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(57) **ABSTRACT**

An analyzer in an embodiment includes processing circuitry. The processing circuitry identifies at least a part of a contour of a heart of a subject for an image corresponding to a first cardiac time phase and an image corresponding to a second cardiac time phase that are included in time-series images including the heart of the subject. The processing circuitry calculates, using the information about the identified contours, a first cardiac function parameter representing at least one of a volume or an ejection fraction of a heart chamber and a second cardiac function parameter representing a global strain of a myocardium corresponding to the heart chamber. The processing circuitry causes the first cardiac function parameter and the second cardiac function parameter to be displayed by common operation.

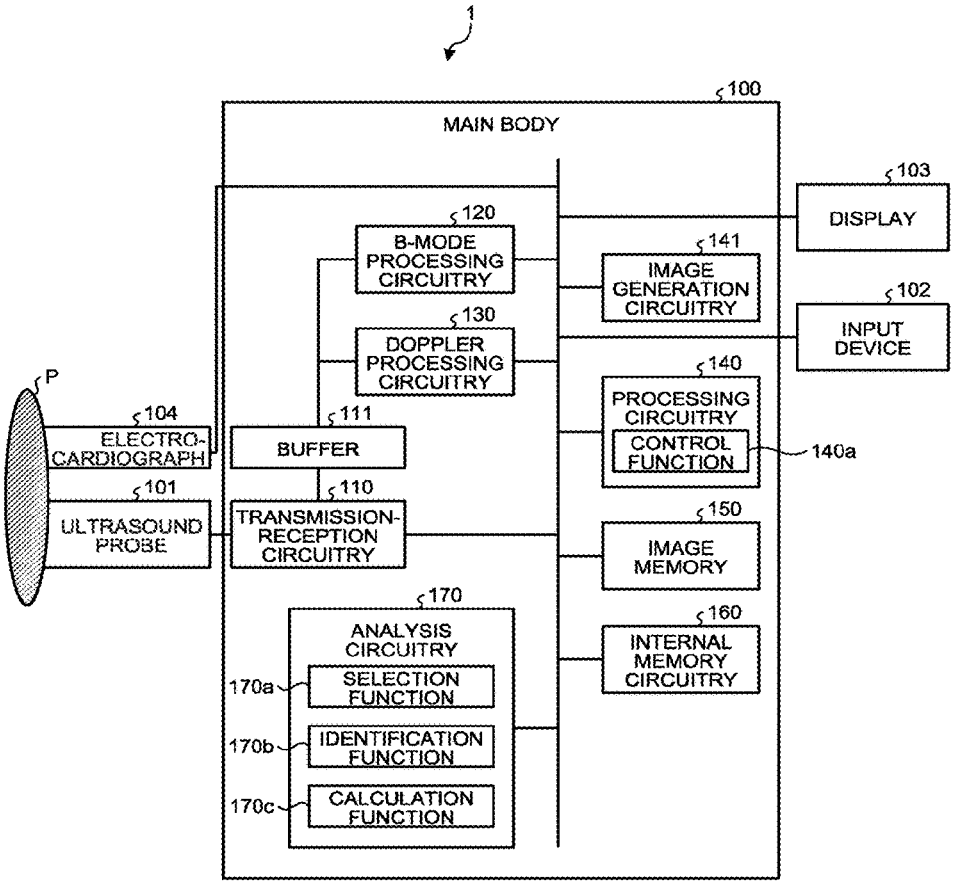


FIG.1

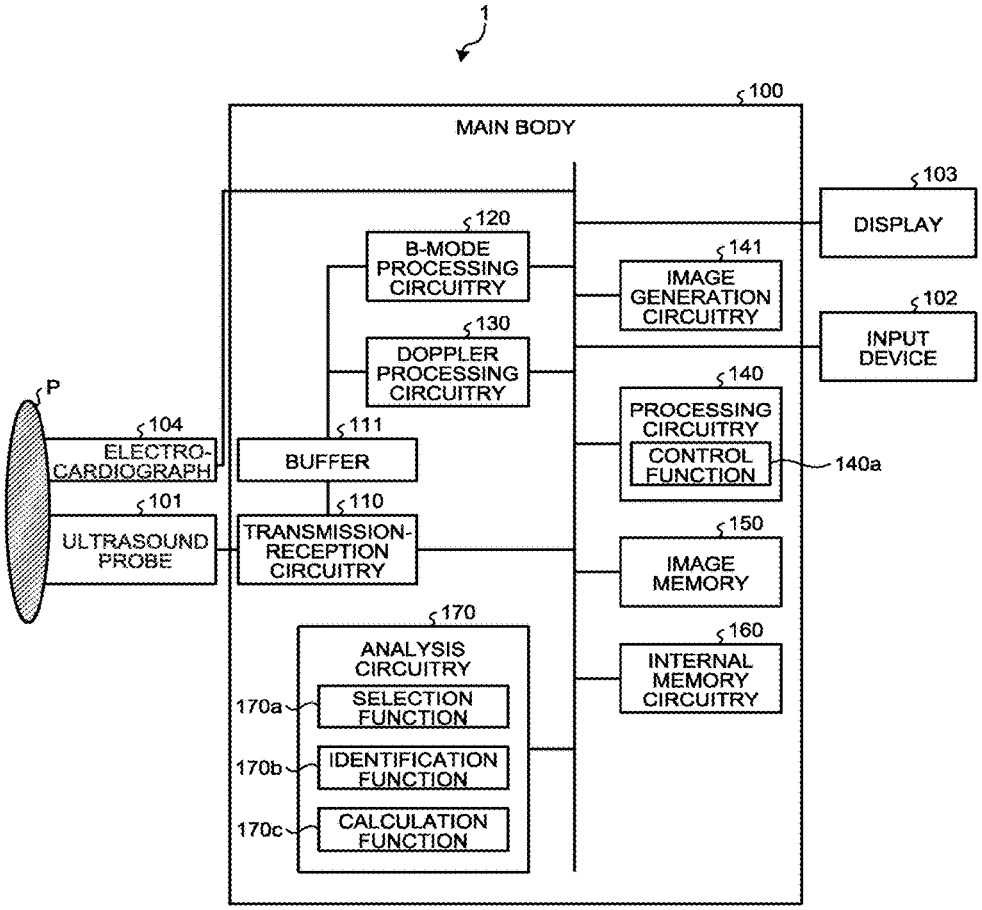

1
100
MAIN BODY
103
DISPLAY
120
B-MODE PROCESSING CIRCUITRY
141
IMAGE GENERATION CIRCUITRY
102
INPUT DEVICE
130
DOPPLER PROCESSING CIRCUITRY
140
PROCESSING CIRCUITRY
CONTROL FUNCTION
140a
P
104
ELECTRO-CARDIOGRAPH
111
BUFFER
101
ULTRASOUND PROBE
110
TRANSMISSION-RECEPTION CIRCUITRY
150
IMAGE MEMORY
170
ANALYSIS CIRCUITRY
160
INTERNAL MEMORY CIRCUITRY
170a
SELECTION FUNCTION
170b
IDENTIFICATION FUNCTION
170c
CALCULATION FUNCTION

FIG.2

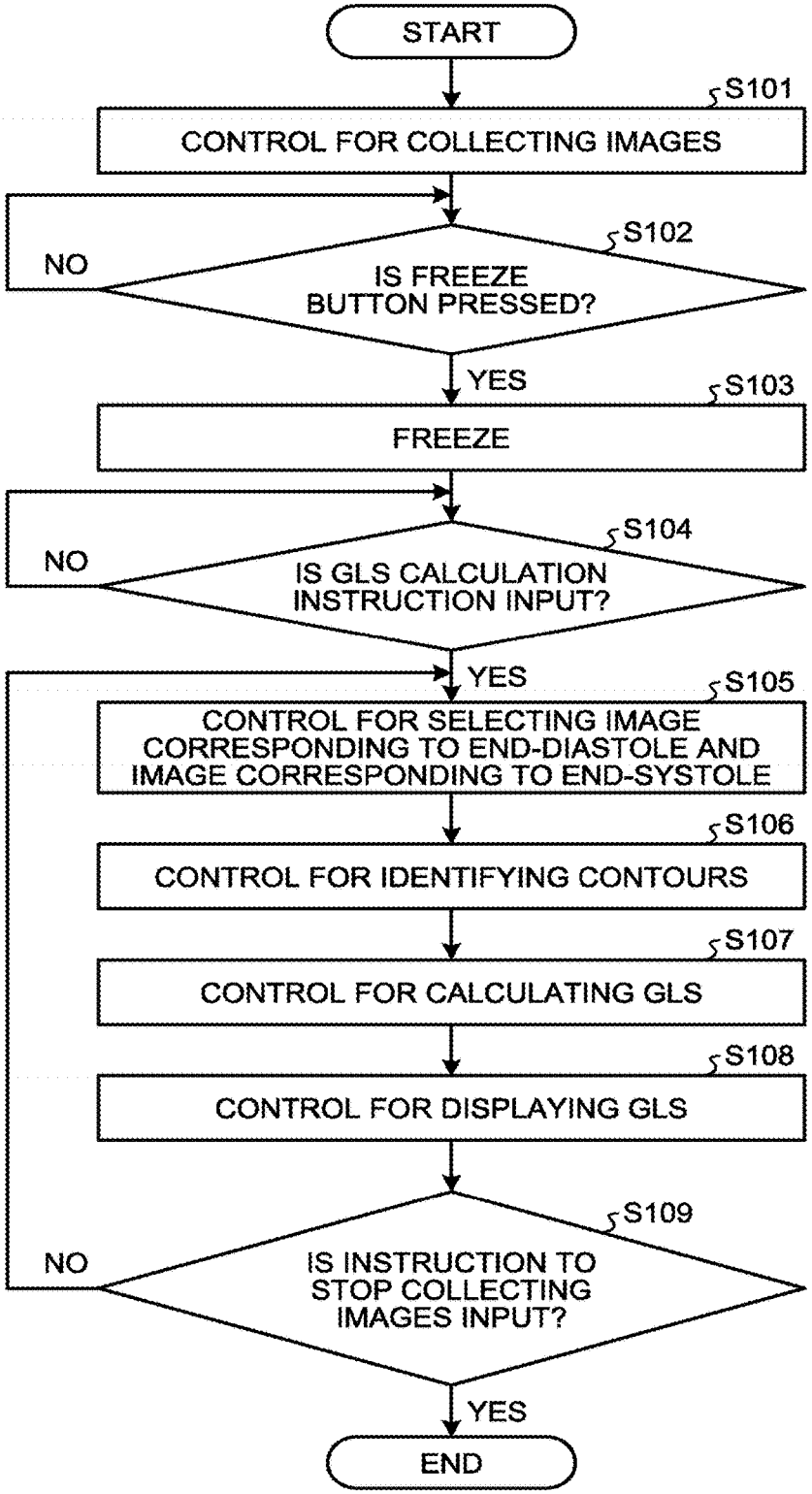

START
S101
CONTROL FOR COLLECTING IMAGES
S102
NO
IS FREEZE BUTTON PRESSED?
YES
S103
FREEZE
S104
NO
IS GLS CALCULATION INSTRUCTION INPUT?
YES
S105
CONTROL FOR SELECTING IMAGE CORRESPONDING TO END-DIASTOLE AND IMAGE CORRESPONDING TO END-SYSTOLE
S106
CONTROL FOR IDENTIFYING CONTOURS
S107
CONTROL FOR CALCULATING GLS
S108
CONTROL FOR DISPLAYING GLS
S109
NO
IS INSTRUCTION TO STOP COLLECTING IMAGES INPUT?
YES
END

