFORMATION B	FETUS ID-B
PLACENTA POSITIONAL INFORMATION C	FETUS ID-C
DISPLAY MODE INFORMATION	

PATIENT ID	
PLACENTA POSITIONAL INFORMATION A	FETUS ID-A
PLACENTA POSITIONAL INFORMATION B	FETUS ID-B
PLACENTA POSITIONAL INFORMATION C	FETUS ID-C
DISPLAY MODE INFORMATION	

⋮

FIG. 15

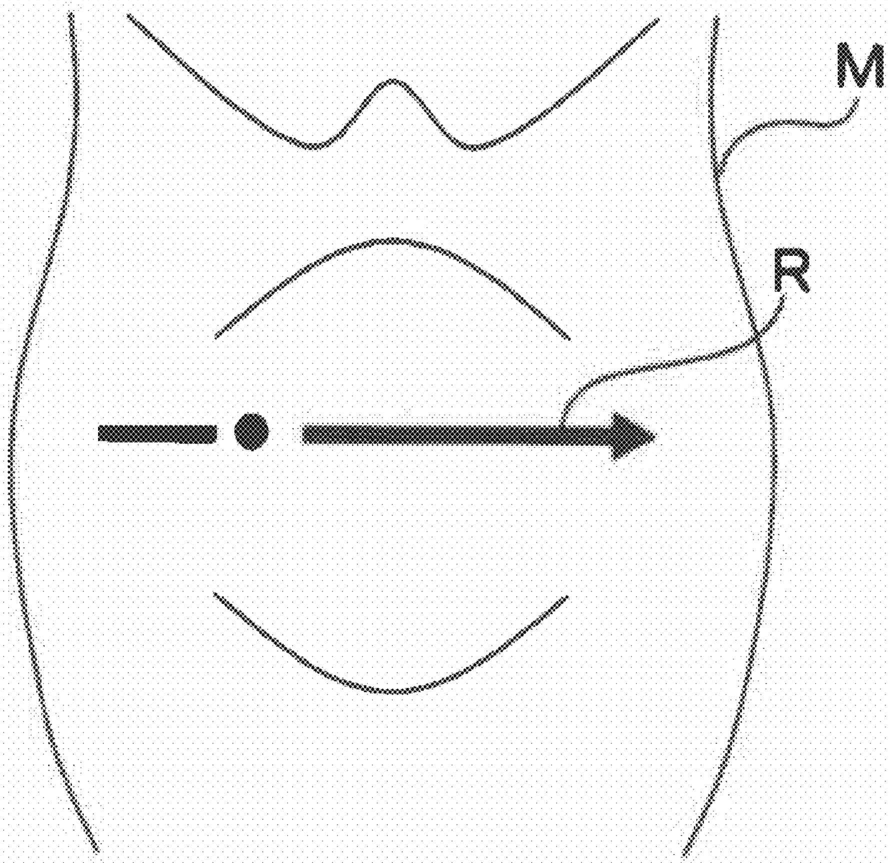


FIG. 16

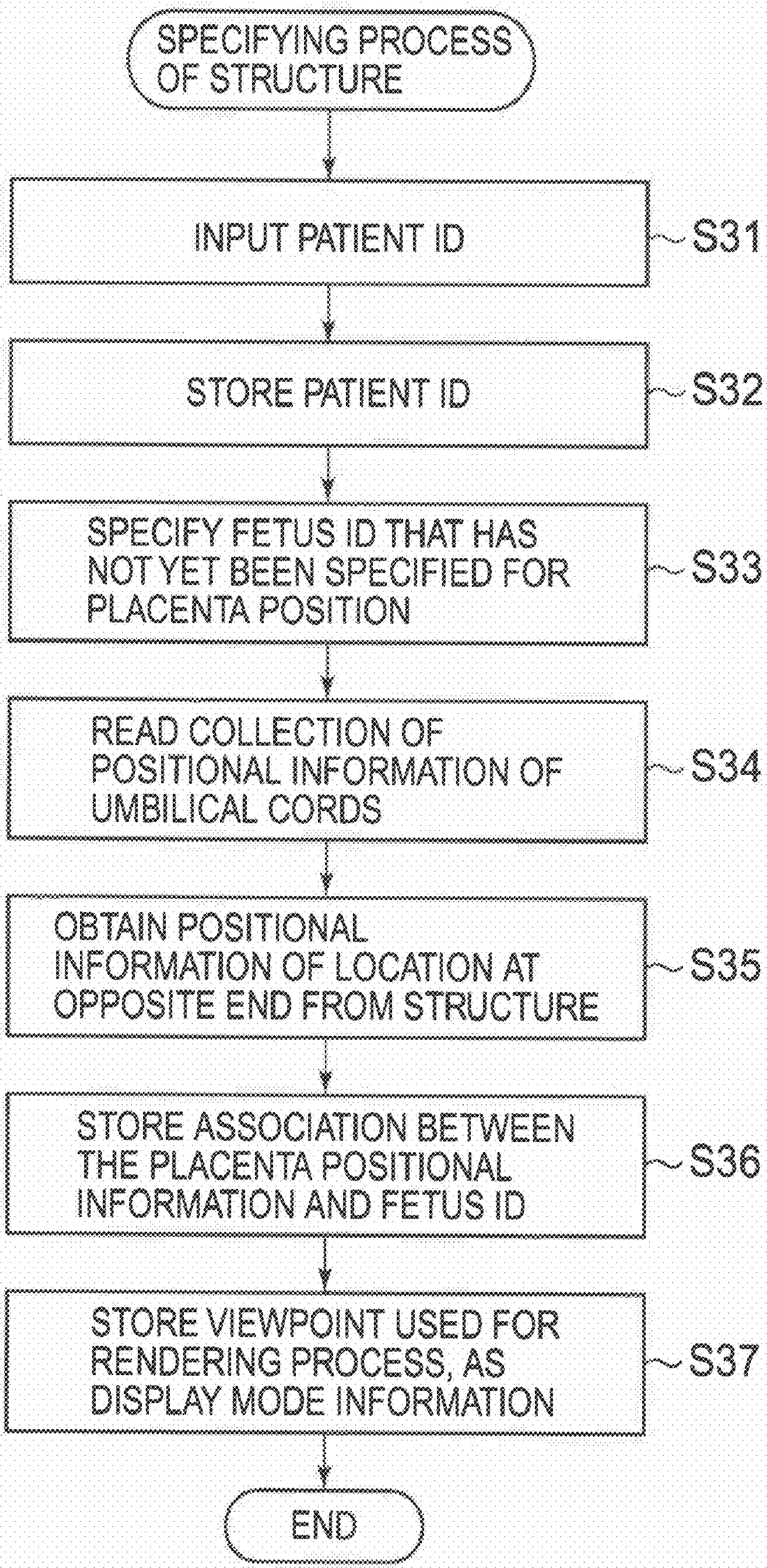
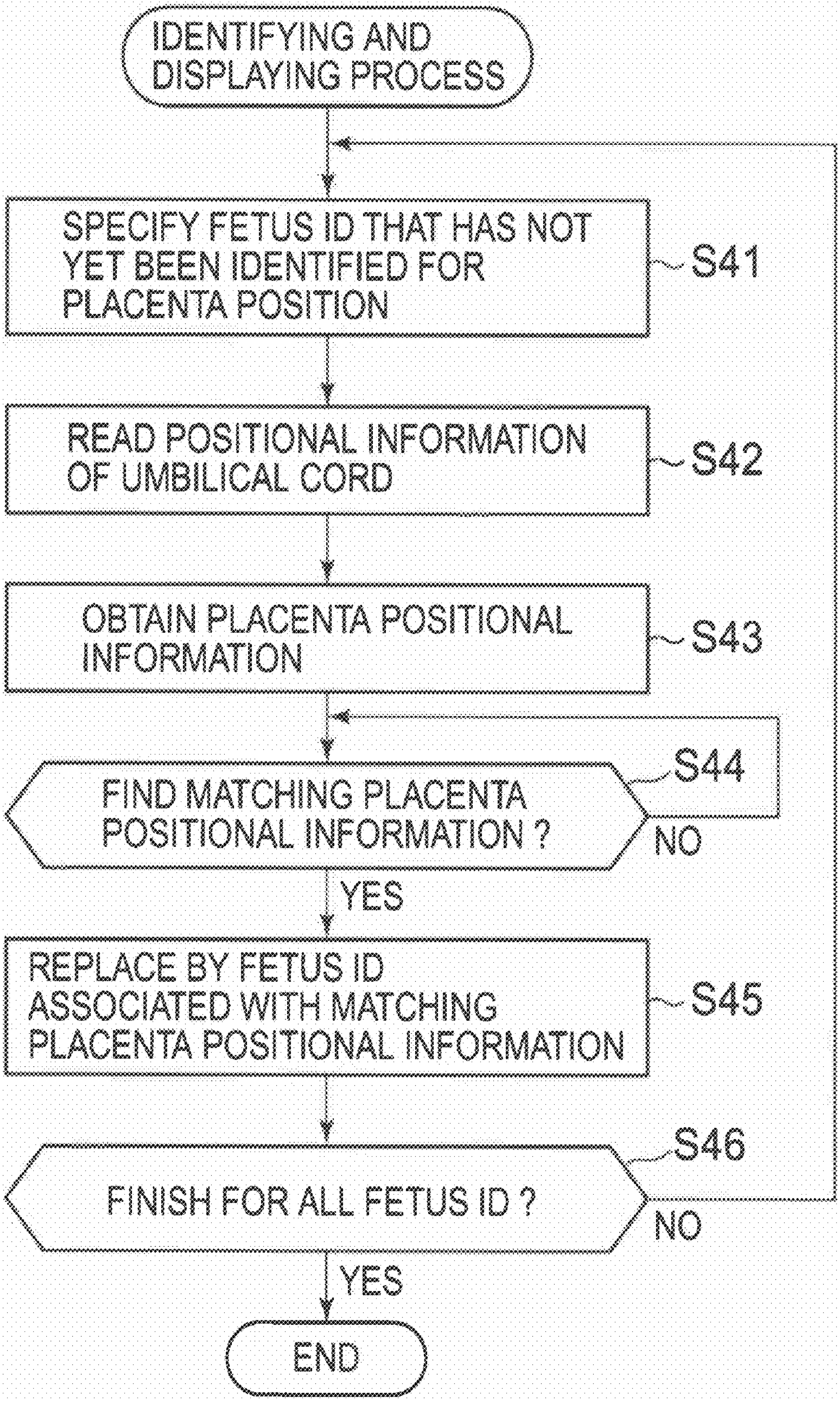

SPECIFYING PROCESS OF STRUCTURE
INPUT PATIENT ID
S31
STORE PATIENT ID
S32
SPECIFY FETUS ID THAT HAS NOT YET BEEN SPECIFIED FOR PLACENTA POSITION
S33
READ COLLECTION OF POSITIONAL INFORMATION OF UMBILICAL CORDS
S34
OBTAIN POSITIONAL INFORMATION OF LOCATION AT OPPOSITE END FROM STRUCTURE
S35
STORE ASSOCIATION BETWEEN THE PLACENTA POSITIONAL INFORMATION AND FETUS ID
S36
STORE VIEWPOINT USED FOR RENDERING PROCESS, AS DISPLAY MODE INFORMATION
S37
END

FIG. 17


IDENTIFYING AND DISPLAYING PROCESS
SPECIFY FETUS ID THAT HAS NOT YET BEEN IDENTIFIED FOR PLACENTA POSITION
S41
READ POSITIONAL INFORMATION OF UMBILICAL CORD
S42
OBTAIN PLACENTA POSITIONAL INFORMATION
S43
FIND MATCHING PLACENTA POSITIONAL INFORMATION ?
S44
NO
YES
REPLACE BY FETUS ID ASSOCIATED WITH MATCHING PLACENTA POSITIONAL INFORMATION
S45
FINISH FOR ALL FETUS ID ?
S46
NO
YES
END

ULTRASOUND IMAGING APPARATUS

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to an ultrasound imaging apparatus that generates an image by transmitting and receiving ultrasound. More particularly, the present invention relates to an ultrasound imaging apparatus that supports identifying multiple fetuses present in the womb.

[0003] 2. Description of the Related Art

[0004] An ultrasound imaging apparatus is an apparatus that generates an image by transmitting and receiving ultrasound to and from the inside of a subject. An examination using this ultrasound imaging apparatus is less invasive for the subject. Therefore, this examination can be repeatedly performed on the subject. Also, with an ultrasound imaging apparatus, it is easy to implement a real time display. For these reasons, an ultrasound imaging apparatus is often utilized in the field of obstetrics when tracking a fetus present in the womb of a pregnant woman over time (e.g., see Japanese published unexamined application No. 2001-120544). Recently, a three-dimensional technology for an ultrasound imaging apparatus has been developed.

[0005] Physicians and others may confirm the condition of the fetus in three dimensions based on this three-dimensional technology in order to comprehend the development and shape of the fetus.