FIG.3

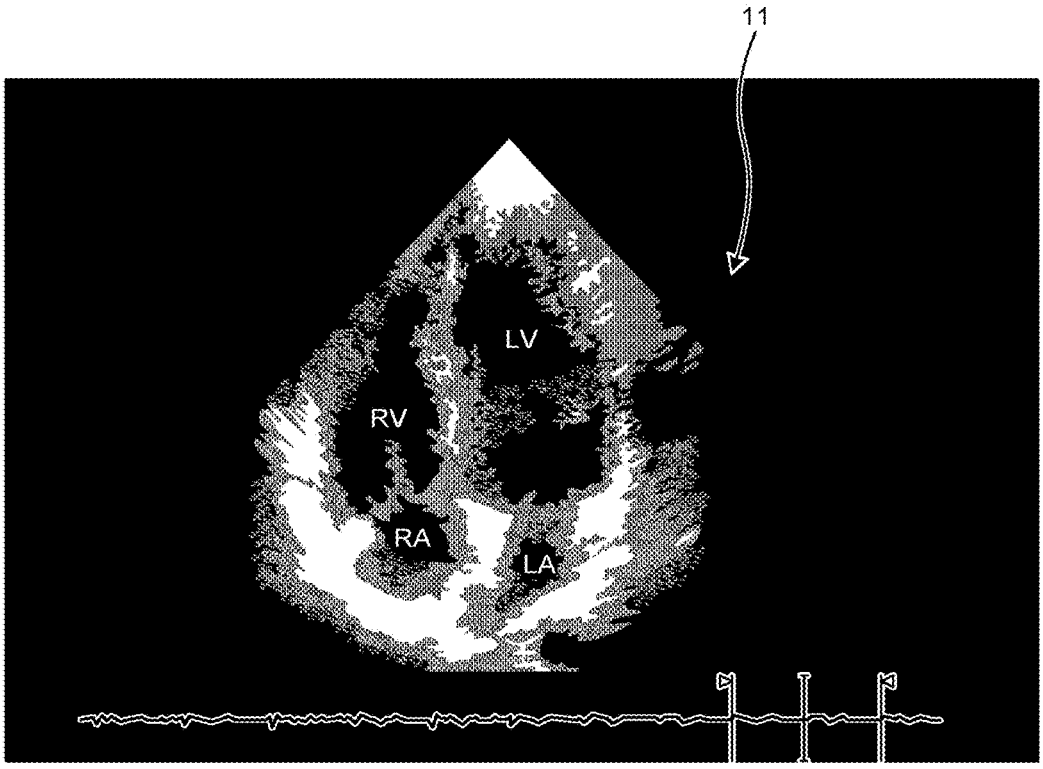


FIG.4

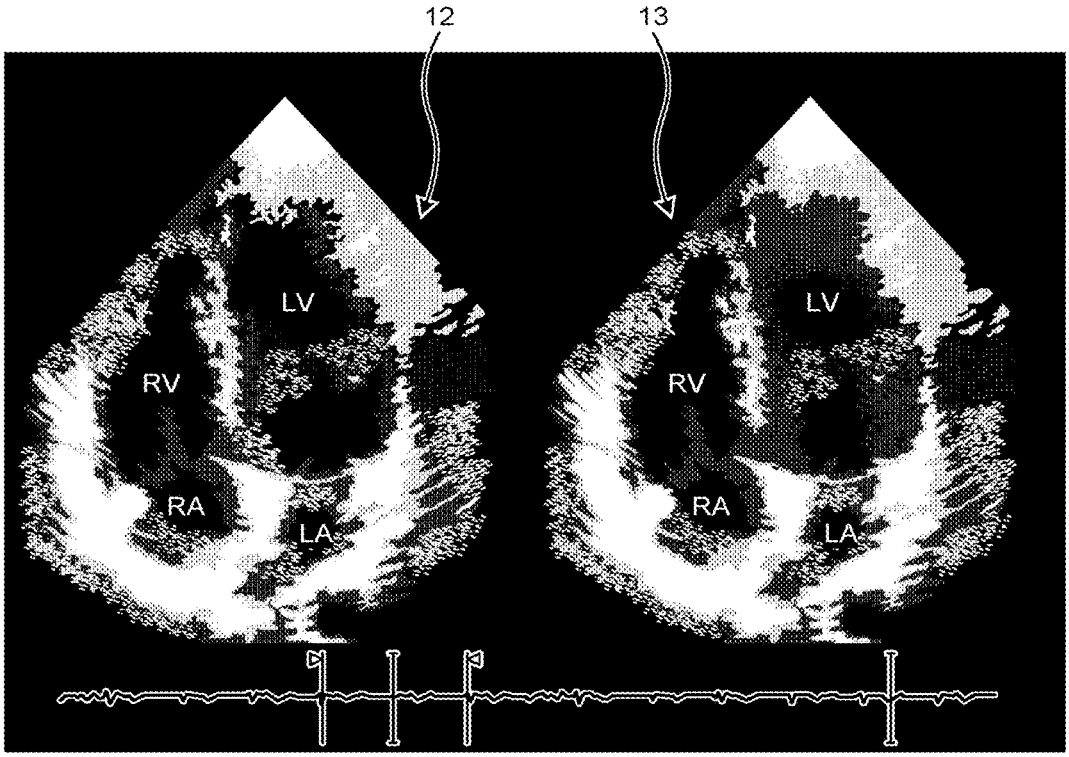


FIG.5

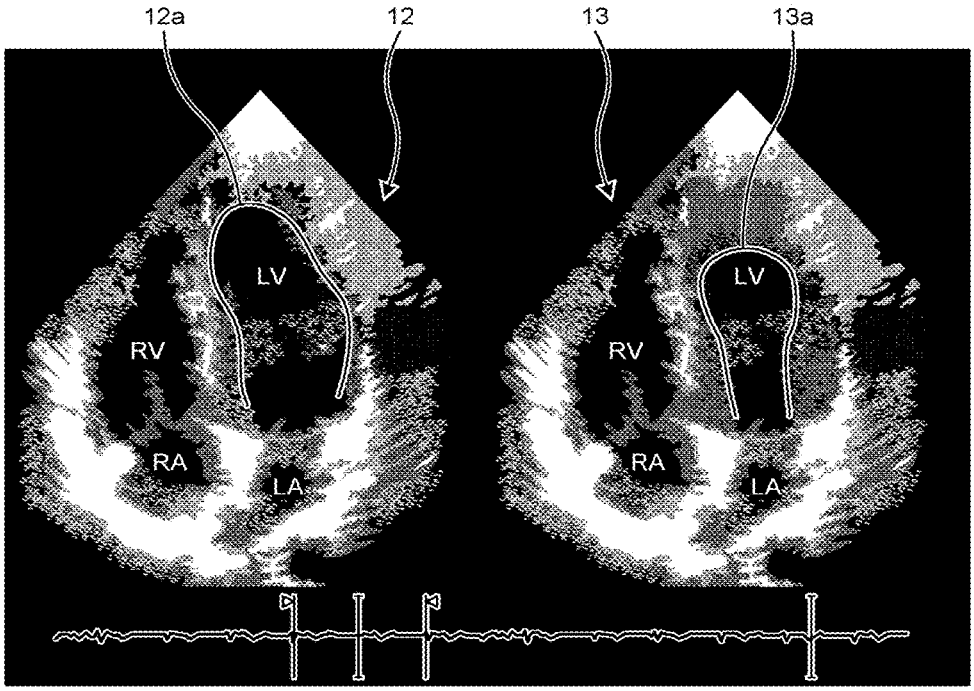


FIG.6

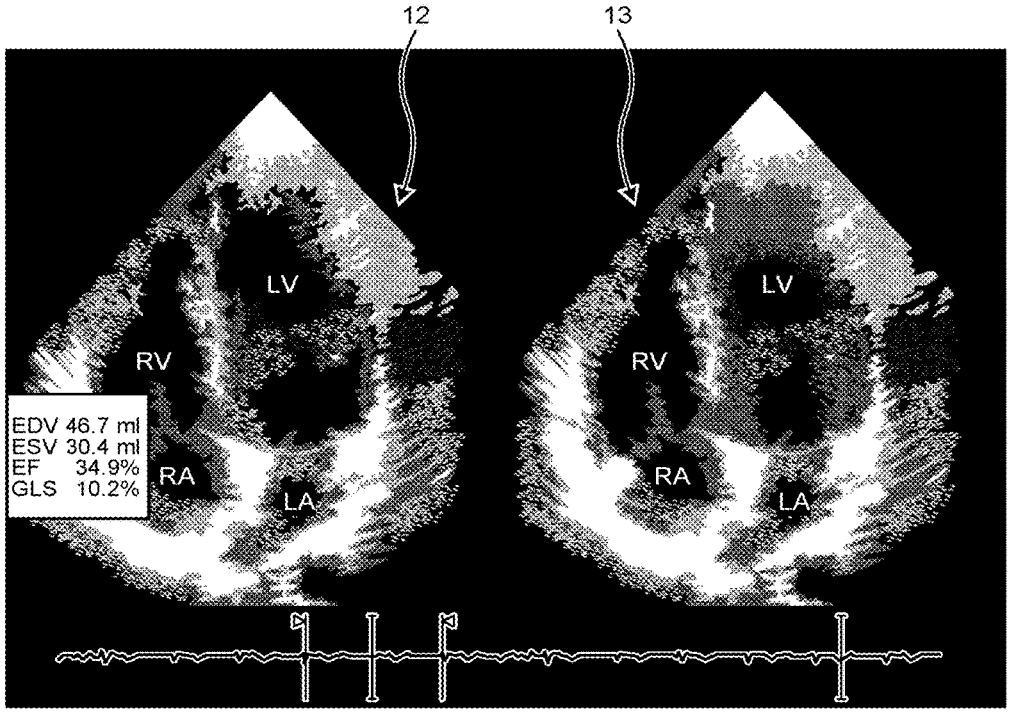

12
13
LV
RV
RA
LA
EDV 46.7 ml
ESV 30.4 ml
EF 34.9%
GLS 10.2%
LV
RV
RA
LA

FIG.7

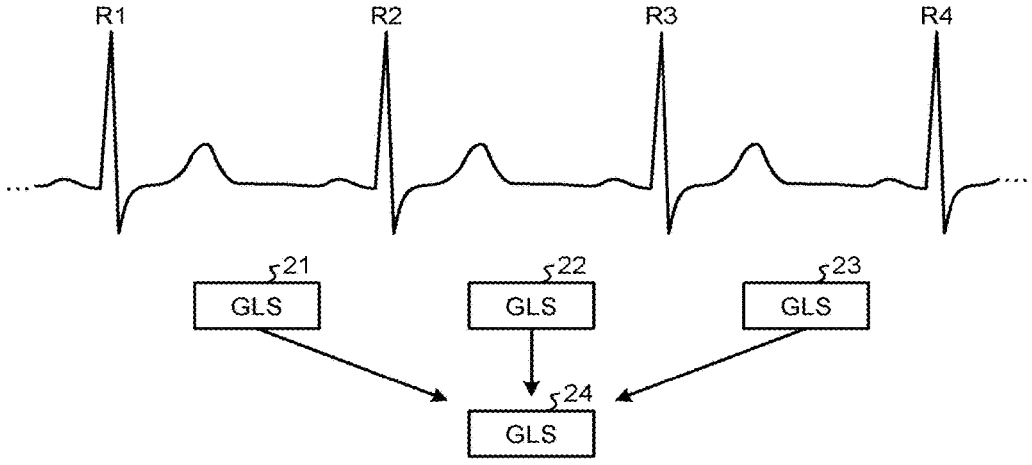

R1
R2
R3
R4
21
GLS
22
GLS
23
GLS
24
GLS

FIG.8A

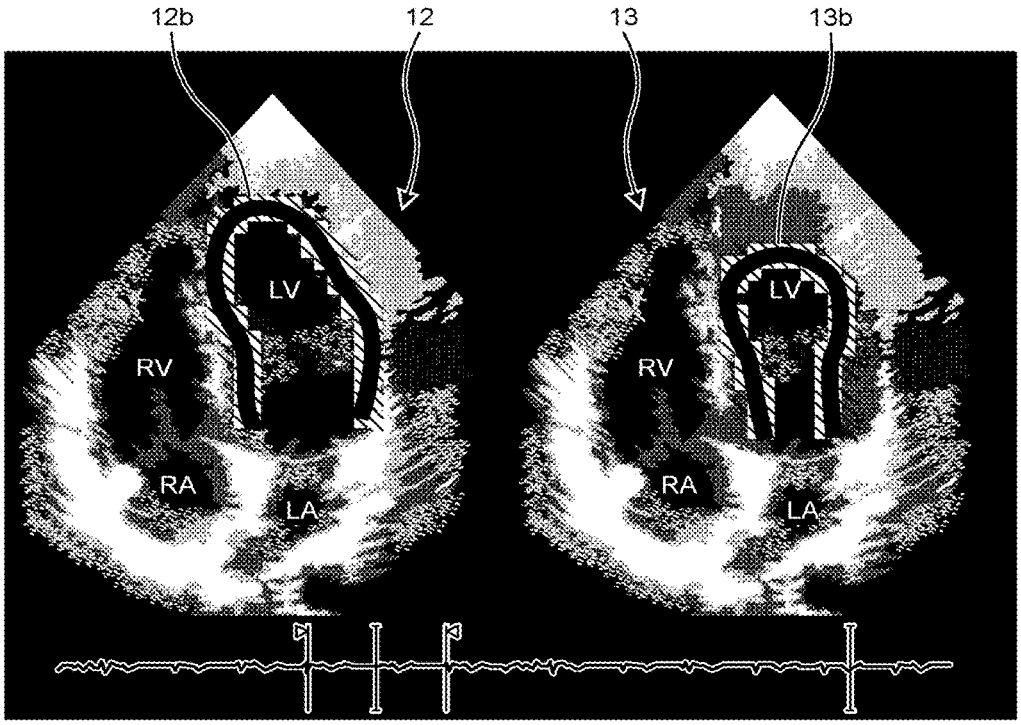


FIG.8B

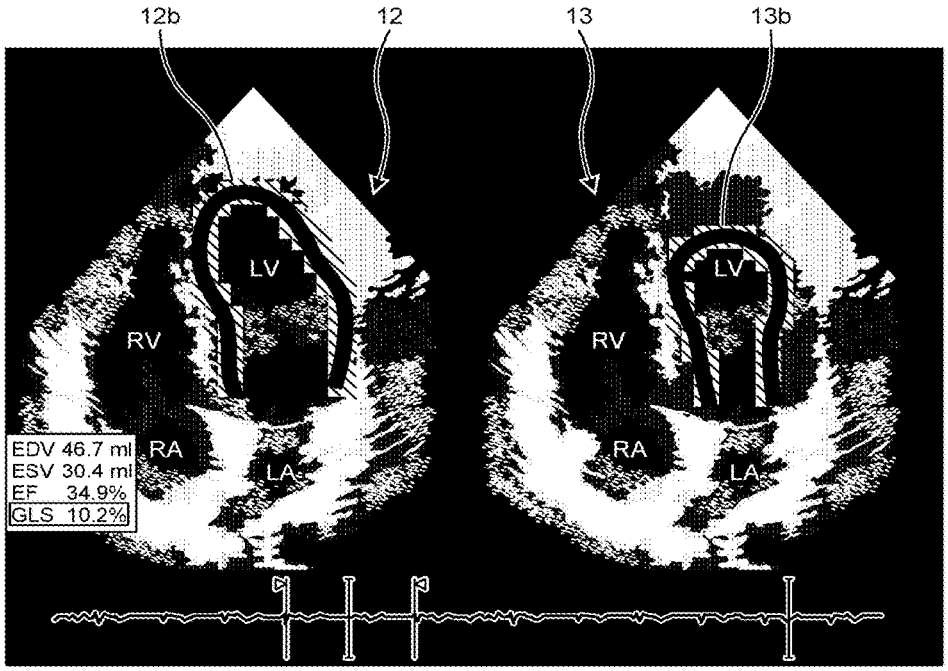

12b
12
13
13b
LV
RV
RA
LA
EDV 46.7 ml
ESV 30.4 ml
EF 34.9%
GLS 10.2%
LV
RV
RA
LA

FIG.9

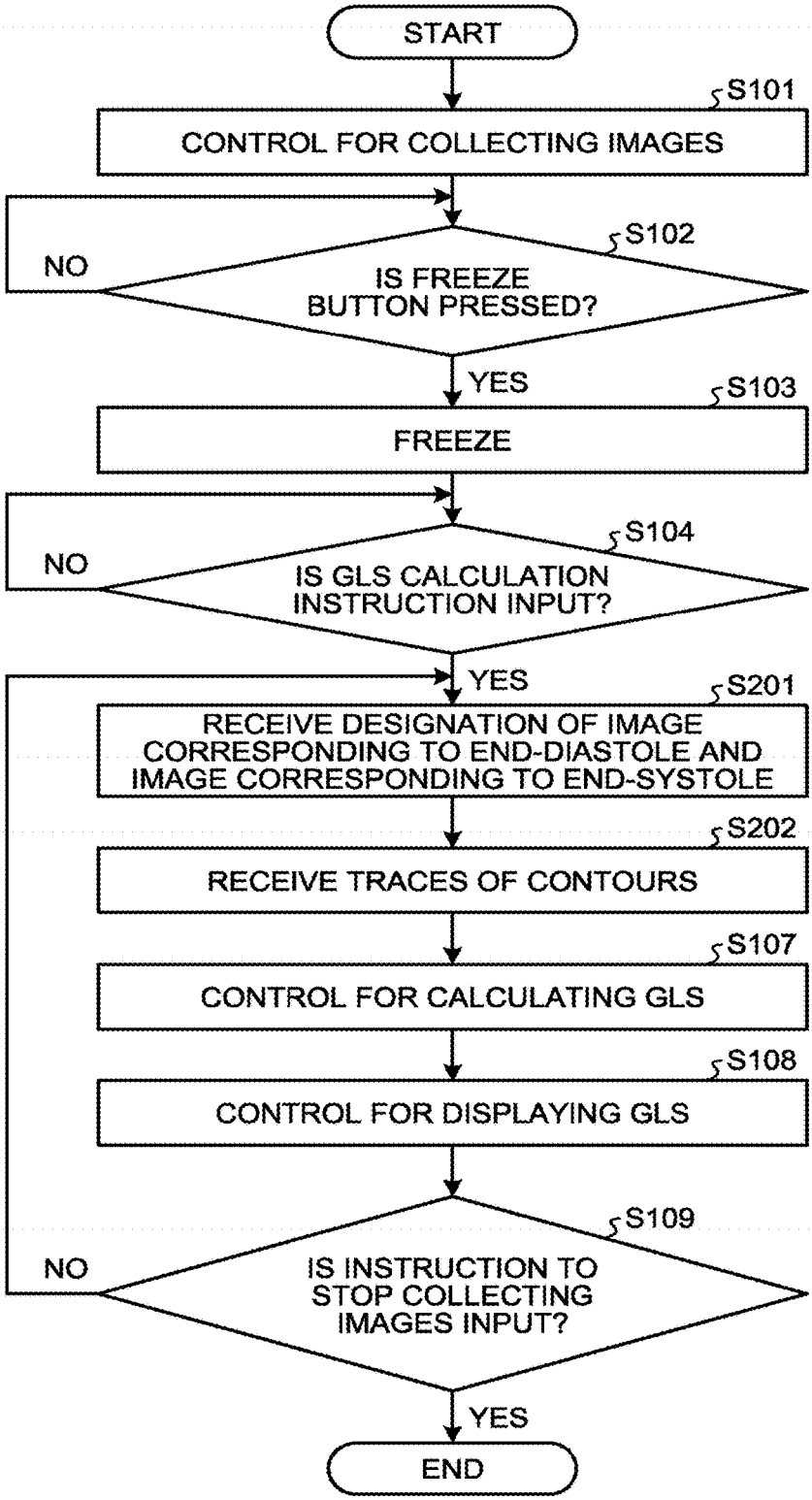

START
S101
CONTROL FOR COLLECTING IMAGES
S102
NO
IS FREEZE BUTTON PRESSED?
YES
S103
FREEZE
S104
NO
IS GLS CALCULATION INSTRUCTION INPUT?
YES
S201
RECEIVE DESIGNATION OF IMAGE CORRESPONDING TO END-DIASTOLE AND IMAGE CORRESPONDING TO END-SYSTOLE
S202
RECEIVE TRACES OF CONTOURS
S107
CONTROL FOR CALCULATING GLS
S108
CONTROL FOR DISPLAYING GLS
S109
NO
IS INSTRUCTION TO STOP COLLECTING IMAGES INPUT?
YES
END

FIG.10

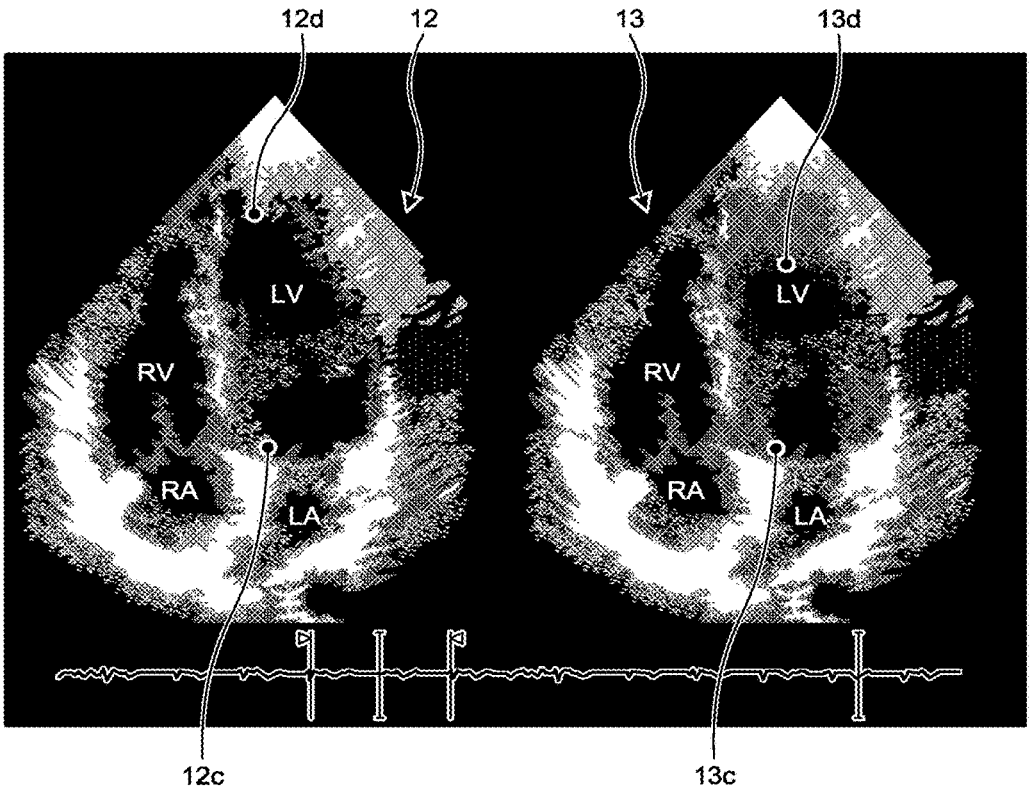
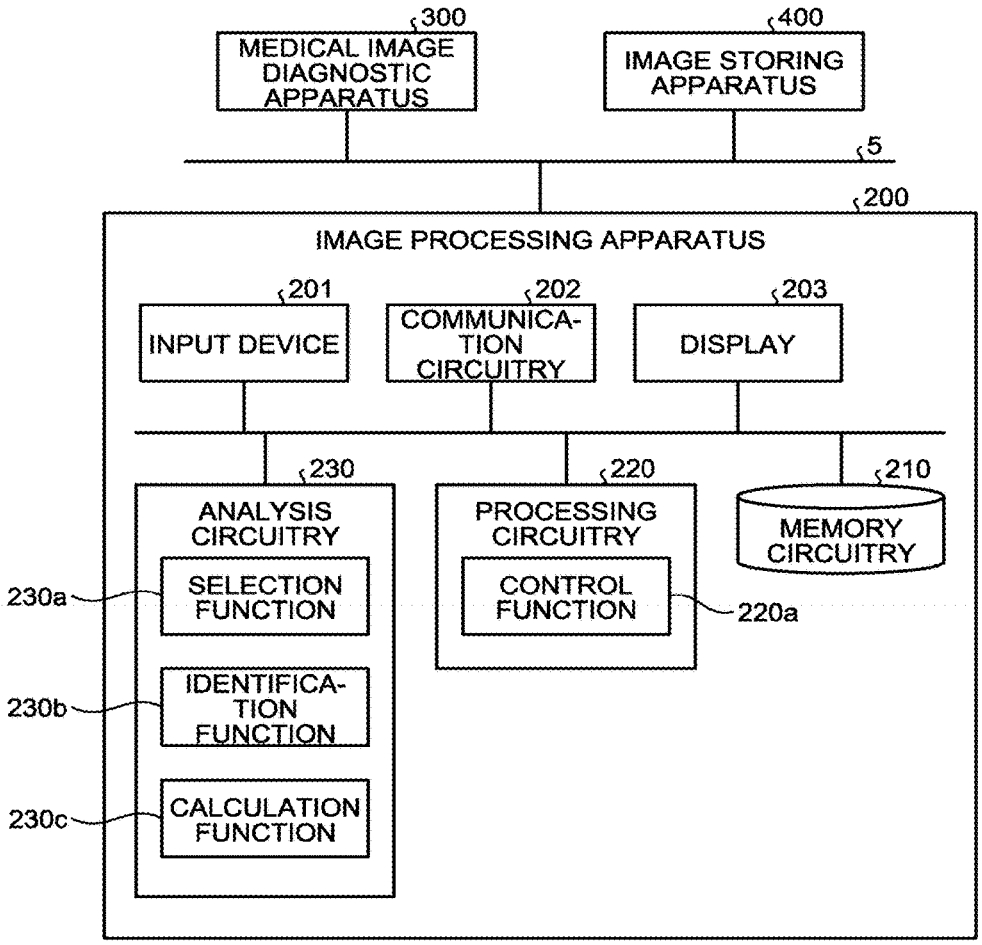


FIG.11


300
MEDICAL IMAGE DIAGNOSTIC APPARATUS
400
IMAGE STORING APPARATUS
5
200
IMAGE PROCESSING APPARATUS
201
INPUT DEVICE
202
COMMUNICA-TION CIRCUITRY
203
DISPLAY
230
ANALYSIS CIRCUITRY
220
PROCESSING CIRCUITRY
210
MEMORY CIRCUITRY
230a
SELECTION FUNCTION
CONTROL FUNCTION
220a
230b
IDENTIFICA-TION FUNCTION
230c
CALCULATION FUNCTION

ANALYZER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2016-042372, filed on Mar. 4, 2016; and Japanese Patent Application No. 2017-040239, filed on Mar. 3, 2017; the entire contents of which are incorporated herein by reference.

FIELD

[0002] Embodiments described herein relate generally to an analyzer.

BACKGROUND

[0003] There have been ultrasound diagnostic apparatuses that calculate, from reflected waves of ultrasound waves, myocardial strain indicators as cardiac function parameters having usefulness for diagnosis of cardiac diseases such as disease state elucidation, therapeutic effect determination, and prognosis estimation of various cardiac diseases. Among such myocardial strain indicators, a global longitudinal strain (GLS) is frequently used as an indicator for quantification of cardiac functions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIG. **1** is a block diagram illustrating an exemplary structure of an ultrasound diagnostic apparatus according to a first embodiment;

[0005] FIG. **2** is a flowchart illustrating an exemplary flow of processing performed by the ultrasound diagnostic apparatus according to the first embodiment;

[0006] FIG. **3** is a diagram for explaining an example of processing performed by a control function according to the first embodiment;

[0007] FIG. **4** is a diagram for explaining an example of processing performed by a selection function according to the first embodiment;

[0008] FIG. **5** is a diagram for explaining an example of processing performed by an identification function according to the first embodiment;

[0009] FIG. **6** is a diagram for explaining an example of the processing performed by the ultrasound diagnostic apparatus according to a second modification of the first embodiment;

[0010] FIG. **7** is a diagram for explaining an example of the processing performed by a calculation function according to a third modification of the first embodiment;

[0011] FIG. **8**A is a diagram for explaining an example of the processing performed by the control function according to a fourth modification of the first embodiment;

[0012] FIG. **8**B is a diagram for explaining another example of the processing performed by the control function according to the fourth modification of the first embodiment;

[0013] FIG. **9** is a flowchart illustrating an exemplary flow of processing performed by the ultrasound diagnostic apparatus according to a fifth modification of the first embodiment;

[0014] FIG. **10** is a diagram for explaining an example of the processing performed by the identification function and the calculation function according to a sixth modification of the first embodiment; and

[0015] FIG. **11** is a schematic diagram illustrating an exemplary structure of an image processing system according to a second embodiment.

DETAILED DESCRIPTION

[0016] An analyzer in each embodiment includes processing circuitry. The processing circuitry identifies a contour of at least a part of the heart of a subject for an image corresponding to a first cardiac time phase and an image corresponding to a second cardiac time phase that are included in time-series images including the heart of the subject. The processing circuitry calculates, using information about the identified contours, a first cardiac function parameter representing at least one of a volume and an ejection fraction of a heart chamber, and a second cardiac function parameter representing a global strain of a myocardium corresponding to the heart chamber. The processing circuitry causes the first cardiac function parameter and the second cardiac function parameter to be displayed by common operation.

[0017] The following describes an ultrasound diagnostic apparatus including a main body serving as the analyzer according to each of the embodiments with reference to the accompanying drawings. The embodiments can be appropriately combined.

First Embodiment

[0018] FIG. **1** is a block diagram illustrating an exemplary structure of the ultrasound diagnostic apparatus according to a first embodiment. As illustrated in FIG. **1**, this ultrasound diagnostic apparatus **1** according to the first embodiment includes an ultrasound probe **101**, an input device **102**, a display **103**, an electrocardiograph **104**, and a main body **100**. The ultrasound probe **101**, the input device **102**, the display **103**, and the electrocardiograph **104** are connected to the main body **100** so as to enable communication with each other. A subject P does not belong to the ultrasonic diagnostic apparatus **1**.

[0019] The ultrasound probe **101** transmits and receives ultrasound waves. The ultrasound probe **101** includes a plurality of transducer elements. The transducer elements generate ultrasound waves on the basis of drive signals supplied from transmission-reception circuitry **110** included in the main body **100**, which is described later. The transducer elements included in the ultrasound probe **101** receive reflected waves from the subject P and convert the reflected waves into electrical signals. The ultrasound probe **101** includes a matching layer provided to the transducer elements and a backing material preventing ultrasound waves from propagating backward from the transducer elements, for example. The ultrasound probe **101** is connected to the main body **100** in a detachable manner.

[0020] Ultrasound waves transmitted from the ultrasound probe **101** to the subject P are reflected by a discontinuous surface of acoustic impedance in body tissues of the subject P one after another, and received by the multiple transducer elements included in the ultrasound probe **101** as reflected wave signals. The amplitudes of the received reflected wave signals depend on differences in acoustic impedance of the discontinuous surfaces where ultrasound waves are reflected. The reflected wave signals of the transmitted ultrasound pulses reflected by moving bloodstream and a surface of a cardiac wall change in frequency depending on

velocity components of the moving object in the ultrasound wave transmission direction by a Doppler effect.

[0021] To the ultrasound probe **101** according to the first embodiment, a one-dimensional (1D) array probe that scans a two-dimensional region, and a fourth-dimensional (4D) array probe and two-dimensional (2D) array probe that scan a three-dimensional region are applicable. When scanning the two-dimensional region, the ultrasound probe **101** receives two-dimensional reflected wave signals. When scanning the three-dimensional region, the ultrasound probe **101** receives three-dimensional reflected wave signals.

[0022] The input device **102** includes devices such as a mouse, a keyboard, a button, a panel switch, a touch command screen, a foot switch, a trackball, a joystick, and a freeze button. The input device **102** receives various setting requests from a user of the ultrasound diagnostic apparatus **1** and transfers the received various setting requests to the main body **100**. The input device **102** is an example of an operation unit.

[0023] The display **103** displays a graphical user interface (GUI) allowing the user of the ultrasound diagnostic apparatus **1** to input various setting requests using the input device **102**, and a B mode image and a color Doppler image that are generated by the main body **100**, for example. The display **103** is achieved by a liquid crystal monitor, a cathode ray tube (CRT) monitor, or a touch panel, for example.

[0024] The electrocardiograph **104** acquires an electrocardiogram (ECG) of the subject P as a biosignal of the subject P. The electrocardiograph **104** transmits the acquired electrocardiogram to the main body **100**.

[0025] The main body **100** generates ultrasound image data on the basis of the reflected wave signals received by the ultrasound probe **101**. The main body **100** illustrated in FIG. **1** generates two-dimensional ultrasound image data on the basis of the two-dimensional reflected wave signals or three-dimensional ultrasound image data on the basis of the three-dimensional reflected wave signals.

[0026] As exemplarily illustrated in FIG. **1**, the main body **100** includes the transmission-reception circuitry **110**, a buffer **111**, B-mode processing circuitry **120**, Doppler processing circuitry **130**, processing circuitry **140**, image generation circuitry **141**, an image memory **150**, internal memory circuitry **160**, and analysis circuitry **170**. The transmission-reception circuitry **110**, the B-mode processing circuitry **120**, the Doppler processing circuitry **130**, the processing circuitry **140**, the image memory **150**, the internal memory circuitry **160**, and the analysis circuitry **170** are connected so as to enable communication one with another.

[0027] The transmission-reception circuitry **110** includes a pulse generator, transmission delay circuitry, and a pulser, for example, and supplies the drive signals to the ultrasound probe **101**. The pulse generator repeatedly generates rate pulses for the formation of transmission ultrasound waves at a certain repetition frequency (a pulse repetition frequency: PRF). The transmission delay circuitry provides, to each rate pulse generated by the pulse generator, a delay time for each transducer element necessary to converge ultrasound waves generated by the ultrasound probe **101** to a beam shape and to determine transmission directivity. The pulser applies drive signals (drive pulses) to the ultrasound probe **101** at timing based on the rate pulses. The transmission delay circuitry adjusts the transmission direction of ultrasound waves transmitted from the surfaces of the transducer elements to any direction by changing the delay time provided to each rate pulse.

[0028] The transmission-reception circuitry **110** has a function that can instantly change a transmission frequency and a transmission drive voltage for performing a certain scan sequence on the basis of an instruction from the processing circuitry **140**. Particularly, the change of the transmission drive voltage is achieved by a mechanism that electrically switches linear amplifier oscillation circuitries that can instantly switch the voltage or a plurality of power source units.

[0029] The transmission-reception circuitry **110** includes amplification circuitry, an analog to digital (A/D) converter, reception delay circuitry, an adder, and an orthogonal detector, for example. The transmission-reception circuitry **110** generates reflected wave data (echo data) by performing various types of processing on the reflected wave signals received by the ultrasound probe **101**. The transmission-reception circuitry **110** generates two-dimensional reflected wave data on the basis of the two-dimensional reflected wave signals. The transmission-reception circuitry **110** generates three-dimensional reflected wave data on the basis of the three-dimensional reflected wave signals.

[0030] The amplification circuitry amplifies the reflected wave signals for each channel to perform gain correction processing. The A/D converter A/D converts the gain corrected reflected wave signals. The reception delay circuitry provides the digital data with the reception delay times necessary to determine the reception directivity. The adder performs addition processing on the reflected wave signals to which the reception delay times are provided by the reception delay circuitry. The addition processing performed by the adder enhances the deflection components from the direction corresponding to the reception directivity of the reflected wave signals.

[0031] The orthogonal detector converts the output signal of the adder into an in-time phase signal (an I signal) and an orthogonal (quadrature-time phase) signal (a Q signal) in a baseband. The orthogonal detector stores the I signal and the Q signal (hereinafter described as the IQ signal) in the buffer **111** as the reflected wave data. The orthogonal detector may convert the output signal of the adder into a radio frequency (RF) signal and thereafter store the RF signal in the buffer **111**. The IQ signal and the RF signal are reception signals that include phase information.

[0032] The buffer **111** temporarily stores therein the reflected wave data (the IQ signal) generated by the transmission-reception circuitry **110**. Specifically, the buffer **111** stores therein the IQ signals corresponding to several frames or the IQ signals corresponding to several volumes. The buffer **111** is a first-in/first-out (FIFO) memory, for example, and stores therein the IQ signals corresponding to a predetermined number of frames. When the IQ signal of one frame is newly generated by the transmission-reception circuitry **110**, the buffer **111** destroys the IQ signal of one frame, the generated time of the IQ signal being the oldest, and stores therein the newly generated IQ signal of one frame, for example. The buffer **111** is connected to the transmission-reception circuitry **110**, the B-mode processing circuitry **120**, and the Doppler processing circuitry **130** so as to enable communication with each other.