[0006] In the tracking of the fetus, physicians and others determine whether the fetus is growing well or not by representing its development using a growth curve. When multiple fetuses are present in the womb, these growth curves are used to represent each fetus.

[0007] Therefore, in order to confirm the degree of growth for each of the multiple fetuses, physicians and others must specify the same fetuses in both the previous and current examinations by distinguishing the fetuses in the womb based on their individual experiences.

[0008] However, in ultrasonic images, it is rare that multiple fetuses are clearly distinguished and represented. Thus, it has not been easy to specify each of the multiple fetuses. Therefore, physicians and others might make a mistake in specifying each of multiple fetuses.

SUMMARY OF THE INVENTION

[0009] The present invention is considered in the light of the aforementioned background. The object of the present invention is to provide an ultrasound imaging apparatus that supports physicians and others in specifying the same fetuses when multiple fetuses are present in the womb.

[0010] The first aspect of this invention is an ultrasound imaging apparatus having a probe configured to transmit ultrasound and receive the reflected waves, a generator configured to generate an image based on the reflected waves, and a display that displays the image, wherein the ultrasound imaging apparatus comprises: a first analyzer configured to specify respectively each umbilical cord present in said image; a second analyzer configured to respectively specify a structure continuing into one end of said umbilical cord; and a display controller configure to cause each said structure to be displayed on said display.

[0011] According to the first embodiment of this invention, even when multiple fetuses are present in the womb, it will be easy to confirm the condition of each fetus by physicians and others, and possible to improve the accuracy of measuring the growth condition of the fetuses, etc.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. **1** is a configuration diagram showing the appearance of an ultrasound imaging apparatus according to the present embodiment.

[0013] FIG. **2** is a configuration diagram showing an ultrasound probe.

[0014] FIG. **3** is a configuration diagram showing an internal configuration of an apparatus body.

[0015] FIG. **4** is a diagram showing a detailed configuration of an analyzer according to the first embodiment.

[0016] FIG. **5** is a pattern diagram showing a Color Doppler image of an umbilical cord.

[0017] FIG. **6** is a pattern diagram showing a B-mode image of a region including a fetus.

[0018] FIG. **7** is a flowchart showing a process of specifying an umbilical cord.

[0019] FIG. **8** is a flowchart showing a process of specifying a structure.

[0020] FIG. **9** is a flowchart showing a process of identifying and displaying a structure.

[0021] FIG. **10** is a pattern diagram showing a screen from the ultrasound imaging apparatus.

[0022] FIG. **11** is a pattern diagram showing a second aspect of a screen from the ultrasound imaging apparatus.

[0023] FIG. **12** is a pattern diagram showing a third aspect of a screen from the ultrasound imaging apparatus.

[0024] FIG. **13** is a configuration diagram of an analyzer according to the second embodiment.

[0025] FIG. **14** is a data configuration diagram for data including placenta positional information.

[0026] FIG. **15** is a pattern diagram showing a display of a probe movement route.

[0027] FIG. **16** is a flowchart showing an operation for storing the placenta position, etc.

[0028] FIG. **17** is a flowchart showing an operation for reproducing an aspect of identifying the fetus, even for a new examination.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0029] A preferred embodiment of an ultrasound imaging apparatus according to the present invention is specifically described as follows, with reference to the drawings.

[0030] FIG. **1** is a configuration diagram showing the appearance of the ultrasound imaging apparatus according to the present embodiment.

[0031] The ultrasound imaging apparatus **1** transmits and receives ultrasound to and from the inside of a subject such as a pregnant woman. Moreover, the ultrasound imaging apparatus **1** generates and displays an image of the inside of the subject based on reflected waves that have been received. More particularly, if tracking of fetuses is an item that is part of the examination, this ultrasound imaging apparatus **1** identifies and displays multiple fetuses in the image.

[0032] This ultrasound imaging apparatus **1** is configured to include an ultrasound probe **2** and an apparatus body **3**. The ultrasound probe **2** and the apparatus body **3** are connected via a cable **4**.

[0033] The ultrasound probe **2** is controlled by the apparatus body **3** and transmits and receives ultrasound to and from the inside of the subject. The apparatus body **3** generates ultrasonic images such as B-mode (Brightness Mode) and Color Doppler mode images by processing signals of the reflected waves that have been received. A B-mode image represents the intensity of the received ultrasound using brightness, and represents each position of those tissues in the subject that reflect the ultrasound sent from ultrasound probe **2**, arranged two-dimensionally or three-dimensionally. A Color Doppler mode image is an image of blood flow information, the image representing frequency changes in the ultrasound, converted into the flow rate of blood flow using colors. In general, in a Color Doppler mode image, something that is close to the ultrasound probe **2** is processed using red, and something that is distant using blue.

[0034] When physicians and others implement three-dimensional scanning with the ultrasound imaging apparatus **1**, the physicians and others move the ultrasound probe **2** held by them in a direction perpendicular to the scan plane. Three-dimensional scanning is scanning in which a scan frame (scan plane) is manually or mechanically moved in a three-dimensional region of the subject to collect a signal received from each point within that three-dimensional region.

[0035] FIG. **2** is a configuration diagram showing the ultrasound probe **2**.

[0036] The ultrasound probe **2** comprises multiple aligned piezoelectric elements **21**, an ultrasound-transmitting circuit **22**, an ultrasound-receiving circuit **23**, and a position detector **24**.

[0037] The piezoelectric element **21** is an acoustically/electrically reversible conversion element consisting of a piezoceramic such as lead titanate. When a signal voltage is applied to the piezoelectric element **21**, the signal voltage produces a piezoelectric effect, and ultrasound is sent from the piezoelectric element **21**. Also, when the piezoelectric element **21** receives ultrasound reflected from the subject, a piezoelectric effect is produced by the ultrasound. Ultrasound is converted by the piezoelectric effect into an echo signal having a voltage value according to the intensity of that ultrasound.

[0038] The ultrasound-transmitting circuit **22** applies a voltage pulse to each piezoelectric element **21**. This ultrasound-transmitting circuit **22** has an oscillator **221**, a frequency divider **222**, a transmission delay circuit **223**, and a pulse generator **224**.

[0039] The oscillator **221** controls the transmission timing of voltage pulses. The oscillator **221** generates a timing signal for each predefined time period, and transmits the timing signal to the transmission delay circuit **223** via the frequency divider **222**. The frequency divider **222** reduces the timing signal to a rate pulse of, e.g., about 5 KHz.

[0040] The transmission delay circuit **223** determines the scanning direction of the ultrasound beam. The transmission delay circuit **223** delays the timing signal per piezoelectric element **21**, setting a time lag.