[0033] The B-mode processing circuitry **120** and the Doppler processing circuitry **130** are each achieved by a pro-

cessor, for example. The B-mode processing circuitry **120** and the Doppler processing circuitry **130** perform various types of signal processing on the reflected wave data generated by the transmission-reception circuitry **110** from the reflected wave signals. The B-mode processing circuitry **120** reads the reflected wave data from the buffer **111** and performs logarithm amplification, envelope detection processing, and logarithm compression on the read reflected wave data to generate B-mode data in which a signal intensity is expressed by luminance for each of a number of points. The B-mode processing circuitry **120** generates two-dimensional B-mode data from the two-dimensional reflected wave data. The B-mode processing circuitry **120** generates three-dimensional B-mode data from the three-dimensional reflected wave data.

[0034] The Doppler processing circuitry **130** performs frequency analysis on the reflected wave data read from the buffer **111** to generate Doppler data in which movement information about a moving object in a scan range based on the Doppler effect is extracted. Specifically, the Doppler processing circuitry **130** generates the Doppler data in which an average speed, an average dispersion value, and the like are estimated as the movement information about the moving object for each of multiple sample points. The moving object is a bloodstream, a tissue of a cardiac wall, or a contrast agent, for example. The bloodstream is a bloodstream in a heart chamber, or a bloodstream in a cardiac wall, for example. The Doppler processing circuitry **130** according to the embodiment generates the Doppler data in which an average speed of a bloodstream, an average dispersion value of the bloodstream, and the like are estimated as the movement information (bloodstream information) about the bloodstream for each of multiple sample points. The Doppler processing circuitry **130** generates the two-dimensional Doppler data from the two-dimensional reflected wave data. The Doppler processing circuitry **130** generates the three-dimensional Doppler data from the three-dimensional reflected wave data.

[0035] The image generation circuitry **141** is achieved by a processor, for example. The image generation circuitry **141** generates ultrasound images from the data generated by the B-mode processing circuitry **120** and the Doppler processing circuitry **130**. Specifically, the image generation circuitry **141** generates a two-dimensional B-mode image in which an intensity of the reflected wave is expressed by luminance from the two-dimensional B-mode data generated by the B-mode processing circuitry **120**. The image generation circuitry **141** generates a two-dimensional Doppler image in which the bloodstream information is imaged from the two-dimensional Doppler data generated by the Doppler processing circuitry **130**. The two-dimensional Doppler image is an image of a velocity image, a distribution image, or an image of the combination of these images. The image generation circuitry **141** generates color Doppler image data displaying the bloodstream information with colors or Doppler image data displaying one piece of bloodstream information with a gray scale.

[0036] The image generation circuitry **141** generally generates the ultrasound image data for display by converting (scan converting) a scanning line signal string for ultrasound scanning into a scanning line signal string in a video format typified by a TV format. Specifically, the image generation circuitry **141** generates the ultrasound image data for display by coordinate transformation in accordance with the ultrasound scanning manner by the ultrasound probe **101**. The image generation circuitry **141** performs various types of image processing beside the scan conversion. For example, the image generating circuitry **141** performs image processing (smoothing processing) in which an image of average luminance is regenerated using a plurality of image frames after scan conversion or image processing (edge enhancement processing) in which a differential filter is used in an image. The image generation circuitry **141** combines character information including various parameters, a scale, and a body mark, for example, with the ultrasound image data.

[0037] The B-mode data and the Doppler data are the ultrasound image data before the scan conversion processing. The data generated by the image generation circuitry **141** is the ultrasound data for display after the scan conversion processing. The B-mode data and the Doppler data are also called raw data.

[0038] Furthermore, the image generation circuitry **141** generates a three-dimensional B-mode image by performing coordinate transformation on the three-dimensional B-mode data generated by the B-mode processing circuitry **120**. The image generation circuitry **141** generates a three-dimensional Doppler image by performing coordinate transformation on the three-dimensional Doppler data generated by the Doppler processing circuitry **130**.

[0039] Furthermore, the image generation circuitry **141** performs rendering processing on the volume data for producing various two-dimensional images used for displaying the volume data on the display **103**. One of the rendering processing performed by the image generation circuitry **141** is processing in which a multi-planar reconstruction (MPR) image is generated from the volume data by an MPR technique. Another one of the rendering processing performed by the image generation circuitry **141** is volume rendering (VR) processing in which the two-dimensional image is generated by reflecting three-dimensional information.

[0040] The image generation circuitry **141** stores the ultrasound image data for display and a time at which the ultrasound scanning is performed for producing the ultrasound image data in the image memory **150** in association with an electrocardiogram transmitted from the electrocardiograph **104**. As a result, a selection function **170***a*, which is described later, can acquire the ultrasound image data at a certain cardiac time phase by referring to the data stored in the image memory **150**.

[0041] The processing circuitry **140** is achieved by a processor, for example. The processing circuitry **140** includes a control function **140***a*. The control function **140***a*, which is the component of the processing circuitry **140** illustrated in FIG. **1**, is recorded in the internal memory circuitry **160** as a computer executable program, for example. The processing circuitry **140** reads the program from the internal memory circuitry **160** and executes the read program, thereby achieving the function corresponding to the program. In other words, the processing circuitry **140** after reading the program has the control function **140***a*. The control function **140***a* in the embodiment is an example of a controller.

[0042] The control function **140***a* controls the whole processing of the ultrasound diagnostic apparatus **1**. For example, the control function **140***a* controls the processing performed by the transmission-reception circuitry **110**, the B-mode processing circuitry **120**, the Doppler processing

circuitry **130**, and the selection function **170***a*, an identification function **170***b*, and a calculation function **170***c*, which are described later, of the analysis circuitry **170** on the basis of various instructions input by the user via the input device **102**, and the various control programs and various types of data read from the internal memory circuitry **160**. The control function **140***a* controls the display **103** such that the display **103** displays the ultrasound images for display stored in the image memory **150** and the internal memory circuitry **160**.

[0043] The control function **140***a* controls ultrasound scanning by controlling the ultrasound probe **101** via the transmission-reception circuitry **110**, for example.

[0044] The analysis circuitry **170** includes the selection function **170***a*, the identification function **170***b*, and the calculation function **170***c*. Each processing function of the selection function **170***a*, the identification function **170***b*, and the calculation function **170***c*, which are the components of the analysis circuitry **170** illustrated in FIG. **1**, is recorded in the internal memory circuitry **160** as a computer executable program, for example. The analysis circuitry **170** is a processor that reads each program from the internal memory circuitry **160** and executes the read program, thereby achieving the function corresponding to the program. In other words, the analysis circuitry **170** after reading the respective programs has the respective functions illustrated in the analysis circuitry **170** illustrated in FIG. **1**. The selection function **170***a* in the embodiment is an example of a selection unit. The identification function **170***b* is an example of an identification unit. The calculation function **170***c* is an example of a calculation unit. The various types of processing executed by the selection function **170***a*, the identification function **170***b*, and the calculation function **170***c* are described later.

[0045] In the embodiment, the term "processor" means a central processing unit (CPU), a graphical processing unit (GPU), an application specific integrated circuit (ASIC), or a circuitry of a programmable logic device such as a simple programmable logic device (SPLD), a complex programmable logic device (CPLD), or a field programmable gate array (FPGA). The processor reads the program stored in the internal memory circuitry **160** and executes the program to achieve the function. The program may be directly built in the circuitry of the processor instead of storing the program in the internal memory circuitry **160**. In this case, the processor reads the program built in the circuitry and executes the read program to achieve the function. Each processor in the embodiment may be achieved as single circuitry. A plurality of independent circuitries may be combined as a single processor and the single processor may achieve the functions of the respective processors.

[0046] The image memory **150** stores therein the ultrasound image data for display generated by the image generation circuitry **141**. The image memory **150** can also store therein the B-mode data generated by the B-mode processing circuitry **120** and the Doppler data generated by the Doppler processing circuitry **130**. The B-mode data and the Doppler data stored by the image memory **150** can be called by the user after diagnosis, for example. The data is retrieved via the image generation circuitry **141** and served as the ultrasound image data for display. The image memory **150** can also store therein the reflected wave data output by the transmission-reception circuitry **110**.

[0047] The internal memory circuitry **160** stores therein a control program for ultrasound transmission and reception, image processing, and display processing, diagnosis information (e.g., a patient's ID, and a doctor's observation), and various types of data such as diagnosis protocols and various body marks. The internal memory circuitry **160** is also used for storing the ultrasound images generated by the image generation circuitry **141**, for example, as needed. The data stored in the internal memory circuitry **160** can be transferred to external apparatuses via an Interface, which is not illustrated. The internal memory circuitry **160** can also store therein data transferred from the external apparatuses via the interface, which is not illustrated. The internal memory circuitry **160** stores therein data used when the selection function **170***a*, the identification function **170***b*, and the calculation function **170***c* perform various types of processing and data calculated as the results of the various types of processing. For example, the internal memory circuitry **160** stores therein information about the contour identified by the identification function **170***b*. The information about the contour is described later. The internal memory circuitry **160** stores therein the information about the contour (e.g., a position of the contour in the image). The internal memory circuitry **160** may store therein the information about the contour for each cross section. The internal memory circuitry **160** is an example of the memory circuitry.

[0048] The whole structure of the ultrasound diagnostic apparatus **1** according to the first embodiment is described as above.

[0049] The following describes an exemplary case where the ultrasound diagnostic apparatus calculates a longitudinal strain in the longitudinal direction for each of 18 segments in the left ventricle of a heart using a speckle tracking method, and calculates an average of the calculated strains in the longitudinal direction as a global longitudinal strain (GLS).

[0050] In this case, the user, such as a doctor, operates the input device so as to cause the display to display one of the time-series B-mode images of the longitudinal cross section of the heart generated by the ultrasound diagnostic apparatus. The user, then, sets the contour of the myocardium of the left ventricle in the B-mode image displayed on the display. The user operates the input device so as to input, to the main body, an instruction to start the speckle tracking that traces a point on the contour of the myocardium over a plurality of frames. The user checks, for each frame, the tracking result of the point on the contour of the myocardium over the multiple frames displayed on the display, and corrects the point on the contour of the myocardium while operating the input device when the tracking result is wrong. The user operates the input device so as to input, to the main body, an instruction to calculate the GLS. The user checks the GLS at each cardiac time phase, which is calculated by the main body and displayed on the display, and performs diagnosis of cardiac diseases.

[0051] When the ultrasound diagnostic apparatus calculates the GLS using the speckle tracking method as described above, the user needs time to operate the input device relatively many times, and thus the user feels troublesome in operating the apparatus. It is, thus, difficult to easily perform diagnosis of cardiac diseases when the ultrasound diagnostic apparatus calculates the GLS using the speckle tracking method.

[0052] The ultrasound diagnostic apparatus **1** according to the first embodiment allows the user to easily perform diagnosis of cardiac diseases by the processing described below.

[0053] FIG. **2** is a flowchart illustrating an exemplary flow of the processing performed by the ultrasound diagnostic apparatus **1** according to the first embodiment. The processing exemplarily illustrated in FIG. **2** is performed when the user operates the input device **102** and an instruction to start collection of images including the heart of the subject P is input from the input device **102**, for example.

[0054] As exemplarily illustrated in FIG. **2**, at step S**101**, the control function **140***a* of the processing circuitry **140** controls the respective circuitries so as to collect images including the heart of the subject P, such as the longitudinal cross section images and volume data. At step S**101**, the control function **140***a* controls the transmission-reception circuitry **110** such that the transmission-reception circuitry **110** causes the ultrasound probe **101** to start the transmission of ultrasound waves, and starts producing the reflected wave data by performing the various types of processing on the received reflected wave signals. When the two-dimensional scanning is performed, the user operates the ultrasound probe **101** such that the longitudinal cross section of the heart of the subject P is scanned. When the three-dimensional scanning is performed, the user operates the ultrasound probe **101** such that a three-dimensional region of the heart of the subject P is scanned. When the two-dimensional scanning is performed, the transmission-reception circuitry **110** sequentially generates the two-dimensional reflected wave data on the basis of the two-dimensional reflected wave signals sequentially received as a result of the scanning of the longitudinal cross section, and starts sequentially storing the generated two-dimensional reflected wave data in the buffer **111**. When the three-dimensional scanning is performed, the transmission-reception circuitry **110** sequentially generates the three-dimensional reflected wave data on the basis of the three-dimensional reflected wave signals sequentially received as a result of the scanning of the three-dimensional region including the heart, and starts sequentially storing the generated three-dimensional reflected wave data in the buffer **111**.

[0055] At step S**101**, the control function **140***a* controls the B-mode processing circuitry **120** such that the B-mode processing circuitry **120** starts producing the time-series B-mode data. When the two-dimensional scanning is performed, the B-mode processing circuitry **120** sequentially generates the two-dimensional B-mode data using the two-dimensional reflected wave data stored in the buffer **111**, and starts sequentially storing the generated time-series two-dimensional B-mode data in the image memory **150**. When the three-dimensional scanning is performed, the B-mode processing circuitry **120** sequentially generates the three-dimensional B-mode data using the three-dimensional reflected wave data stored in the buffer **111**, and starts sequentially storing the generated time-series three-dimensional B-mode data in the image memory **150**.

[0056] At step S**101**, the control function **140***a* controls the image generation circuitry **141** such that the image generation circuitry **141** starts producing the time-series B-mode images. When the two-dimensional scanning is performed, the image generation circuitry **141** sequentially reads the B-mode data from the image memory **150** and starts sequentially producing the longitudinal cross-sectional images of the heart of the subject P from the read B-mode data. Types of longitudinal cross-sectional image are an apical four-chamber image (apical four-chamber cross-sectional image) visualizing four chambers of the heart, an apical three-chamber image (apical three-chamber cross-sectional image) visualizing three chambers of the heart, and an apical two-chamber image (apical two-chamber cross-sectional image) visualizing two chambers of the heart. The longitudinal cross-sectional image is the image including the heart of the subject P.

[0057] When the three-dimensional scanning is performed, the image generation circuitry **141** sequentially reads the B-mode data from the image memory **150** and starts sequentially producing the three-dimensional B-mode images (volume data) including the heart of the subject P from the read B-mode data. The volume data is the image including the heart of the subject P.

[0058] At step S**101**, when the two-dimensional scanning is performed, the image generation circuitry **141** starts sequentially storing each of the sequentially generated longitudinal cross-sectional images and a time at which the ultrasound scanning is performed for producing the longitudinal cross-sectional image in the image memory **150** in association with an electrocardiogram transmitted from the electrocardiograph **104**. At step S**101**, when the three-dimensional scanning is performed, the image generation circuitry **141** starts sequentially storing each of the sequentially generated volume data and a time at which the ultrasound scanning is performed for producing the volume data in the image memory **150** in association with an electrocardiogram transmitted from the electrocardiograph **104**.

[0059] At step S**101**, when the two-dimensional scanning is performed, the control function **140***a* starts causing the display **103** to display the longitudinal cross-sectional images stored in the image memory **150** in the time-series order.

[0060] When the three-dimensional scanning is performed, the control function **140***a* controls the image generation circuitry **141** such that image generation circuitry **141** starts sequentially producing surfaces A from the volume data and sequentially storing the generated surfaces A in the image memory **150**. The control function **140***a* starts causing the display **103** to display the surfaces A sequentially generated by the image generation circuitry **141** in the time-series order. The image generation circuitry **141** starts storing each of the sequentially generated surfaces A, the volume data from which the surface A is generated, and a time at which the ultrasound scanning is performed for producing the surface A in the image memory **150** in association with an electrocardiogram transmitted from the electrocardiograph **104**.

[0061] At step S**101**, when the two-dimensional scanning is performed, the control function **140***a* controls a data amount of the longitudinal cross-sectional images stored in the image memory **150** such that the longitudinal cross-sectional images in a certain time period from the present time to the past by a certain time are stored in the image memory **150**. When the three-dimensional scanning is performed, the control function **140***a* controls a data amount of the volume data stored in the image memory **150** such that the volume data in a certain time period from the present time to the past by a certain time is stored in the image memory **150**. For example, the control function **140***a* con-

trols a data amount of the longitudinal cross-sectional images or the volume data stored in the image memory **150** such that the longitudinal cross-sectional images or the volume data in at least one cardiac beat (one cardiac period) is stored in the image memory **150**.

[0062] The control function **140***a* determines whether the freeze button is pressed (step S**102**). If the freeze button is not pressed (No at step S**102**), the control function **140***a* performs the determination again at step S**102**.

[0063] If the freeze button is pressed (Yes at step S**102**), the control function **140***a* performs the processing described below at step S**103**. At step S**103**, the control function **140***a* causes the longitudinal cross-sectional image or the surface A displayed on the display **103** at timing when the freeze button is pressed to continue to be displayed without any change. The control function **140***a* freezes the display of the longitudinal cross-sectional image or the surface A. The longitudinal cross-sectional image or the surface A continues to be displayed until the longitudinal cross-sectional image corresponding to an end-diastole and the longitudinal cross-sectional image corresponding to an end-systole are displayed on the display **103** at step S**105**, which is described later.

[0064] At step S**103**, when the two-dimensional scanning is performed, the control function **140***a* acquires the longitudinal cross-sectional images corresponding to the certain time period stored in the image memory **150** at the timing when the freeze button is pressed. At step S**103**, when the three-dimensional scanning is performed, the control function **140***a* acquires the volume data that corresponds to the certain time period and is stored in the image memory **150** at the timing when the freeze button is pressed.

[0065] FIG. **3** is a diagram for explaining an example of the processing performed by the control function **140***a* according to the first embodiment. As exemplarily illustrated in FIG. **3**, when an apical four-chamber image **11** is displayed on the display **103** at timing when the freeze button is pressed, the control function **140***a* causes the apical four-chamber image **11** to continue to be displayed without any change. In FIG. **3**, the apical four-chamber image **11** is illustrated in which a left ventricle (LV), a left atrium (LA), a right ventricle (RV), and a right atrium (RA) are visualized.

[0066] Referring back to FIG. **2**, the control function **140***a* determines whether an instruction to automatically calculate the GLS (GLS calculation instruction) is input from the input device **102** by the user operating the input device **102** (step S**104**).

[0067] The following describes the GLS. The myocardial strain indicators are used as cardiac function parameters having usefulness for diagnosis of cardiac diseases, such as disease state elucidation, therapeutic effect determination, and prognosis estimation of various cardiac diseases. Among such myocardial strain indicators, the GLS is frequently used as an indicator for quantification of cardiac functions. The GLS is calculated using the following expression (1), for example.

$$\mathrm{GLS}\ (\%)=[(L1-L0)/L0]*100 \quad (1)$$

where "−" is the operator indicating subtraction, "/" is the operator indicating division, "*" is the operator indicating multiplication, L**1** is the length of the contour of an endocardium or an epicardium of the left ventricle of the heart at a certain time phase (first time phase) in one cardiac beat, L**0** is the length of the contour of the endocardium or the epicardium of the left ventricle of the heart at another time phase (second time phase) in one cardiac beat. The GLS is a value of a ratio of a value obtained by subtracting Lo, which is the length of the contour at the second time phase, from L**1**, which is the length of the contour at the first time phase, to Lo, and expressed by percent. The length of the contour in the left ventricle in the apical two-chamber image is the length of the contour from a mitral valve to an aortic valve via a cardiac apex because the mitral valve and the aortic valve are visualized in the apical two-chamber image. The length of the contour in the left ventricle in the apical three-chamber image is the length of the contour from the mitral valve to the aortic valve via the cardiac apex because the mitral valve and the aortic valve are visualized in the apical three-chamber image. The length of the contour in the left ventricle in the apical four-chamber image is the length of the contour from the mitral valve to the mitral valve via the cardiac apex because only the mitral valve is visualized out of the mitral valve and the aortic valve in the apical four-chamber image. The length of the contour in the left ventricle in the volume data is the length of the contour from the mitral valve to the aortic valve via the cardiac apex in the apical two-chamber cross section and the apical three-chamber cross section, and the length of the contour from the mitral valve to the mitral valve via the cardiac apex in the apical four-chamber cross section, for example.

[0068] It is particularly useful information for diagnosis of cardiac diseases to use the GLS obtained by applying the end-systole to the first time phase (first cardiac time phase) and the end-diastole to the second time phase (second cardiac time phase). The following, thus, describes a case where the end-systole is applied to the first time phase and the end-diastole is applied to the second time phase. Any time phase can be applied to the first time phase and the second time phase. In the following description, the first cardiac time phase corresponds to the end-systole while the second cardiac time phase corresponds to the end-diastole.

[0069] If no GLS calculation instruction is input (No at step S**104**), the control function **140***a* performs the processing again at step S**104**.

[0070] If the GLS calculation instruction is input (Yes at step S**104**), the control function **140***a* performs the processing described below at step S**105**. At step S**105**, when the two-dimensional scanning is performed, the control function **140***a* controls the selection function **170***a* such that the selection function **170***a* selects the longitudinal cross-sectional image corresponding to the end-diastole and the longitudinal cross-sectional image corresponding to the end-systole in one cardiac beat out of the longitudinal cross-sectional images that correspond to the certain time period and are acquired from the image memory **150** at step S**103**. The selection function **170***a* refers to the data that is stored in the image memory **150** and in which the longitudinal cross-sectional image, the ultrasound scanning time, and the electrocardiogram are in association with one another, and selects the longitudinal cross-sectional image corresponding to the end-diastole and the longitudinal cross-sectional image corresponding to the end-systole in one cardiac beat out of the time-series longitudinal cross-sectional images. The selection function **170***a* may select the longitudinal cross-sectional image corresponding to the end-diastole and the longitudinal cross-sectional image corresponding to the end-systole by setting an R wave to be the end-diastole and

a T wave to be the end-systole. The selection function **170***a* may select, using other known techniques, the longitudinal cross-sectional image corresponding to the end-diastole and the longitudinal cross-sectional image corresponding to the end-systole in one cardiac beat out of the time-series longitudinal cross-sectional images.

[0071] At step S**105**, when the three-dimensional scanning is performed, the control function **140***a* controls the selection function **170***a* such that the selection function **170***a* selects the volume data corresponding to the end-diastole and the volume data corresponding to the end-systole in one cardiac beat out of the volume data that corresponds to the certain time period and is acquired from the image memory **150** at step S**103**. The selection function **170***a* refers to the data that is stored in the image memory **150** and in which the volume data, the ultrasound scanning time, the electrocardiogram, and the surface A are in association with one another, and selects the volume data corresponding to the end-diastole and the volume data corresponding to the end-systole in one cardiac beat out of the time-series volume data.

[0072] When the longitudinal cross-sectional image corresponding to the end-diastole and the longitudinal cross-sectional image corresponding to the end-systole are selected at step S**105**, the control function **140***a* causes the display **103** to display the selected longitudinal cross-sectional image corresponding to the end-diastole and longitudinal cross-sectional image corresponding to the end-systole.

[0073] When the volume data corresponding to the end-diastole and the volume data corresponding to the end-systole are selected at step S**105**, the control function **140***a* controls the image generation circuitry **141** such that the image generation circuitry **141** generates, by the MPR, the longitudinal cross-sectional image from each of the selected volume data corresponding to the end-diastole and volume data corresponding to the end-systole. The control function **140***a* causes the display **103** to display the longitudinal cross-sectional image corresponding to the end-diastole and the longitudinal cross-sectional image corresponding to the end-systole that are generated by the image generation circuitry **141**.

[0074] FIG. **4** is a diagram for explaining an example of the processing performed by the selection function **170***a* according to the first embodiment. At step S**105**, when the two-dimensional scanning is performed, the selection function **170***a* selects an apical four-chamber image **12** corresponding to the end-diastole and an apical four-chamber image **13** corresponding to the end-systole out of the time-series apical four-chamber images, for example. As exemplarily illustrated in FIG. **4**, the selection function **170***a* causes the display **103** to display the selected apical four-chamber image **12** and apical four-chamber image **13**.

[0075] At step S**106**, when the two-dimensional scanning is performed, the control function **140***a* controls the identification function **170***b* such that the identification function **170***b* automatically traces and identifies the two-dimensional contour of the heart for each of the selected longitudinal cross-sectional image corresponding to the end-diastole and longitudinal cross-sectional image corresponding to the end-systole. The identification function **170***b* identifies the contour from the mitral valve to the mitral valve via the cardiac apex as the contour of the left ventricle of the heart when the longitudinal cross-sectional image is the apical four-chamber image, for example. The identification function **170***b* identifies the contour from the mitral valve to the aortic valve via the cardiac apex as the contour of the left ventricle of the heart when the longitudinal cross-sectional image is the apical three-chamber image, for example. The identification function **170***b* identifies the contour from the mitral valve to the aortic valve via the cardiac apex as the contour of the left ventricle of the heart when the longitudinal cross-sectional image is the apical two-chamber image, for example.

[0076] At step S**106**, when the three-dimensional scanning is performed, the control function **140***a* controls the identification function **170***b* such that identification function **170***b* automatically traces and identifies the three-dimensional contour of the heart for each of the selected volume data corresponding to the end-diastole and volume data corresponding to the end-systole. The identification function **170***b* identifies the three-dimensional contour of the left ventricle of the heart for each of the selected volume data corresponding to the end-diastole and volume data corresponding to the end-systole.

[0077] When the three-dimensional scanning is performed, the identification function **170***b* may generate a plurality of longitudinal cross-sectional images different from one another by the MPR processing for each of the volume data corresponding to the end-diastole and the volume data corresponding to the end-systole, and identify the contour of the left ventricle of the heart for each of the longitudinal cross-sectional images. The identification function **170***b* may identify a plurality of contours for each volume data. For example, the identification function **170***b* may generate the apical four-chamber image and the apical two-chamber image for each volume data, and identify the contour of the left ventricle of the heart for each of the apical four-chamber image and the apical two-chamber image. For another example, the identification function **170***b* may generate the apical four-chamber image, the apical three-chamber image, and the apical two-chamber image for each volume data, and identify the contour of the left ventricle of the heart for each of the apical four-chamber image, the apical three-chamber image, and the apical two-chamber image.

[0078] As described above, the identification function **170***b* identifies the contour of at least a part of the heart. The identification function **170***b* identifies the contour of the endocardium of the heart chamber.

[0079] The identification function **170***b* may identify the contour using dictionary data, for example. In the dictionary data, the position of the contour of the left ventricle is registered for each of the types of images such as the apical four-chamber image, the apical three-chamber image, and the apical two-chamber image, for example. For example, in the dictionary data, a position of the contour from the mitral valve to the mitral valve via the cardiac apex in the apical four-chamber image is registered. For another example, in the dictionary data, a position of the contour from the mitral valve to the aortic valve via the cardiac apex in the apical three-chamber image is registered. For another example, in the dictionary data, a position of the contour from the mitral valve to the aortic valve via the cardiac apex in the apical two-chamber image is registered. For example, when the longitudinal cross-sectional image visualizing the left ventricle serving as the target to identify its contour is the apical four-chamber image, the identification function **170***b* per-

forms, on the apical four-chamber image registered in the dictionary data, the image processing such as deformation and rotation to align the left ventricle visualized in the apical four-chamber image registered in the dictionary data and the left ventricle visualized in the longitudinal cross-sectional image serving as the target to identify its contour. The identification function **170***b* identifies the contour after the alignment as the result of the deformation and rotation as the contour of the left ventricle serving as the target to identify its contour. The identification function **170***b* performs the same processing as described above when the longitudinal cross-sectional image visualizing the left ventricle serving as the target to identify its contour is the apical two-chamber image or the apical three-chamber image.

[0080] The identification function **170***b* may identify the contour using a snake method, for example. When using the snake method, the identification function **170***b* extracts the contour by correcting the shape of a curve in the longitudinal cross-sectional image visualizing the left ventricle serving as the target to identify its contour using an energy function representing a linear sum of internal energy and image energy such that the energy function becomes minimum. The identification function **170***b* may identify the contour using an active shape model method that extracts a contour line using an active contour model.

[0081] FIG. **5** is a diagram for explaining an example of the processing performed by the identification function **170***b* according to the first embodiment. When the apical four-chamber image **12** and the apical four-chamber image **13** that are exemplarily illustrated in FIG. **4** are selected by the selection function **170***a*, the identification function **170***b* identifies a contour **12***a* of the left ventricle visualized in the apical four-chamber image **12** and a contour **13***a* of the left ventricle visualized in the apical four-chamber image **13**.

[0082] As described above, the identification function **170***b* automatically identifies the contour of the heart without using the speckle tracking at step S**106**. When the cardiac contour is identified using the speckle tracking, relatively many operations are required as described above. In the first embodiment, the cardiac contour is automatically identified by only the user's single operation of inputting the instruction to automatically calculate the GLS via the input device **102**. The single operation is an example of the common operation. The first embodiment, thus, can identify the contour of the myocardium relatively without requiring the user's operation. The ultrasound diagnostic apparatus **1** according to the first embodiment can assist the user to easily perform diagnosis of cardiac diseases.

[0083] The control function **140***a* calculates the GLS serving as a cardiac function parameter representing a myocardial strain using the information about the contour identified by the identification function **170***b*, and controls the calculation function **170***c* so as to display the calculated GLS on the display **103** (step S**107**). At step S**107**, when the two-dimensional scanning is performed, the calculation function **170***c* calculates the length L**0** of the identified contour in the longitudinal cross-sectional image corresponding to the end-diastole and the length L**1** of the identified contour in the longitudinal cross-sectional image corresponding to the end-systole. The calculation function **170***c* calculates the GLS using the length L**0** of the contour and the length L**1** of the contour using expression (1).

[0084] At step S**107**, when the three-dimensional scanning is performed, the calculation function **170***c* calculates the length L**0** of the identified three-dimensional contour in the volume data corresponding to the end-diastole and the length L**1** of the identified three-dimensional contour in the volume data corresponding to the end-systole. The calculation function **170***c* calculates the GLS using the length L**0** of the contour and the length L**1** of the contour using expression (1).

[0085] When the three-dimensional scanning is performed and a plurality of contours are identified in each of the volume data corresponding to the end-diastole and the volume data corresponding to the end-systole, two types of methods are available for calculating the GLS.

[0086] The following describes one of the two methods. At step S**107**, the calculation function **170***c* calculates the lengths of a plurality of contours identified from the volume data corresponding to the end-diastole, and calculates an average of the calculated lengths of the multiple contours as L**0**. The calculation function **170***c* also calculates the lengths of a plurality of contours identified from the volume data corresponding to the end-systole, and calculates an average of the calculated lengths of the multiple contours as L**1**. The calculation function **170***c* calculates the GLS using L**0** and L**1** using expression (1).

[0087] A specific example of the one method is described. For example, at step S**107**, the calculation function **170***c* calculates the lengths of the contour identified in the apical four-chamber image, the contour identified in the apical three-chamber image, and the contour identified in the apical two-chamber image from the volume data corresponding to the end-diastole, and calculates a statistic of the calculated lengths of the three contours, e.g., an average, as L**0**. The calculation function **170***c* also calculates the lengths of the contour identified in the apical four-chamber image, the contour identified in the apical three-chamber image, and the contour identified in the apical two-chamber image from the volume data corresponding to the end-systole, and calculates a statistic of the calculated lengths of the three contours, e.g., an average, as L**1**. The calculation function **170***c* calculates the GLS using L**0** and L**1** using expression (1).

[0088] The following describes the other one of the two methods. At step S**107**, the calculation function **170***c* calculates the lengths of a plurality of contours identified from the volume data corresponding to the end-diastole. The calculation function **170***c* calculates the lengths of a plurality of contours identified from the volume data corresponding to the end-systole. The calculation function **170***c* calculates the GLS using expression (1) for each of the multiple contours. The calculation function **170***c* calculates the GLS for each of a plurality of longitudinal cross-sectional images generated by the MPR from the volume data.

[0089] The calculation function **170***c* calculates the GLS on the basis of the lengths of the identified contour in the same manner as described above.

[0090] The control function **140***a* causes the display **103** to display the GLS (step S**108**). When a plurality of GLSs are calculated at step S**107**, the control function **140***a* causes the display **103** to display the multiple GLSs at step S**108**.

[0091] The control function **140***a* determines whether an instruction to stop collecting the images including the heart of the subject P is input from the input device **102** by the user operating the input device **102** (step S**109**). If no instruction to stop collecting the images is input (No at step S**109**), the processing returns to step S**105**, from which to step S**109**, the processing is performed on the next cardiac time phase

in the same manner as described above. If the instruction to stop collecting the images is input (Yes at step S**109**), the control function **140***a* controls the respective circuitries such that the collection of the images is stopped, and thereafter ends the processing.