[0041] This transmission delay circuit **223** receives a scanning direction signal that selects the scanning direction from the apparatus body **3**.

[0042] Moreover, the transmission delay circuit **223** sets a delay in applying voltage pulse to each piezoelectric element **21** so that the ultrasound beam is focused in the scanning direction based on the received signal.

[0043] The pulse generator **224** applies a voltage pulse to each piezoelectric element **21** in tune with the timing signal received from the transmission delay circuit **223**.

[0044] The ultrasound-receiving circuit **23** receives an echo signal output by each piezoelectric element **21**. This ultrasound-receiving circuit **23** has a preamplifier **231**, a partial reception delay circuit **233**, and a partial adder **234**.

[0045] The preamplifier **231** amplifies echo signals. The partial reception delay circuit **233** provides a delay time that is required to determine the receiving directionality for the amplified echo signals.

[0046] In order to decrease the number of signal lines in the cable **4**, once the partial adder **234** partially phases and adds signals from each piezoelectric element **21**, it decreases the number of signal lines to, e.g., **16**. The partial adder **234** sends the partially phased and added echo signals respectively via the cable **4** to the apparatus body **3**.

[0047] The position detector **24** detects positional information indicating the position of the ultrasound probe **2**. The positional information is information indicating the reference position PO (x0, y0, z0), angle θa (rotational angle around the X-axis), and angle θB (rotational angle around the Y-axis), angle θY (rotational angle around the Z-axis) of the ultrasound probe **2**.

[0048] FIG. **3** is a configuration diagram showing the internal configuration of the apparatus body **3**. As shown in FIG. **3**, the apparatus body **3** has a receiving circuit **31**, an amplitude detector **32**, a data memory **33**, a blood flow information detection circuit **34**, a DSC (digital scan converter) **35**, an analyzer **36**, a display controller **37**, a display **38**, and an operating part **39**.

[0049] Echo signals are input into the receiving circuit **31** from the ultrasound probe **2**. This receiving circuit **31** has an A/D (analog to digital) converter **311**, a main reception delay circuit **312**, and an adder **313**. The A/D converter **311** converts signals that are input from the ultrasound probe **2** into digital signals. The main reception delay circuit **312** provides a delay time that is required to determine the receiving directionality for the echo signals. The adder **313** generates a signal echo signal by phasing and adding multiple echo signals that have been input.

[0050] Echo signals are input into the amplitude detector **32** from the receiving circuit **31**. The amplitude detector **32** detects envelopes. The amplitude detector **32** detects the intensity of the received ultrasound by implementing compression with logarithmic conversion on the detected data. The data of that intensity value becomes an element of a B-mode image due to its correspondence with the reflected position of the ultrasound.

[0051] The blood flow information detection circuit **34** has a perpendicular detection circuit **342**, a MTI (moving target indicator) filter **343**, an autocorrelator **344**, a mean flow rate calculator **345**, a dispersion calculator **346**, and a power calculator **347**.

[0052] The perpendicular detection circuit **342** extracts Doppler signals that have shift frequency components from echo signals, using perpendicular detection processing. The MTI filter **343** implements high-pass filter processing that separates tissue signals and blood flow signals from the Doppler signals. The autocorrelator **344** implements frequency analysis of the Doppler signals to obtain the shift frequency of the blood flow. The mean flow rate calculator **345** calculates the mean velocity of the blood flow from the shift frequency. The dispersion calculator **346** calculates velocity distribution of the blood flow from the shift frequency. The power calculator **347** calculates power that reflects the blood flow volume from the shift frequency.

[0053] Data representing the mean average, velocity distribution, and power of the blood flow constitute a Color Doppler mode image, and is sent to the data memory **33**.

[0054] The data memory **33** stores the data of each pixel value constituting a B-mode image corresponding to the positions where the ultrasound was reflected. In addition, the data memory **33** stores the data representing the mean average, velocity distribution, and power of the blood flow, which constitute a Color Doppler mode image corresponding to the positions where the ultrasound was reflected.

[0055] The DSC **35** constructs volume data according to the actual space from signals of B-mode image and Color Doppler mode image stored in the data memory **33**. The DSC **35** distributes B-mode image and Color Doppler mode image of each scan frame stored in the data memory **33** in a three-dimensional memory space based on positional information detected by the position detector **24** and the oscillation angle of the scanning line.

[0056] The analyzer **36** specifies a fetus based on a three-dimensional image generated by the DSC **35**. If there are multiple fetuses present in the three-dimensional image, each fetus is separately specified.

[0057] FIG. **4** is a diagram showing the detailed configuration of the analyzer **36** according to the first embodiment. As shown in FIG. **4**, the analyzer **36** has an umbilical cord-analyzer **361** that specifies an umbilical cord, and a structure-analyzer **362** that specifies a structure continuing from the umbilical cord. The analyzer **36** first specifies the umbilical cord from a three-dimensional image. Next, the analyzer **36** specifies multiple fetuses respectively by specifying the structures continuing from the umbilical cord. The structure continuing from the umbilical cord is a fetus.

[0058] Specifying the umbilical cord is described based on FIG. **5**. FIG. **5** is a pattern diagram showing a Color Doppler image of the umbilical cord.

[0059] The umbilical cord-analyzer **361** specifies a region occupied by the umbilical cord P**3** using the Color Doppler mode image. The umbilical cord P**3** has a characteristic pattern in blood vessels running therein. For the blood vessels in the umbilical cord P**3**, an artery P**1** and a vein P**2** run in a spiral. So, the umbilical cord-analyzer **361** specifies the region occupied by the umbilical cord P**3** by detecting this spiral running pattern of blood vessels.

[0060] Specifying the region of the umbilical cord P**3** with the umbilical cord-analyzer **361** is specifically as follows. The umbilical cord-analyzer **361** has prestored a predicted running pattern of blood vessels **361***a*. This predicted running pattern of blood vessels **361***a* is image data with crossing lines that represent blood vessels. The umbilical cord-analyzer **361** compares the data of each image, for the entire region of the Color Doppler mode image, to this predicted running pattern of blood vessels **361***a*. The umbilical cord-analyzer **361** makes the comparison while zooming in and out the predicted running pattern of blood vessels **361***a* according to a predefined rule and varying the crossing angle of the lines. Then, when the image data array pattern of the comparison subject and the predicted running pattern of blood vessels **361***a* match, a region comprising that image data is specified as a portion of the region occupied by the umbilical cord P**3**.

[0061] The umbilical cord-analyzer **361** scans the entire region of the Color Doppler mode image for all the umbilical cords P**3** respectively.

[0062] The umbilical cord-analyzer **361** regards as one umbilical cord P**3**, any region where the region matching the predicted running pattern of blood vessels **361***a* continues on. To continue on means that matched regions are connected with each other by the same artery P**1** and vein P**2**.

[0063] In other words, the umbilical cord-analyzer **361** determines whether any blood vessel is present between neighboring regions matched to the predicted running pattern of blood vessels **361***a*. If a blood vessel is present, the umbilical cord-analyzer **361** tracks that blood vessel to determine whether the regions to be determined are connected with each other by this blood vessel. Moreover, if the umbilical cord-analyzer **361** determines that the regions are connected with each other, it determines that those regions and the blood vessel region therebetween constitute the umbilical cord P**3**. Then, the umbilical cord-analyzer **361** puts a series of regions connected by the same blood vessels into one group. On the other hand, other matching regions that have been determined by the umbilical cord-analyzer **361** not to be in a relationship with the series of regions for this group are regarded as constituting another umbilical cord P**3**. Moreover, the umbilical cord-analyzer **361** further puts a group of regions that have a continuing region relationship with those matching regions into the other group. Grouping by the umbilical cord-analyzer **361** is done by associating with the same fetus ID a collection of positional information that indicates the position of each region that belongs to one group.

[0064] In addition, the umbilical cord-analyzer **361** may detect a corded structure using a B-mode image to specify the umbilical cord P**3**. In this case, the umbilical cord-analyzer **361** detects the corded structure by detecting a collection of portions having diameters below the predefined value in the image.

[0065] Next, specifying the fetus is described based on FIG. **6**. FIG. **6** is a pattern diagram showing a B-mode image of a region including a fetus.

[0066] The structure-analyzer **362** specifies a fetus using the B-mode image. This structure-analyzer **362** specifies a collection of voxels continuing into the region of the umbilical cord P**3** specified by the umbilical cord-analyzer **361** and having a pixel value above a predefined threshold. The predefined threshold is a value that characterizes brightness exhibited by a structure P**4** present in the womb and that is also an empirical value.

[0067] Specifying a fetus using the structure-analyzer **362** is specifically performed as follows. The structure-analyzer **362** tracks the region occupied by the specified umbilical cord P**3**, with a reference point P**5** as its end point. This reference point P**5** is a connection point between the umbilical cord P**3** and the structure P**4**.

[0068] Then, the structure-analyzer **362** expands the voxels of the comparison subject from this reference point P**5** and compares the pixel values of the voxels of the comparison subject with the predefined threshold. As a result of comparison by the structure-analyzer **362**, if a pixel value is above the predefined threshold, the structure-analyzer **362** regards that voxel of the comparison subject as one component of the structure P**4**. On the other hand, if the pixel value is below the predefined threshold, the structure-analyzer **362** does not regard that voxel as one component of the structure P**4**. In addition, the structure-analyzer **362** does not expand the voxels around the comparison subject having pixel values below the predefined threshold.

[0069] If there are multiple umbilical cords P**3** specified by the umbilical cord-analyzer **361**, the structure-analyzer **362** specifies a structure P**4** continuing into the umbilical cord for each umbilical cord P3. When the structure P4 is specified by the structure-analyzer 362, the umbilical cord P3 continuing into that structure P4 is regarded as being in the same group as the structure P4. In other words, it further associates a collection of positional information for voxels continuing from one umbilical cord P3 and having a pixel value above the predefined threshold, with the fetus ID associated with that one umbilical cord P3.

[0070] In addition, the analyzer **36** may model a collection of associated positional information using models such as rectangular solids and spheres and further associate the type and arranged position of the models and the coupling relationship between the models with the fetus ID.

[0071] The display controller **37** receives voxels of all the structures P**4** output from the DSC **35**, and implements volume rendering processing and color processing on them to constitute one screen. The display controller **37** outputs it to the display **38**. The display **38** is a liquid crystal display, an organic EL display, CRT, etc.

[0072] In volume rendering processing, the display controller **37** takes a sample of the pixel value of each voxel in all the structures P4 from the direction of the viewpoint, and calculates light transmission according to the opacity and reflection with respect to the viewpoint, and applies shading, thereby generating a projected image. The viewpoint in volume rendering processing is input by an operator via an operating part **39**. The operating part **39** is a keyboard, a mouse, a trackball, etc. When the direction of the viewpoint, angle around the axis of the viewpoint, viewpoint, and distance to the three-dimensional image are input by physicians and others via the operating part **39**, the display controller **37** sets the viewpoint corresponding to that operation, i.e., the direction of the viewpoint, rotational angle of the image, and zoom-in volume, so as to implement rendering processing on the three-dimensional image.

[0073] In color processing, a hue, such as one in the RGB format, is assigned to each voxel of the structures P**4**. This hue that is assigned is different for each structure P**4**.

[0074] This color processing is specifically performed as follows. The display controller **37** obtains a collection of positional information associated with one fetus ID from the analyzer **36**. The display controller **37** also assigns the same hue to each voxel specified based on that obtained positional information. Similarly, the display controller **37** obtains a collection of positional information for other fetus IDs and assigns the same hue for each collection of the positional information based on the obtained positional information. The display controller **37** assigns a different hue to a group with a different fetus ID. For example, the ultrasound imaging apparatus **1** has prestored a list of corresponding fetus IDs and hues. The analyzer **36** assigns a fetus ID to a group from the list. Then, the display controller **37** refers to the list and assigns a hue corresponding to the fetus ID.

[0075] FIGS. **7** through **9** are flowcharts showing operation of the ultrasound imaging apparatus **1** to identify and display the fetus.

[0076] First, FIG. **7** is a flowchart showing the process of specifying the umbilical cord P3. The umbilical cord-analyzer **361** obtains image data of the next region in a Color Doppler mode image (S**01**). When the image data is obtained, the umbilical cord-analyzer **361** compares the predicted running pattern of blood vessels **361***a* to the array pattern in that image data (S**02**). The umbilical cord-analyzer **361** implements S**01** and S**02** until all the regions are scanned (S03, No).

[0077] When scanning using the predicted running pattern of blood vessels **361***a* is finished (S**03**, Yes), among matching regions matched by comparison at S**02**, the umbilical cord-analyzer **361** defines as a reference region any matching region that is located in the outermost outline on the Color Doppler mode image and has not yet become a reference region (S**04**). Moreover, the umbilical cord-analyzer **361** issues a new fetus ID to associate the fetus ID with the positional information of that reference region (S**05**).