[0092] As described above, when the time-series volume data (the time-series three-dimensional images generated by the scanning performed on a three-dimensional region) is collected, the identification function **170***b* of the ultrasound diagnostic apparatus **1** identifies the three-dimensional cardiac contour for each of the three-dimensional image corresponding to the end-systole and the three-dimensional image corresponding to the end-diastole included in the time-series three-dimensional images, and the calculation function **170***c* calculates the cardiac function parameter using the information about the identified three-dimensional contours.

[0093] When the time-series longitudinal cross-sectional images (the time-series two-dimensional images generated by the scanning performed on a two-dimensional region) are collected, the identification function **170***b* of the ultrasound diagnostic apparatus **1** identifies the two-dimensional cardiac contour for each of the two-dimensional image corresponding to the end-systole and the two-dimensional image corresponding to the end-diastole included in the time-series two-dimensional images, and the calculation function **170***c* calculates the cardiac function parameter using the information about the identified two-dimensional contours.

[0094] The ultrasound diagnostic apparatus **1** according to the first embodiment is described as above. As described above, the control function **140***a* of the ultrasound diagnostic apparatus **1** causes the selection function **170***a* to select the images, the identification function **170***b* to identify the contours, and the calculation function **170***c* to calculate the GLS by only the user's single operation of inputting the instruction to automatically calculate the GLS. The ultrasound diagnostic apparatus **1** automatically calculates the GLS by only a single operation, in this way. The ultrasound diagnostic apparatus **1**, thus, can calculate the GLS relatively without requiring the user's operation. The ultrasound diagnostic apparatus **1**, thus, can assist the user to easily perform diagnosis of cardiac diseases.

[0095] The calculation of the GLS using the speckle tracking method needs to perform tracking in all of the time phases. As a result, the processing amount is huge. The first embodiment, however, calculates the GLS using the images corresponding to the two time phases. The ultrasound diagnostic apparatus **1** according to the first embodiment, thus, can easily calculate the GLS, which is the cardiac function parameter frequently used as the indicator for quantification of cardiac functions.

[0096] First Modification of the First Embodiment

[0097] In the first embodiment, when the time-series volume data is collected, the identification function **170***b* of the ultrasound diagnostic apparatus **1** identifies the three-dimensional cardiac contour for each of the volume data corresponding to the end-systole and the volume data corresponding to the end-diastole included in the time-series volume data, and the calculation function **170***c* calculates the cardiac function parameter using the information about the identified three-dimensional contours. Although when the time-series volume data is collected, the image generation circuitry **141** of the ultrasound diagnostic apparatus **1** may generate the longitudinal cross-sectional image from each volume data in the time-series volume data by the MPR, and the control function **140***a* may cause the display **103** to display the longitudinal cross-sectional images in the time-series order at step S**101** illustrated in FIG. **2**. At step S**106**, the identification function **170***b* may identify the two-dimensional cardiac contour for each of the longitudinal cross-sectional image corresponding to the end-systole and the longitudinal cross-sectional image corresponding to the end-diastole included in the time-series longitudinal cross-sectional images, and the calculation function **170***c* may calculate the GLS using the information about the identified two-dimensional contours at step S**107**. In the first modification, the user operates the ultrasound probe **101** such that the ultrasound probe **101** scans the apical two-chamber cross section or the apical four-chamber cross section.

[0098] Second Modification of the First Embodiment

[0099] The ultrasound diagnostic apparatus **1** according to the first embodiment calculates the GLS, which is the cardiac function parameter, using the information about the lengths of the identified contours, and causes the display **103** to display the calculated GLS. The ultrasound diagnostic apparatus **1** may calculate the cardiac function parameters such as the volume of the heart (the volume of the heart chamber) and the ejection fraction of the heart chamber besides the GLS using the information about the lengths of the identified contours, and may cause the display **103** to display the cardiac function parameters such as the volume of the heart and the ejection fraction of the heart chamber. The following describes such an embodiment as a second modification of the first embodiment.

[0100] For example, the calculation function **170***c* according to the second modification calculates, using the identified contours, a volume of the left ventricle formed by the identified contour at the end-systolic (end-systolic volume (ESV)) and a volume of the left ventricle formed by the identified contour at the end-diastolic (end-diastolic volume (EDV)) by a Simpson method or a modified Simpson method.

[0101] The following describes an example where the calculation function **170***c* calculates the volume of the left ventricle using the identified contour by the Simpson method. The calculation function **170***c* detects the long axis of an inner cavity of the left ventricle formed by the identified contour, for example. The calculation function **170***c* divides the inner cavity of the left ventricle into a plurality of disks (e.g., 20 disks) perpendicular to the long axis of the left ventricle. The calculation function **170***c* calculates a distance between two points intersecting the endocardial surface for each of the multiple disks. The calculation function **170***c* approximates each disk as a columnar slice having a diameter of the calculated distance between the two points. The calculation function **170***c* calculates a volume of each disk approximated as a columnar slice. The calculation function **170***c* calculates a sum of the volumes of the respective disks as the volume of the left ventricle.

[0102] The following describes an example where the calculation function **170***c* calculates the volume of the left ventricle using the identified contour by the modified Simpson method. In this case, the apical four-chamber image and the apical two-chamber image are used. The calculation function **170***c* detects the long axis of an inner cavity of the left ventricle formed by the identified contour in the apical four-chamber image, for example. The calculation function

170*c* detects the long axis of an inner cavity of the left ventricle formed by the identified contour in the apical two-chamber image. The calculation function **170***c* divides the inner cavity of the left ventricle formed by the identified contour in the apical four-chamber image into a plurality of disks (e.g., 20 disks) perpendicular to the long axis of the left ventricle (disks in the apical four-chamber image). The calculation function **170***c* divides the inner cavity of the left ventricle formed by the identified contour in the apical two-chamber image into a plurality of disks (e.g., 20 disks) perpendicular to the long axis of the left ventricle (disks in the apical two-chamber image). The calculation function **170***c* calculates a distance A between two points intersecting the endocardial surface for each of the multiple disks in the apical four-chamber image. The calculation function **170***c* calculates a distance B between two points intersecting the endocardial surface for each of the multiple disks in the apical two-chamber image. The calculation function **170***c* approximates the three-dimensional shape of each disk as an ellipsoidal slice having a major axis estimated from the calculated distance A between two points and a minor axis estimated from the calculated distance B between two points. The calculation function **170***c* calculates a volume of each disk approximated as an ellipsoidal slice. The calculation function **170***c* calculates a sum of the volumes of the respective disks as the volume of the left ventricle.

[0103] The calculation function **170***c* calculates the ESV and the EDV as described above. The calculation function **170***c* calculates the ejection fraction (EF) using the following expression (2).

$$EF=(ESV-EDV)/ESV \quad (2)$$

[0104] The control function **140***a* according to the second modification causes the display **103** to display the ESV, the EDV, and the EF in addition to the GLS. FIG. **6** is a diagram for explaining an example of the processing performed by the ultrasound diagnostic apparatus **1** according to the second modification of the first embodiment. For example, when the calculation function **170***c* calculates the EDV "46.7 ml", the ESV "30.4 ml", the EF "34.9%", and the GLS "10.2%", the control function **140***a* causes the display **103** to display the EDV "46.7 ml", the ESV "30.4 ml", the EF "34.9%", and the GLS "10.2%" as exemplarily illustrated in FIG. **6**. The control function **140***a* causes the display **103** to simultaneously display the EDV "46.7 ml", the ESV "30.4 ml", the EF "34.9%", and the GLS "10.2%". The calculation function **170***c* may calculate at least one of the EDV "46.7 ml", the ESV "30.4 ml", and the EF "34.9%". The calculation function **170***c* may calculate the cardiac function parameter (first cardiac function parameter) representing at least one of the volume and the ejection fraction of the heart chamber, and the GLS serving as the cardiac function parameter (second cardiac function parameter) representing the global strain of the myocardium corresponding to the heart chamber. The control function **140***a* may cause the display **103** to display the first cardiac function parameter and the second cardiac function parameter. The control function **140***a* may cause the display **103** to display the first cardiac function parameter and the second cardiac function parameter by the common operation described above.

[0105] The second modification calculates at least one of the volume and the ejection fraction using the already identified contour, thereby making it possible to easily calculate the other cardiac function parameter other than the GLS.

[0106] In the second modification, the control function **140***a* causes the selection function **170***a* to select the images, the identification function **170***b* to identify the contours, and controls the display **103** such that the display **103** displays the first cardiac function parameter and the second cardiac function parameter by only the user's single operation of inputting the instruction to automatically calculate the GLS. The ultrasound diagnostic apparatus **1** causes the display **103** to automatically display the first cardiac function parameter and the second cardiac function parameter by only a single operation, in this way. The ultrasound diagnostic apparatus **1** can cause the display **103** to automatically display the first cardiac function parameter and the second cardiac function parameter relatively without requiring the user's operation. The ultrasound diagnostic apparatus **1**, thus, can assist the user to easily perform diagnosis of cardiac diseases.

[0107] Third Modification of the First Embodiment

[0108] The ultrasound diagnostic apparatus **1** according to the first embodiment calculates a single GLS per one cardiac time phase, and causes the display **103** to display the calculated GLS. The ultrasound diagnostic apparatus **1** may calculate the GLS for each of a plurality of cardiac time phases, calculate a statistic of the calculated multiple GLSs, and cause the display **103** to display the calculated statistic of the GLSs. The following describes such an embodiment as a third modification of the first embodiment.

[0109] FIG. **7** is a diagram for explaining an example of the processing performed by the calculation function **170***c* according to the third modification of the first embodiment. FIG. **7** illustrates an exemplary case where the GLS to be displayed on the display **103** is calculated for each of the three cardiac time phases. As exemplarily illustrated in FIG. **7**, the calculation function **170***c* according to the third modification calculates a single GLS per one cardiac time phase in the same manner as the first embodiment. Specifically, the calculation function **170***c* calculates a GLS **21** between an R wave R**1** and an R wave R**2**. The calculation function **170***c* calculates a GLS **22** between the R wave R**2** and an R wave R**3**. The calculation function **170***c* calculates a GLS **23** between the R wave R**3** and an R wave R**4**. The calculation function **170***c* calculates an average of the GLS **21**, the GLS **22**, and the GLS **23** as a GLS **24** for the three cardiac time phases. The calculation function **170***c* causes the display **103** to display the GLS **24**. The calculation function **170***c* updates the GLS displayed on the display **103** every three cardiac time phases.

[0110] Although the GLS calculated at a certain cardiac time phase is largely different from those at other cardiac time phases by chance due to the influence of disturbance, for example, the third modification does not cause the display **103** to display the GLS largely different from the others without any change. There is a case where the user performs miss diagnosis when the user sees the GLS largely different from the others, thereby reducing the accuracy in diagnosis result of cardiac diseases. The third modification can prevent the reduction in accuracy in diagnosis result of cardiac diseases by making the user see the extremely different cardiac function parameter.

[0111] Fourth Modification of the First Embodiment

[0112] The ultrasound diagnostic apparatus **1** may cause the display **103** to display the identified contours. The following describes such an embodiment as a fourth modification of the first embodiment. FIG. **8**A is a diagram for explaining an example of the processing performed by the control function **140***a* according to the fourth modification of the first embodiment. The following description is based on the case where the contour **12***a* and the contour **13***a* are identified by the identification function **170***b* as exemplarily illustrated in FIG. **5**. In this case, as exemplarily illustrated in FIG. **8**A, the control function **140***a* generates an image **12***b* that represents a shape of a portion anatomically along the myocardium in the contour **12***a*. The control function **140***a* generates an image **13***b* that represents a shape of a portion anatomically along the myocardium in the contour **13***a*. In the production, when the image **12***b* overlaps with a portion along the myocardium in the contour **12***a* in the apical four-chamber image **12**, the control function **140***a* generates the image **12***b* such that the display form of the portion along the myocardium, i.e., the display form of the image **12***b*, is differentiated from a portion that is not along the myocardium. For example, the control function **140***a* generates the image **12***b* in such a manner that the image **12***b* is a certain pattern. The control function **140***a* may generate the image **12***b* in a color different from that of the portion that is not along the myocardium.

[0113] Likewise, when the image **13***b* overlaps with a portion along the myocardium in the contour **13***a* in the apical four-chamber image **13**, the control function **140***a* generates the image **13***b* such that the display form of the portion along the myocardium, i.e., the display form of the image **13***b*, is differentiated from a portion that is not along the myocardium.

[0114] The control function **140***a* overlaps the generated image **12***b* with the portion anatomically along the myocardium in the contour **12***a* in the apical four-chamber image **12** displayed on the display **103**. The control function **140***a* overlaps the generated image **13***b* with the portion anatomically along the myocardium in the contour **13***a* in the apical four-chamber image **13** displayed on the display **103**. As a result, the control function **140***a* causes the display **103** to display the image **12***b* representing the identified contour **12***a* on the apical four-chamber image **12** in such a manner that the display form of the portion along the myocardium in the identified contour **12***a* is differentiated from that of the portion that is not along the myocardium. The control function **140***a* causes the display **103** to display the image **13***b* representing the identified contour **13***a* on the apical four-chamber image **13** in such a manner that the display form of the portion along the myocardium in the identified contour **13***a* is differentiated from that of the portion that is not along the myocardium.

[0115] The ultrasound diagnostic apparatus **1** according to the fourth modification can cause the user to easily grasp the shape and the position of the contour serving as the information useful for the diagnosis of cardiac diseases. The ultrasound diagnostic apparatus **1** according to the fourth modification can assist the user to easily perform diagnosis of cardiac diseases.

[0116] As exemplarily illustrated in FIG. **8**B, the control function **140***a* may display the image **12***b* on the apical four-chamber image **12** and the image **13***b* on the apical four-chamber image **13** when the GLS displayed on the display **103** is designated by the user via the input device **102**. The control function **140***a* may display, in accordance with the operation to designate the GLS, the images **12***b* and **13***b* each representing a partial contour of the heart serving as the target of the calculation of the designated GLS on the image **12** corresponding to the end-diastole and the image **13** corresponding to the end-systole, respectively. The control function **140***a* may display, in accordance with the operation to designate the GLS, the image representing a partial contour of the heart serving as the target of the calculation of the designated GLS on at least one of the image **12** corresponding to the end-diastole and the image **13** corresponding to the end-systole. The images **12***b* and **13***b* each representing a part of the contour of the heart are examples of the contour marker.

[0117] Fifth Modification of the First Embodiment

[0118] In the first embodiment, the ultrasound diagnostic apparatus **1** automatically selects the image corresponding to the end-diastole and the image corresponding to the end-systole at step S**105** illustrated in FIG. **2**, and performs the various types of processing using the selected images. In the first embodiment, the ultrasound diagnostic apparatus **1** automatically identifies the contours at step S**106** illustrated in FIG. **2**, and performs the various types of processing using the selected contours. The ultrasound diagnostic apparatus **1** may receive the user's designation of the image corresponding to the end-diastole and the image corresponding to the end-systole, and may perform various types of processing using the designated image corresponding to the end-diastole and image corresponding to the end-systole in the same manner as the first embodiment. The ultrasound diagnostic apparatus **1** may receive the trace of the contour from the user, and may perform various types of processing using the traced contour in the same manner as the first embodiment. The following describes such an embodiment as a fifth modification of the first embodiment.

[0119] The ultrasound diagnostic apparatus **1** according to the fifth modification does not include the selection function **170***a* and the identification function **170***b*. FIG. **9** is a flowchart illustrating an exemplary flow of the processing performed by the ultrasound diagnostic apparatus **1** according to the fifth modification of the first embodiment.

[0120] The processing performed from step S**101** to step S**104** in the flowchart exemplarily illustrated in FIG. **9** is the same as that performed from step S**101** to step S**104** in the flowchart according to the first embodiment exemplarily illustrated in FIG. **2**. The description thereof is, thus, omitted.

[0121] As exemplarily illustrated in FIG. **9**, at step S**201**, the control function **140***a* causes the display **103** to display the longitudinal cross-sectional images out of the longitudinal cross-sectional images that correspond to the certain time period and are acquired from the image memory **150** at step S**103** such that the longitudinal cross-sectional image corresponding to the end-diastole and the longitudinal cross-sectional image corresponding to the end-systole can be designated in one cardiac beat when both of the case where the two-dimensional scanning is performed and the case where the three-dimensional scanning is performed.