[0078] When the reference region is determined, the umbilical cord-analyzer **361** searches for each matching region present within a predefined search range from this reference region, which is defined in advance. As a result of the search, the umbilical cord-analyzer **361** defines regions other than the reference regions as continuous regions to be determined (S**06**).

[0079] Then, the umbilical cord-analyzer **361** determines whether any blood vessel is present between any of respective regions to be determined and the reference regions (S**07**). When there is a blood vessel (S**07**, Yes), the umbilical cord-analyzer **361** tracks that blood vessel to determine whether it leads to a reference region and a region to be determined (S**08**). If it does (S**08**, Yes), the umbilical cord-analyzer **361** associates the positional information indicating that region to be determined with the same fetus ID as the reference region (S**09**).

[0080] Moreover, the umbilical cord-analyzer **361** defines the region to be determined associated with the same fetus ID as a new reference region (S**10**) and repeats S**06**-S**09**.

[0081] As a result of the determination by the umbilical cord-analyzer **361**, there may be no regions to be determined where blood vessels are present between those regions and a reference region (S**07**, No) and also there may be no regions to be determined that are connected with a reference region via a blood vessel (S**08**, No), and moreover, there may be the case where all the matching regions have not been set as reference regions (S**11**, No). In these cases, the umbilical cord-analyzer **361** repeats processing from S**04** to S**10**. In other words, the umbilical cord-analyzer **361** issues a new fetus ID for a matching region not associated with a fetus ID and searches for a new umbilical cord P3 that includes that region.

[0082] If the umbilical cord-analyzer **361** has set all the matching regions as reference regions (S**11**, Yes), the process of specifying the umbilical cord P3 is finished.

[0083] Next, FIG. **8** is a flowchart showing the process of specifying the structure P4. When the process of specifying the umbilical cord P3 using the umbilical cord-analyzer **361** is finished, the structure-analyzer **362** reads a B-mode image (S**12**). Then, the structure-analyzer **362** specifies a fetus ID that has not yet been identified for the structure P4 (S**13**). Moreover, the structure-analyzer **362** reads the collection of positional information associated with that fetus ID (S**14**).

[0084] When the structure-analyzer **362** reads the B-mode image and collection of positional information, the structure-analyzer **362** further searches for a reference point P**5** located at the farthest point of that positional information (S**15**). Then, the structure-analyzer **362**, using as comparison subjects, from among the voxels around that reference point P5, voxels that have not yet been determined to be one component of the structure P**4**, compares the predefined threshold to the pixel value of those voxels. (S**16**).

[0085] As a result of the comparison, when there is any voxel that has a pixel value above the predefined threshold

(S**16**, Yes), the structure-analyzer **362**, treating that voxel as one component of the structure P**4**, associates positional information of that voxel with the specified fetus ID (S**17**).

[0086] Moreover, the structure-analyzer **362** handles each voxel that has been made one component of the structure P**4** as a reference point **P5** (S**18**), and repeats S**16** and S**17**. On the other hand, as a result of the comparison, if there is no voxel that has a pixel value above the predefined threshold (S**16**, No) and if specifying all the fetus IDs is not finished (S**19**, No), structure-analyzer **362** repeats S**13**-S**19**. In this way, it implements the process of specifying the structure P**4** for a new fetus ID.

[0087] If specifying the structures P**4** for all the fetus IDs is finished (S**19**, Yes), the structure-analyzer **362** finishes the process of specifying the structure P**4** continuing into the umbilical cord for each fetus ID, in other words, for each specified umbilical cord P**3**.

[0088] Next, FIG. **9** is a flowchart showing the process of identifying the structure P**4**. When the process of specifying the structure P**4** is finished, from the viewpoint set by the operator via the operating part **39**, the display controller **37** implements the process of volume rendering on the collection of voxels indicated by the positional information associated with all the fetus IDs (S**20**).

[0089] Moreover, the display controller **37** specifies one pixel representing a projected image generated by the volume rendering process (S**21**). The display controller **37** obtains positional information of the voxel corresponding to the specified pixel (S**22**). When the display controller **37** obtains positional information, it searches for a fetus ID associated with the obtained positional information (S**23**). The display controller **37** refers to the list and reads hue information corresponding to the fetus ID (S**24**).

[0090] When the display controller **37** reads hue information, it adds a pixel value representing the hue corresponding to that hue information to the pixel specified at S**20** (S**25**).

[0091] The display controller **37** repeats processing from S**21** to S**25** for all the pixels representing the projected image (S**26**, No). When the display controller **37** finishes processing all the pixels (S**26**, Yes), the display controller **37** outputs the projected image that has been generated to the display **38** (S**27**).

[0092] FIG. **10** is a pattern diagram showing a screen from the ultrasound imaging apparatus **1**. As shown in FIG. **10**, the structures P**4**, i.e., the fetuses, are displayed on the screen, with each individual being distinguished by color. Therefore, even when there are multiple fetuses in the womb, it is easy for physicians and others to confirm the condition of each fetus, thus improving the accuracy of measuring the growth condition of the fetuses, etc.

[0093] FIG. **11** is a pattern diagram showing a second aspect of a screen from the ultrasound imaging apparatus **1**. Although the case where the fetuses are displayed such that they are distinguished by color has been described above, alternatively, as shown in FIG. **11**, the screen may be divided so as to display a separate window for each fetus.

[0094] In this case, from the viewpoint set by the operator via the operating part **39**, the display controller **37** implements a volume rendering process for each collection of voxels indicated by positional information associated with each fetus ID. Then, the display controller **37** causes the respective projected images to be displayed in separate windows.

[0095] FIG. **12** is a pattern diagram showing a third aspect of a screen from the ultrasound imaging apparatus **1**. Although the examples of identification and display by means of distinguishing fetuses by color and dividing the screen for each fetus have been described above, alternatively, as shown in FIG. **12**, the display controller **37** may display only one fetus in response to a switching operation via the operating part **39**.

[0096] In this case, in the volume rendering process at S**20**, from the viewpoint set by the operator via the operating part **39**, the display controller **37** implements a volume rendering process per collection of voxels indicated by positional information associated with each fetus ID. Then, the display controller **37** switches each P**4** that has undergone volume rendering to cause it to be displayed in series, according to the number of times the switching operation has taken place.

[0097] For example, suppose that there is a collection of positional information associated with fetus IDs A, B, and C respectively, i.e. there are three fetuses. In the first display, the display controller **37** implements a volume rendering process on the collection of voxels indicated by positional information associated with the fetus ID A. The display controller **37** causes only the fetus obtained by the process to be displayed.

[0098] When the first switching operation is performed, the display controller **37** implements a volume rendering process on the collection of voxels indicated by positional information associated with the fetus ID B. The display controller **37** causes only the fetus obtained by the process to be displayed.

[0099] When the second switching operation is performed, the display controller **37** implements a volume rendering process on the collection of voxels indicated by positional information associated with the fetus ID C. The display controller **37** causes only the fetus obtained by the process to be displayed.

[0100] When the third switching operation is performed, returning to the first display, the display controller **37** implements a volume rendering process on the collection of voxels indicated by positional information associated with the fetus ID A The display controller **37** causes only the fetus obtained by the process to be displayed.

[0101] With these modes of identification and display indicated by FIGS. **11** and **12** also, it becomes easy for physicians and others to identify multiple fetuses, improving the accuracy of measuring the growth condition of the fetuses, etc.

[0102] Next, the second embodiment for identifying and displaying fetuses is described. The ultrasound imaging apparatus **1** according to the second embodiment specifies the same fetuses both in the past and in new examinations. More particularly, specification using this ultrasound imaging apparatus **1** is as follows. The ultrasound imaging apparatus **1** stores the position of the placenta connected to a fetus.

[0103] The ultrasound imaging apparatus **1** specifies the same fetus in a new examination based on the stored placenta position. Because the fetus moves about freely in the womb and the umbilical cord also moves following it, it is difficult for physicians and others to specify the same fetus based on the position where the fetus is present, etc.

[0104] However, because the placenta position is specific to each fetus and that position has been determined, by linking the placenta position with the fetus connected to it, the same fetus can be identified.

[0105] FIG. **13** is a configuration diagram of the analyzer **36** according to the second embodiment. As shown in FIG. **13**, in addition to the umbilical cord-analyzer **361** and the structure-analyzer **362**, this analyzer **36** has a storage **363** and a placenta-analyzer **364**.

[0106] The storage **363** is nonvolatile memory. As shown in FIG. **14**, for each patient ID, the storage **363** stores combinations of fetus IDs and placenta positional information, and display mode information. The placenta positional information is information indicating the position at the farthest point opposite the structure P**4** of the umbilical cord P**3**, which is represented using coordinates (X, Y, Z). The display mode information is indicated by the position of the viewpoint, rotational angle and distance to the three-dimensional image, which are set by the operator via the operating part **39**. The patient ID is the ID of a subject, which is preinput by the operator via the operating part **39**. In other words, the storage **363** stores placenta positional information for each structure P**4** that continues into the same umbilical cord as that placenta; that is, for each fetus ID.

[0107] The placenta-analyzer **364**, in each examination, specifies the position of the placenta that continues into each umbilical cord P**3** and generates placenta positional information based on the specified position. More particularly, it tracks the collection of positional information obtained by the umbilical cord-analyzer **361** and defines the positional information as the farthest position of the placenta. The placenta-analyzer **364**, from both ends of the umbilical cord P**3**, defines as the placenta positional information an end point that is opposite to the end point defined as reference point P**5** by the structure-analyzer **362**.

[0108] In addition, the placenta-analyzer **364** causes the placenta positional information to be stored in the storage **363**. More particularly, the placenta-analyzer **364** obtains a fetus ID associated with the collection of positional information that indicates the tracked umbilical cord P**3**. The placenta-analyzer **364** associates this obtained fetus ID with the placenta positional information to cause it to be stored under the patient ID.

[0109] If the combination of fetus ID and placenta positional information has been already stored for the patient ID, in order to incorporate changes in the placenta position depending on differences in gestational weeks so as to improve the accuracy, the placenta-analyzer **364** may replace the combination with the new combination, thereby causing it to be stored. It is desirable that the replacing and storing is implemented after the placenta-analyzer **364** reproduces the identifying mode of the fetus used in the previous examination, e.g., after the examination is finished. Alternatively, first-time only storage of the placenta positional information may be implemented.

[0110] In a new examination, if the patient ID input using the operating part **39** has been stored in the storage **363**, the display controller **37** adds a hue that corresponds to the fetus ID in the list, combined with the placenta positional information generated at the placenta-analyzer **364**, to the structure P**4** that continues from the placenta position indicated by the placenta positional information generated by this placenta-analyzer **364**, and causes it to be displayed.

[0111] In comparing the placenta positional information obtained in a new examination to the placenta positional information stored in the storage **363**, it is necessary that these sets of placenta positional information be represented with the same coordinate system. Therefore, before starting the examination, the display controller **37** causes a probe movement route R that guides the movement route of the ultrasound probe **2** to be displayed on the display **38**, as shown in FIG. **15**. The probe movement route R is the start position of scanning with the ultrasound probe **2**; in other words, an arrow indicating the origin position at which the ultrasound probe **2** is initially placed, and the direction in which the ultrasound probe **2** is to be moved.

[0112] The display controller **37** prestores a subject model M, origin position, and directional information for drawing this probe movement route R. The display controller **37** draws the probe movement route R pointing in the direction indicated by the directional information from the origin point, and causes it to be displayed on the display **38**.

[0113] In addition, if the patient ID input using the operating part **39** has been stored in the storage **363**, the display controller **37** implements a volume rendering process at the viewpoint indicated by the display mode information stored in association with that patient ID. This display mode information is stored in association with the patient ID by the display controller **37**.

[0114] FIG. **16** is a flowchart showing an operation to store the placenta position in the storage **363**. First, the patient ID is input in advance by the operator via the operating part **39** (S**31**). If the input patient ID has not been stored in the storage **363**, the placenta-analyzer **364** causes that patient ID to be stored (S**32**).

[0115] Subsequently, after the umbilical cord-analyzer **361** specifies the umbilical cord P**3**, the structure-analyzer **362** specifies the structure P**4**.

[0116] Either after the structure P**4** is specified or after an image is output, the placenta-analyzer **364** first specifies a fetus ID that has not yet been specified for the placenta position (S**33**). The placenta-analyzer **364** reads an umbilical cord P**3** part based on the collection of positional information associated with the specified fetus ID (S**34**). When the umbilical cord P**3** is read, the placenta-analyzer **364**, from among the positional information of the umbilical cord P**3**, obtains positional information of the location at the opposite end from the structure P**4** (S**35**).

[0117] When the positional information is obtained, the placenta-analyzer **364** links the association between the placenta positional information represented by this positional information and the fetus ID specified at S**31** with the input patient ID, and causes it to be stored in the storage **363** (S**36**).

[0118] Next, triggered by end of the examination, etc., the display controller **37** links the viewpoint used for the volume rendering process, as the display mode information, with the input patient ID, and causes it to be stored in the storage **363** (S**37**).