[0122] At step S**201**, the control function **140***a* receives the designation of the longitudinal cross-sectional image corresponding to the end-diastole and the longitudinal cross-sectional image corresponding to the end-systole from the user via the input device **102**. The longitudinal cross-

sectional image corresponding to the end-diastole and the longitudinal cross-sectional image corresponding to the end-systole that are designated at step S**201** are used in the various types of processing in the same manner as the first embodiment.

[0123] At step S**202**, the control function **140***a* causes the display **103** to display the longitudinal cross-sectional image corresponding to the end-diastole and the longitudinal cross-sectional image corresponding to the end-systole that are designated by the user.

[0124] At step S**202**, the control function **140***a* receives the designation of the traces of the contour at the end-diastole and the contour at the end-systole from the user via the input device **102**. The traced contours at the end-diastole and at the end-systole are used in the various types of processing in the same manner as the first embodiment.

[0125] The processing performed from step S**107** to step S**109** in the flowchart exemplarily illustrated in FIG. **9** is the same as that performed from step S**107** to step S**109** in the flowchart according to the first embodiment exemplarily illustrated in FIG. **2**. The description thereof is, thus, omitted. At step S**108**, the control function **140***a* may cause the display **103** to display the GLS and the contours, and may receive the correction of the contours from the user via the input device **102**. When receiving the correction of the contour, the control function **140***a* may correct the contour on the basis of the received correction.

[0126] The fifth modification is described as above. The ultrasound diagnostic apparatus **1** according to the fifth modification can calculate the GLS although the ultrasound diagnostic apparatus **1** does not include the selection function **170***a* and the identification function **170***b*. The ultrasound diagnostic apparatus **1** according to the fifth modification can assist the user to perform diagnosis of cardiac diseases with an inexpensive structure.

[0127] Sixth Modification of the First Embodiment

[0128] The ultrasound diagnostic apparatus **1** may calculate the other cardiac function parameters besides the GLS, the ESV, the EDV, and the EF. The following describes such an embodiment in which the ultrasound diagnostic apparatus **1** calculates the other cardiac function parameters besides the GLS, the ESV, the EDV, and the EF as a sixth modification of the first embodiment.

[0129] In the sixth modification, the ultrasound diagnostic apparatus **1** calculates a moving distance of an annulus between the end-diastole and the end-systole as the cardiac function parameter.

[0130] The control function **140***a* according to the sixth modification controls the identification function **170***b* such that the identification function **170***b* identifies a position of the annulus of the mitral valve (annulus position) and a position of the cardiac apex in each of the image corresponding to the end-diastole and the image corresponding to the end-systole, at step S**106** illustrated in FIG. **2** in addition to the control described in the first embodiment.

[0131] FIG. **10** is a diagram for explaining an example of the processing performed by the identification function **170***b* and the calculation function **170***c* according to the sixth modification of the first embodiment. As exemplarily illustrated in FIG. **10**, the identification function **170***b* identifies an annulus position **12***c* of the mitral valve in the apical four-chamber image **12** corresponding to the end-diastole at step S**106**. At step S**106**, the identification function **170***b* identifies a position **12***d* of the cardiac apex in the apical four-chamber image **12** corresponding to the end-diastole.

[0132] As exemplarily illustrated in FIG. **10**, the identification function **170***b* identifies an annulus position **13***c* of the mitral valve in the apical four chamber image **13** corresponding to the end-systole at step S**106**. At step S**106**, the identification function **170***b* identifies a position **13***d* of the cardiac apex in the apical four-chamber image **13** corresponding to the end-systole.

[0133] At step S**107** illustrated in FIG. **2**, the control function **140***a* controls the calculation function **170***c* such that the calculation function **170***c* calculates a moving distance of the annulus between the end-diastole and the end-systole as the cardiac function parameter in addition to the control described in the first embodiment or any of the modifications described above. At step S**107**, the calculation function **170***c* calculates a moving distance of the annulus.

[0134] As exemplarily illustrated in FIG. **10**, the calculation function **170***c* calculates a distance (distance d**1**) between the identified annulus position **12***c* of the mitral valve and the identified position **12***d* of the cardiac apex in the apical four-chamber image **12** corresponding to the end-diastole. The calculation function **170***c* calculates a distance (distance d**2**) between the identified annulus position **13***c* of the mitral valve and the identified position **13***d* of the cardiac apex in the apical four-chamber image **13** corresponding to the end-systole. The calculation function **170***c* calculates a value obtained by subtracting the distance d**2** from the distance d**1** as the moving distance of the annulus of the mitral valve.

[0135] The moving distance of the annulus is the cardiac function parameter representing a cardiac strain and is the information useful for diagnosis of cardiac diseases.

[0136] The ultrasound diagnostic apparatus **1** according to the sixth modification of the first embodiment is described as above. As described above, the control function **140***a* according to the sixth modification causes the identification function **170***b* to identify the annulus position, and the calculation function **170***c* to calculate the moving distance of the annulus in addition to cause the selection function **170***a* to select the images, the identification function **170***b* to identify the contours, and the calculation function **170***c* to calculate the GLS by only the user's single operation of inputting the instruction to automatically calculate the GLS. The ultrasound diagnostic apparatus **1** automatically calculates the moving distance of the annulus in addition to the calculation of the GLS by only a single operation. The ultrasound diagnostic apparatus **1**, thus, can calculate the moving distance of the annulus and the GLS relatively without requiring the user's operation. The ultrasound diagnostic apparatus **1**, thus, can assist the user to easily perform diagnosis of cardiac diseases.

[0137] The identification function **170***b* according to the sixth modification may identify the annulus positions of the two mitral valves visualized in each of the apical four-chamber image corresponding to the end-diastole and apical four-chamber image corresponding to the end-systole, at step S**106**. In this case, at step S**107**, the calculation function **170***c* may calculate a distance (distance d**3**) between the identified annulus positions of the two mitral valves in the apical four-chamber image corresponding to the end-diastole, and a distance (distance d**4**) between the identified annulus positions of the two mitral valves in the apical four-chamber image corresponding to the end-systole. The

calculation function **170***c* may calculate a value obtained by subtracting the distance d**4** from the distance d**3** as the moving distance of the annulus of the mitral valve.

[0138] At step S**106**, the identification function **170***b* according to the sixth modification may identify the annulus position of the mitral valve and an annulus position of the aortic valve visualized in each of the apical two-chamber image corresponding to the end-diastole and the apical two-chamber image corresponding to the end-systole. In this case, at step S**107**, the calculation function **170***c* may calculate a distance (distance d**5**) between the identified annulus position of the mitral valve and the identified annulus position of the aortic valve in the apical two-chamber image corresponding to the end-diastole, and a distance (distance d**6**) between the identified annulus position of the mitral valve and the identified annulus position of the aortic valve in the apical four-chamber image corresponding to the end-systole. The calculation function **170***c* may calculate a value obtained by subtracting the distance d**6** from the distance d**5** as the moving distance of the annulus of the mitral valve.

[0139] The identification function **170***b* according to the sixth modification may identify the annulus positions of the two mitral valves and the position of the cardiac apex visualized in each of the apical four-chamber image corresponding to the end-diastole and the apical four-chamber image corresponding to the end-systole, at step S**106**. In this case, at step S**107**, the calculation function **170***c* may calculate distances (distances d**7** and d**8**) between the identified position of the cardiac apex and the respective identified annulus positions of the two mitral valves in the apical four-chamber image corresponding to the end-diastole, and distances (distances d**9** and d**10**) between the identified position of the cardiac apex and the respective identified annulus positions of the two mitral valves in the apical four-chamber image corresponding to the end-systole. The calculation function **170***c* may calculate a value obtained by subtracting the average of the distances d**9** and d**10** from the average of the distances d**7** and d**8** as the moving distance of the annulus of the mitral valve.

[0140] At step S**106**, the identification function **170***b* according to the sixth modification may identify the annulus position of the mitral valve, and the annulus position of the aortic valve, and the position of the cardiac apex visualized in each of the apical two-chamber image corresponding to the end-diastole and the apical two-chamber image corresponding to the end-systole. In this case, at step S**107**, the calculation function **170***c* may calculate a distance (distance d**11**) between the identified annulus position of the mitral valve and the identified position of the cardiac apex, and a distance (distance d**12**) between the identified annulus position of the aortic valve and the identified position of the cardiac apex in the apical two-chamber image corresponding to the end-diastole. The calculation function **170***c* may calculate a distance (distance d**13**) between the identified annulus position of the mitral valve and the identified position of the cardiac apex, and a distance (distance d**14**) between the identified annulus position of the aortic valve and the identified position of the cardiac apex in the apical two-chamber image corresponding to the end-systole. The calculation function **170***c* may calculate a value obtained by subtracting the average of the distances d**13** and d**14** from the average of the distances d**11** and d**12** as the moving distance of the annulus of the mitral valve.

[0141] Seventh Modification of the First Embodiment

[0142] In the first embodiment, if the control function **140***a* determines that the GLS calculation instruction is input at step S**104**, the processing from step S**105** to step S**108** is repeated until it is determined that the instruction to stop the collection is input at step S**109**. When the control function **140***a* acquires diagnosis items in the inspection at step S**101** and determines that the images collected at step S**101** are the images including the heart, i.e., determines that the inspection is performed on the heart, the processing at step S**104** may be omitted and the processing at step S**105** may be performed after the processing at step S**103** has been performed.

[0143] In this case, the control function **140***a* according to the seventh modification causes the selection function **170***a* to select the images, the identification function **170***b* to identify the contours, and the calculation function **170***c* to calculate the GLS without the operation via the input device **102**. The ultrasound diagnostic apparatus **1** according to the seventh modification automatically calculates the GLS without the operation. The ultrasound diagnostic apparatus **1** according to the seventh modification can calculate the GLS substantially without the user's operation. The ultrasound diagnostic apparatus **1**, thus, can assist the user to easily perform diagnosis of cardiac diseases.

[0144] When the seventh modification and the sixth modification are combined, the control function **140***a* according to the sixth modification causes the identification function **170***b* to identify the annulus position, and the calculation function **170***c* to calculate the moving distance of the annulus in addition to cause the selection function **170***a* to select the images, the identification function **170***b* to identify the contours, and the calculation function **170***c* to calculate the GLS without the operation via the input device **102**. The ultrasound diagnostic apparatus **1** automatically calculates the moving distance of the annulus in addition to the calculation of the GLS without the operation. The ultrasound diagnostic apparatus **1**, thus, can calculate the GLS and the moving distance of the annulus substantially without requiring the user's operation. The ultrasound diagnostic apparatus **1**, thus, can assist the user to more easily perform diagnosis of cardiac diseases.

[0145] Eighth Modification of the First Embodiment

[0146] The calculation function **170***c* may calculate the GLS by a method different from that described in the first embodiment. The following describes such an embodiment in which the calculation function **170***c* calculates the GLS by a method different from that described in the first embodiment as an eighth modification of the first embodiment.

[0147] For example, at step S**107**, the calculation function **170***c* according to the eighth modification divides the contour identified by the identification function **170***b* into a plurality of segments to determine a plurality of regional portions in the myocardium. For example, the calculation function **170***c* divides the three-dimensional contour into 18 segments to determine **18** regional portions in the myocardium. The calculation function **170***c* divides the two-dimensional contour into two segments to determine two regional portions in the myocardium, for example.

[0148] The calculation function **170***c* calculates a strain of the myocardium in the regional portion in the longitudinal direction for each of the multiple regional portions. The calculation function **170***c* calculates a length L**2** of the contour at the end-diastole for each regional portion, for

example. The calculation function **170***c* calculates a length L**3** of the contour at the end-systole for each regional portion, for example. The calculation function **170***c* calculates a strain "Regional Longitudinal Strain" (RLS) of the myocardium in the regional portion in the longitudinal direction for each of the multiple regional portions using expression (3).

$$\text{RLS}\ (\%)=[(L3-L2)/L2]*100 \quad (3)$$

[0149] The calculation function **170***c* calculates a statistic of the calculated strains as the cardiac function parameter. For example, the calculation function **170***c* may calculate an average of the RLSs each of which is the strain of the myocardium in the regional portion in the longitudinal direction, as the cardiac function parameter of the myocardium, and may cause the display **103** to display the average of the RLSs each of which is the strain of the myocardium in the regional portion in the longitudinal direction.

[0150] The user may operate the input device **102** so as to divide the contour at the end-diastole and the contour at the end-systole into a plurality of segments. In this case, the control function **140***a* may cause the display **103** to display the average of the RLSs, each of which is the strain of the myocardium in the regional portion in the longitudinal direction, and the multiple segments set by the user such that they can be corrected by the user. When receiving the correction from the user, the control function **140***a* may correct the segments on the basis of the received content of the correction. The calculation function **170***c* may calculate again the average of the RLSs using the segments after the correction. The display **103** may display the average of the RLSs.

[0151] Ninth Modification of the First Embodiment

[0152] At step S**101**, the image generation circuitry **141** of the ultrasound diagnostic apparatus **1** may generate only the image corresponding to the end-diastole and the image corresponding to the end-systole as the time-series images. The following describes such an embodiment as a ninth modification of the first embodiment. When the two-dimensional scanning is performed, at step S**101**, the image generation circuitry **141** according to the ninth modification generates, as the time-series images, only the longitudinal cross-sectional image corresponding to the end-diastole and the longitudinal cross-sectional image corresponding to the end-systole on the basis of the electrocardiogram from the electrocardiograph **104**. When the three-dimensional scanning performed, at step S**101**, the image generation circuitry **141** generates, as the time-series images, only the volume data corresponding to the end-diastole and the volume data corresponding to the end-systole on the basis of the electrocardiogram from the electrocardiograph **104**.

[0153] In the processing from step S**105** to step S**108**, the image corresponding to the end-diastole and the image corresponding to the end-systole are used. The other images are not used in the processing from step S**105** to step S**108** although they are generated. The ninth modification prevents the production of unnecessary images, thereby making it possible to calculate the GLS more easily.

[0154] Tenth Modification of the First Embodiment

[0155] The transmission-reception circuitry **110** may control the ultrasound probe **101** such that the ultrasound probe **101** performs multi-cross-section scanning, which is a scanning method scanning a number of a plurality of cross sections. The following describes such an embodiment as a tenth modification of the first embodiment.

[0156] The multi-cross-section scanning includes simultaneous multi-cross-section scanning that collects images of a number of cross sections at substantially the same timing, and scanning that scans a certain cross section for a certain number of times and thereafter scans another cross section for a certain number of times. Examples of the multi-cross-section scanning include two-cross-section scanning that scans two cross sections and three-cross-section scanning that scans three cross sections. The following describes an example where the ultrasound probe **101** according to the tenth modification performs the three-cross-section scanning that scans the apical four-chamber cross section, the apical three-chamber cross section, and the apical two-chamber cross section as the multi-cross-section scanning. The multi-cross-section scanning performed by the ultrasound probe **101** is not limited to the three-cross-section scanning. The ultrasound probe **101** may perform other multi-cross-section scanning.

[0157] At step S**101**, the control function **140***a* according to the tenth modification controls the transmission-reception circuitry **110** such that the transmission-reception circuitry **110** causes the ultrasound probe **101** to start the three-cross-section scanning to scan the apical four-chamber cross section, the apical three-chamber cross section, and the apical two-chamber cross section, and starts producing the reflected wave data by performing the various types of processing on the received reflected wave signals. At step S**101**, the image generation circuitry **141** sequentially generates the apical four-chamber images, the apical three-chamber images, and the apical two-chamber images, and starts sequentially storing the apical four-chamber images, the apical three-chamber images, and the apical two-chamber images in the image memory **150**. At step S**101**, the control function **140***a* causes the display **103** to display the apical four-chamber images, the apical three-chamber images, and the apical two-chamber images that are stored in the image memory **150** in the time-series order.