[0119] In this way, for the past examinations of the subject represented with the patient ID, the fact that structure P**4** specified with the placenta positional information has been displayed in the identifying mode is stored, represented by the fetus ID, in addition to which the viewpoint at that time is stored.

[0120] FIG. **17** is a flowchart showing an operation to reproduce the mode of identifying the fetus, even in a new examination.

[0121] First, among fetus IDs issued at S**05** in the current examination, the placenta-analyzer **364** specifies a fetus ID that has not yet been identified for the placenta position (S**41**). The placenta-analyzer **364** reads an umbilical cord P**3** part from the collection of positional information associated with that fetus ID (S**42**). When the umbilical cord P**3** is read, the placenta-analyzer **364**, from among the positional information of the umbilical cord P**3**, obtains positional information of a location at the opposite end from the structure P**4**, as placenta positional information (S**43**).

[0122] When the placenta positional information is obtained, the display controller **37** compares the obtained placenta positional information to each placenta positional information associated with the preinput patient ID (S**44**). When the comparison finds matching placenta positional information (S**44**, Yes), the display controller **37** replaces the fetus ID specified at S**41** by the fetus ID associated with that placenta positional information (S**45**).

[0123] In addition, in the comparison of placenta positional information, if a coordinate (x, y, z) indicated by the obtained placenta positional information is within a sphere of a predefined diameter around the coordinate (X, Y, Z) indicated by the placenta positional information stored in the storage **363**, both sets of information are considered to be a match.

[0124] In the current examination, if processing is not finished for all fetus IDs issued at S**05** (S**46**, No), S**41**-S**46** are repeated for the next fetus ID. Then, if processing is finished for all fetus IDs (S**46**, Yes), the display controller **37** implements the processes of identifying and displaying, starting from S**20**.

[0125] In addition, the display controller **37** may store the origin position of the probe movement route R for each gestational week, and cause the probe movement route R, extending from the origin point according to the gestational weeks input via the operating part **39**, to be displayed.

[0126] Also, the ultrasound imaging apparatus **1** may store the route along which the ultrasound probe **2** was actually moved, and convert the coordinates of placenta positional information obtained in a new examination from differences in the movement route of the new examination.

[0127] Specifically, the display controller **37** causes the subject model M to be displayed on the display **38** after the examination. Then, when the actual route along which the ultrasound probe **2** was moved in the examination is input by the operator via the operating part **39**, the display controller **37** causes that route to be drawn on the subject model M and also associates the origin position and directional information indicated by that route with the patient ID, and causes it to be stored in the storage **363**.

[0128] Upon a new examination, the display controller **37** generates a determinant that converts the coordinate system of the route input using the operating part **39** into the coordinate system indicated by the route stored in the storage **363**. The display controller **37** converts the coordinates indicated by placenta positional information obtained in the new examination using this determinant.

[0129] Then, the display controller **37** compares this placenta positional information after conversion to each placenta positional information stored in the storage **363** and colors the structure P**4** with a hue corresponding to the fetus ID associated with matching placenta positional information.

[0130] In this way, because the ultrasound imaging apparatus **1** according to the second embodiment specifies the same fetus in both past and new examinations, it is possible to reproduce, even in a new examination, the mode of identifying each fetus identified and displayed in past examinations. Therefore, it is possible for physicians and others to eliminate the task of confirming whom an identified and displayed fetus is, which provides good operational efficiency.

What is claimed is:

1. An ultrasound imaging apparatus having a probe configured to transmit ultrasound and receive reflected waves, a generator configured to generate an image based on said reflected waves, and a display that displays said image, wherein the ultrasound imaging apparatus comprising:

a first analyzer configured to specify respectively each umbilical cord present in said image;

a second analyzer configured to respectively specify a structure continuing into one end of said umbilical cord; and

a display controller configure to cause each said structure to be displayed on said identified and display.

2. The ultrasound imaging apparatus according to claim **1**, further comprising:

a third analyzer configured to specify a placenta position continuing into the other end of said umbilical cord; and

a storage configured to store said placenta position at the time of a past examination, for each said structure continuing into the same umbilical cord;

wherein said display controller is configured to compare said placenta position at the time of a new examination to the placenta position stored in said storage and to display said structure continuing from substantially the same placenta position as the said past examination, in the same identification mode.

3. The ultrasound imaging apparatus according to claim **2**, wherein:

said third analyzer is configured to specify the other end of said umbilical cord as the placenta position.

4. The ultrasound imaging apparatus according to claim **2**, further comprising:

an operating part configured to enter an actual route along which said probe moves, upon transmitting and receiving said ultrasound, wherein:

said storage is further configured to store said actual route when storing said placenta; and

said display controller is configured to perform said comparison after transforming said placenta position specified by said third analyzer upon the new examination, based on the coordinate system of said stored actual route.

5. The ultrasound imaging apparatus according to claim **2**, wherein:

said display controller is configured to cause said display to display in advance a probe movement route that guides the movement route of said probe before transmitting and receiving the ultrasound.

6. The ultrasound imaging apparatus according to claim **5**, wherein:

said display controller is configured to:

store gestational weeks in association with a correction value for correcting said probe movement route; and

cause said probe movement route corrected with the correction value corresponding to the gestational weeks of the subject to be displayed.

7. The ultrasound imaging apparatus according to claim **1**, wherein:

said first analyzer is configured to:

store in advance a predicted running pattern of blood vessels running in the said umbilical cord; and

scan said image using the predicted running pattern to identify said umbilical cord.

8. The ultrasound imaging apparatus according to claim **1**, wherein:

said display controller is configured to color said each structure with a different color, and cause it to be displayed.

9. The ultrasound imaging apparatus according to claim **1**, further comprising:

an operating part configured to enter a switching operation, wherein said display controller is configured to color only one structure according to said switching operation, and cause it to be displayed.

10. The ultrasound imaging apparatus according to claim **1**, wherein:

said display controller is configured to divide a screen for each said structure, and cause it to be displayed.

11. The ultrasound imaging apparatus according to claim **1**, further comprising:

an operating part configured to enter a display mode including at least the angle of the image, wherein:

said storage is further configured to store the display mode displayed on said display; and

said display controller is configured to display the image in the same display mode each time.

* * * * *

patsnap

专利名称(译)	超声成像设备		
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申请(专利权)人(译)	株式会社东芝 东芝医疗系统公司		
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摘要(译)

发送超声波并接收反射波，并基于反射波生成图像。然后，分别指定图像中存在的每个脐带，并且指定连续到指定脐带的一端的相应结构。通过分色，分屏，显示切换等识别每个指定的结构并在监视器上显示。