[0158] At step S**105**, the control function **140***a* controls the selection function **170***a* such that the selection function **170***a* selects, out of the apical four-chamber images, the apical three-chamber images, and the apical two-chamber images that correspond to a certain time period and are acquired from the image memory **150**, the apical four-chamber image corresponding to the end-diastole, the apical three-chamber image corresponding to the end-diastole, and the apical two-chamber image corresponding to the end-diastole, and the apical four-chamber image corresponding to the end-systole, the apical three-chamber image corresponding to the end-systole, and the apical two-chamber image corresponding to the end-systole, in one cardiac beat. As a result, the selection function **170***a* selects six images of the apical four-chamber image corresponding to the end-diastole, the apical three-chamber image corresponding to the end-diastole, and the apical two-chamber image corresponding to the end-diastole, and the apical four-chamber image corresponding to the end-systole, the apical three-chamber image corresponding to the end-systole, and the apical two-chamber image corresponding to the end-systole, in one cardiac beat.

[0159] At step S**105**, the control function **140***a* causes the display **103** to display the selected six images.

[0160] At step S**106**, the control function **140***a* controls the identification function **170***b* such that identification function **170***b* automatically traces and identifies the two-dimensional contour of the heart for each of the selected six images. The identification function **170***b* identifies the contour for each of the selected six images.

[0161] At step S**107**, the control function **140***a* controls the calculation function **170***c* such that the calculation function **170***c* calculates the GLS using the information about the contours identified by the identification function **170***b*, and causes the calculated GLS to be displayed on the display **103**. The calculation function **170***c* calculates the lengths of the three contours each identified in the apical four-chamber image corresponding to the end-diastole, the apical three-chamber image corresponding to the end-diastole, and the apical two-chamber image corresponding to the end-diastole, and calculates a statistic of the calculated lengths of the three contours, e.g., an average, as L**0**. The calculation function **170***c* calculates the lengths of the three contours each identified in the apical four-chamber image corresponding to the end-systole, the apical three-chamber image corresponding to the end-systole, and the apical two-chamber image corresponding to the end-systole, and calculates a statistic of the calculated lengths of the three contours, e.g., an average, as L**1**. The calculation function **170***c* calculates the GLS using L**0** and L**1** using expression (1). The calculation function **170***c* causes the display **103** to display the calculated GLS.

[0162] In the tenth modification, the ultrasound probe **101** scans a plurality of cross sections by the multi-cross-section scanning under the control of the transmission-reception circuitry **110**. The user may operate the ultrasound probe **101** such that the ultrasound probe **101** scans a plurality of cross sections by the multi-cross-section scanning. For example, the user may operate the ultrasound probe **101** such that the ultrasound probe **101** scans the apical four-chamber cross section, the apical three-chamber cross section, and the apical two-chamber cross section.

[0163] Eleventh Modification of the First Embodiment

[0164] The user who has checked the GLS displayed on the display **103** may want to check the RLS of the subject P for inspecting the heart of the subject P further in detail in some cases. The following describes such an embodiment in which the RLS is calculated and displayed after the calculation and display of the GLS as an eleventh modification of the first embodiment.

[0165] In the eleventh modification, the control function **140***a* or the identification function **170***b* reads, from the internal memory circuitry **160**, the information (e.g., the positions of the contours in the images) about the contours (the contours identified by the identification function **170***b*) used when the GLS is calculated, after the GLS is calculated and displayed, for example. The internal memory circuitry **160** may store therein at least the information about the contour identified in the image corresponding to the end-diastole.

[0166] The control function **140***a* or the identification function **170***b* reads the information about the contours from the internal memory circuitry **160** when the user operates the input device **102** and the instruction to calculate the RLS is input to the input device **102**, for example. The control function **140***a* or the identification function **170***b* reads the information about the contours from the internal memory circuitry **160** in accordance with the operation performed after the GLS is displayed. The control function **140***a* or the identification function **170***b* reads the information about the contours from the internal memory circuitry **160** in accordance with the operation performed subsequently after the common operation.

[0167] The calculation function **170***c* calculates the RLS, which is a third cardiac function parameter that represents a regional strain of the myocardium corresponding to the heart chamber, using the read information about the contours. The control function **140***a* causes the display **103** to display the calculated RLS. The calculation function **170***c* calculates the RLS after the calculation of the GLS, and the control function **140***a* causes the display **103** to display the calculated RLS.

[0168] The following describes a case where the ultrasound diagnostic apparatus calculates the GLS by executing routine inspection software in a routine inspection and calculates the RLS by executing non-routine inspection software in a non-routine inspection performed sequentially after the routine inspection. When there is a lack in cooperation between the routine inspection software and the non-routine inspection software, the processing to identify the contours is performed again in calculating the RLS by the non-routine inspection software although the contours have been identified in calculating the GLS by the routine inspection software. It is, thus, difficult to easily calculate the RLS.

[0169] In the eleventh modification, the information about the already identified contours is used in calculating the RLS without performing the processing to identify the contours. The eleventh modification reuses, in the non-routine inspection, the information about the contours identified in the routine inspection. The eleventh modification can easily calculate the RLS.

[0170] Twelfth Modification of the First Embodiment

[0171] In the eleventh modification, the ultrasound diagnostic apparatus **1** may identify the contours by the speckle tracking, calculate the GLS using the information about the identified contours, and thereafter may calculate the RLS reusing the information about the contours used in calculating the GLS. The following describes such an embodiment as a twelfth modification of the first embodiment.

[0172] In the twelfth modification, the identification function **170***b* identifies a contour of at least a part of the heart for each of a plurality of images (e.g., all of the images) included in the time-series images including the heart of the subject P by the speckle tracking so as to select the image corresponding to the end-systole and the image corresponding to the end-diastole. The images used for identifying the contours are three or more images, for example. The identification function **170***b* stores the information about the identified contour in the internal memory circuitry **160** for each of the multiple images. The internal memory circuitry **160** stores therein the information about the identified contour for each of the multiple images. The internal memory circuitry **160** may store therein at least the information about the contour identified in the image corresponding to the end-diastole.

[0173] The control function **140***a* or the identification function **170***b* reads the information about the contour stored in the internal memory circuitry **160** for each of the images.

[0174] The identification function **170***b* identifies again the contour of at least a part of the heart for each of the images by the speckle tracking using the read information about the contour.

[0175] The calculation function **170***c* calculates again the RLS using the information about the contours identified by the speckle tracking. The calculation function **170***c* calculates the RLS using the information about the contour identified in the image corresponding to the end-systole and information about the contour identified in the image corresponding to the end-diastole out of the images, for example.

Second Embodiment

[0176] The functions described in the first embodiment are applicable to an image processing apparatus beside the ultrasound diagnostic apparatus **1**, for example.

[0177] FIG. **11** is a schematic diagram illustrating a structural example of an image processing system according to a second embodiment. As illustrated in FIG. **11**, the image display processing system according to the second embodiment includes an image processing apparatus **200**, a medical image diagnostic apparatus **300**, and an image storing apparatus **400**. The respective apparatuses exemplarily illustrated in FIG. **11** can communicate directly or indirectly among them via an in-hospital local area network (LAN) **5** installed in a hospital, for example. For example, when a picture archiving and communication system (PACS) is introduced to the image processing system, the respective apparatuses transmit and receive medical image data among them in conformity with the digital imaging and communications in medicine (DICOM) standard.

[0178] In FIG. **11**, the medical image diagnostic apparatus **300** stores medical images including the hearts of subjects in the image storing apparatus **400**, for example. The medical image diagnostic apparatus **300** is the ultrasound diagnostic apparatus **1**, an X-ray diagnostic apparatus, an X-ray computed tomography (CT) apparatus, a magnetic resonance imaging (MRI) apparatus, a single photon emission computed tomography (SPECT) apparatus, a positron emission tomography (PET) apparatus, an SPECT-CT apparatus in which the SPECT apparatus and the X-ray CT apparatus are integrated, a PET-CT apparatus in which the PET apparatus and the X-ray CT apparatus are integrated, a PET-MRI apparatus in which the PET apparatus and the MRI apparatus are integrated, or an apparatus group including a plurality of apparatuses described above, for example.

[0179] The image storing apparatus **400** is a database that stores therein medical images. Specifically, the image storing apparatus **400** puts and stores various medical images generated by the medical image diagnostic apparatus **300** in a storage unit. The medical images are each stored in the image storing apparatus **400** in such a manner that the medical image and supplementary information such as a patient ID, an inspection ID, an apparatus ID, and a series ID in association with one another, for example.

[0180] The image processing apparatus **200** is a work station or a personal computer (PC), which is used by doctors and laboratory technicians who work in a hospital for browsing the medical images, for example. Operators of the image processing apparatus **200** acquire necessary medical images from the image storing apparatus **400** by performing searches using the patient IDs, the inspection IDs, the apparatus IDs, and the series IDs, for example. The image processing apparatus **200** may receive the medical images directly from the medical image diagnostic apparatus **300**. The image processing apparatus **200** is an example of the analyzer.

[0181] The image processing apparatus **200** includes an input device **201**, communication circuitry **202**, a display **203**, memory circuitry **210**, processing circuitry **220** and analysis circuitry **230**. The input device **201**, the communication circuitry **202**, the display **203**, the memory circuitry **210**, the processing circuitry **220**, and the analysis circuitry **230** are connected to one another.

[0182] The input device **201**, which includes a pointing device such as a mouse or a pen tablet, a keyboard, and a trackball, receives various types of operation input to the image processing apparatus **200** from the operator. When the mouse is used, input can be performed by a mouse wheel. When the pen tablet is used, input can be performed by flick operation or swipe operation. The communication circuitry **202**, which is a network interface card (NIC), for example, communicates with another apparatus. The display **203** is a monitor or a liquid crystal display, for example, and displays various types of information.

[0183] The memory circuitry **210**, which is a hard disk drive or a semiconductor memory, for example, stores therein various types of information. The memory circuitry **210** stores therein a plurality of pieces of processing performed by the processing circuitry **220**, for example.

[0184] The processing circuitry **220** is achieved by a processor, for example. The processing circuitry **220** controls the whole of the image processing apparatus **200**. The processing circuitry **220** includes a control function **220***a*.

[0185] The analysis circuitry **230** includes a selection function **230***a*, an identification function **230***b*, and a calculation function **230***c*.

[0186] The control function **220***a* has the same function as the control function **140***a* illustrated in FIG. **1**. The selection function **230***a* has the same function as the selection function **170***a*. The identification function **230***b* has the same function as the identification function **170***b*. The calculation function **230***c* has the same function as the calculation function **170***c*. The control function **220***a*, the selection function **230***a*, the identification function **230***b*, and the calculation function **230***c* perform, on the medical images, the same processing as the first embodiment and the respective modifications. The image processing apparatus **200** according to the second embodiment can obtain the same effects as the first embodiment and the respective modifications.

[0187] In the embodiments, the components of the apparatuses illustrated in the drawings are functionally conceptual ones, and are not always required to be physically configured as illustrated in the drawings. The specific forms of distributions and integrations of the apparatuses are not limited to those illustrated in the drawings. All or part of the apparatuses can be configured to be functionally or physically distributed or integrated in arbitrary units in accordance with various loads, the usage states, and the like. Furthermore, all or part of the processing functions performed by the respective apparatuses may be implemented by a CPU and a program analyzed and executed by the CPU, or may be implemented as hardware by wired logics.

[0188] The various types of processing described in the embodiments and the modifications described above can be achieved by a computer, such as a personal computer or a

work station, executing preliminarily prepared programs. The programs can be distributed via a network such as the Internet. The programs can be recorded on a computer readable recording medium such as a hard disk, a flexible disk (FD), a compact disc read only memory (CD-ROM), a magneto-optical (MO) disc, or a digital versatile disc (DVD), and read from the recording medium and executed by the computer.

[0189] At least one of the embodiments described above can assist the user to easily perform diagnosis of cardiac diseases.

[0190] While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

What is claimed is:

1. An analyzer, comprising processing circuitry configured to

identify at least a part of a contour of a heart of a subject for an image corresponding to a first cardiac time phase and an image corresponding to a second cardiac time phase that are included in time-series images including the heart of the subject,

calculate, using information about the identified contours, a first cardiac function parameter representing at least one of a volume and an ejection fraction of a heart chamber, and a second cardiac function parameter representing a global strain of a myocardium corresponding to the heart chamber, and

cause the first cardiac function parameter and the second cardiac function parameter to be displayed by common operation.

2. The analyzer according to claim **1**, further comprising memory circuitry configured to store therein at least the information about the contour identified in the image corresponding to the second cardiac time phase, wherein

the processing circuitry

reads the information about the contour, the information being stored in the memory circuitry, and

calculates a third cardiac function parameter that represents a regional strain of the myocardium using the read information about the contour after the second cardiac function parameter is calculated.

3. The analyzer according to claim **2**, wherein the processing circuitry reads the information about the contour stored in the memory circuitry in accordance with operation performed after the second cardiac function parameter is displayed.

4. The analyzer according to claim **3**, wherein the processing circuitry reads the information about the contour stored in the memory circuitry in accordance with operation performed subsequently after the common operation.

5. The analyzer according to claim **1**, wherein the processing circuitry causes a contour marker representing the contour of the part of the heart, the contour serving as a target of the calculation of the second cardiac function parameter, to be displayed on at least one of the image corresponding to the first cardiac time phase and the image corresponding to the second cardiac time phase, in accordance with operation to designate the second cardiac function parameter.

6. The analyzer according to claim **2**, wherein

the processing circuitry identifies the contour for each of three or more images included in the time-series images in order to select the image corresponding to the first cardiac time phase and the image corresponding to the second cardiac time phase,

the memory circuitry stores therein the information about the identified contour for each of the three or more images, and

the processing circuitry further reads the information about the contour, the information being stored in the memory circuitry, for each of the three or more images.

7. The analyzer according to claim **2**, wherein the processing circuitry

identifies the contour for each of a plurality of images included in the time-series images by speckle tracking using the read information about the contour, and

calculates the third cardiac function parameter using the information about the contour identified by the speckle tracking.

8. The analyzer according to claim **2**, wherein the memory circuitry stores therein the information about the contour for each cross section.

9. The analyzer according to claim **2**, wherein

the time-series images are time-series cross-sectional images each corresponding to a longitudinal cross section of the heart, and

the processing circuitry

identifies a contour of an endocardium of the heart chamber, and

calculates the second cardiac function parameter on the basis of a length of the identified contour.

10. The analyzer according to claim **1**, wherein the processing circuitry

selects the image corresponding to the first cardiac time phase and the image corresponding to the second cardiac time phase out of the time-series images, and

causes the selection of the images, the identification of the contours, and control for displaying the first cardiac function parameter and the second cardiac function parameter on a display to be performed by single operation.

11. The analyzer according to claim **1**, wherein the first cardiac time phase corresponds to an end-systole while the second cardiac time phase corresponds to an end-diastole.

12. The analyzer according to claim **1**, wherein the processing circuitry calculates the second cardiac function parameter for each of a plurality of cross sections different from one another, and calculates a statistic of a plurality of calculated second cardiac function parameters.

13. The analyzer according to claim **1**, wherein the processing circuitry calculates the second cardiac function parameter for each of a plurality of cardiac periods different from one another, and calculates a statistic of a plurality of calculated second cardiac function parameters.

14. The analyzer according to claim **1**, wherein

the time-series images are time-series two-dimensional images generated from time-series three-dimensional images generated by scanning a three-dimensional region, and

the processing circuitry

identifies a two-dimensional contour of the heart for the two-dimensional image corresponding to the end-systole and the two-dimensional image corresponding to the end-diastole that are included in the time-series two-dimensional images, and

calculates the first cardiac function parameter and the second cardiac function parameter using the information about the identified two-dimensional contours.

15. An analyzer, comprising processing circuitry configured to

identify a contour of a heart of a subject, the heart being included in a cross-sectional image corresponding to a longitudinal cross section of the heart of the subject, and

cause the identified contour to be displayed on the cross-sectional image displayed on a display while a display form of a portion along a myocardium in the identified contour and a display form of a portion that is not along the myocardium are differentiated from each other.

16. An analyzer, comprising processing circuitry configured to

identify a position of an annulus of a heart of a subject for a cross-sectional image corresponding to a first cardiac time phase and a cross-sectional image corresponding to a second cardiac time phase that are included in time-series cross-sectional images corresponding to a longitudinal cross section of the heart of the subject, and

calculate a moving distance of the annulus between the first cardiac time phase and the second cardiac time phase on the basis of the identified position of the annulus.

17. The analyzer according to claim **1**, wherein the second cardiac function parameter is a global longitudinal strain (GLS).

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