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(54) **OPTIMIZING ULTRASOUND ACQUISITION BASED ON ULTRASOUND-LOCATED LANDMARKS**

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A61B 8/02 (2006.01)
(52) **U.S. Cl.** **600/450**

(57) **ABSTRACT**

An ultrasound device is disclosed that includes a method and apparatus for generating an image responsive to moving cardiac structure and blood, and for adjusting at least one acquisition parameter based on, at least in part, locating at least one anatomical landmark within a heart. At least one processor, responsive to signals received from the heart, locates anatomical landmarks within the cardiac structure, generate position information of the anatomical landmarks, and adjusts at least one acquisition parameter. The landmarks and acquisition parameters may be displayed to a user of the ultrasound device.

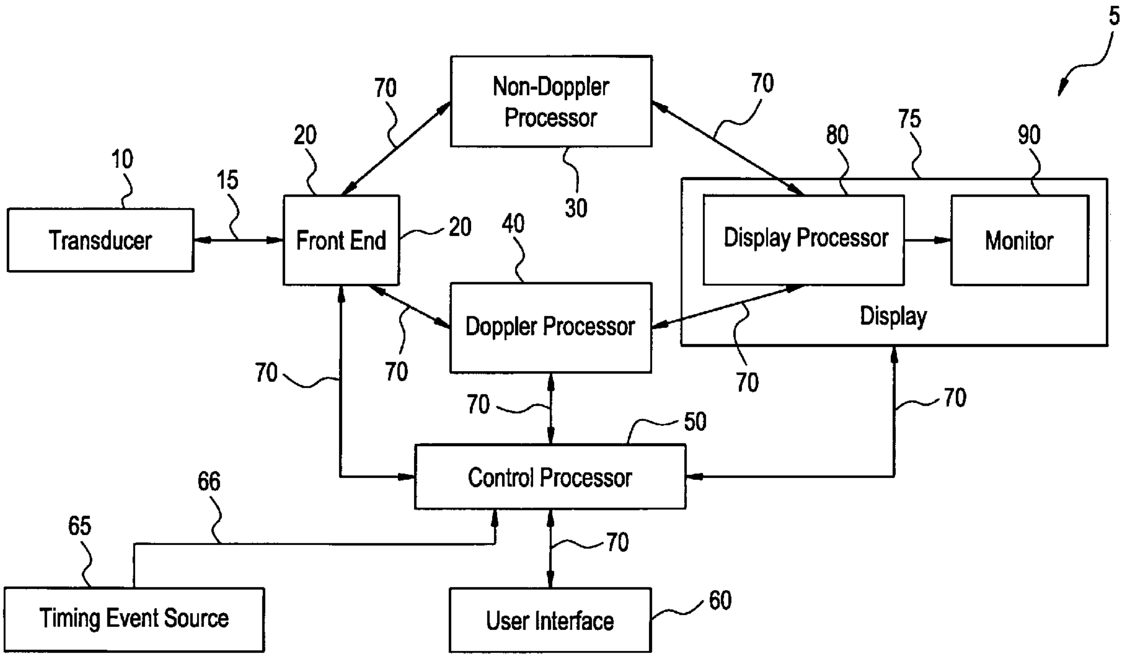


FIG. 1

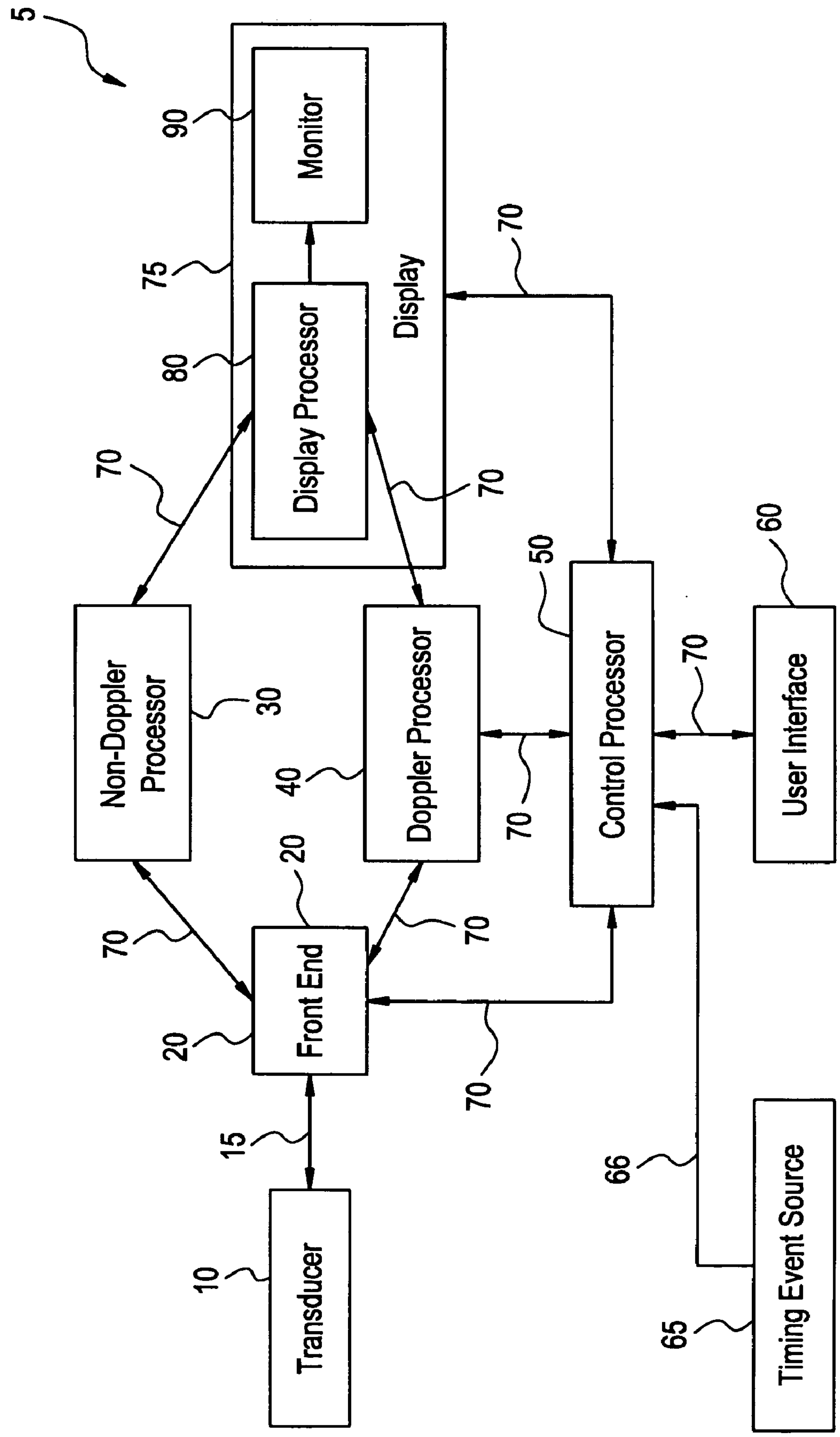

5
Monitor
90
75
Display Processor
80
Display
70
Non-Doppler Processor
30
Doppler Processor
40
Control Processor
50
User Interface
60
Front End
20
Transducer
10
15
Timing Event Source
65
66

FIG. 2

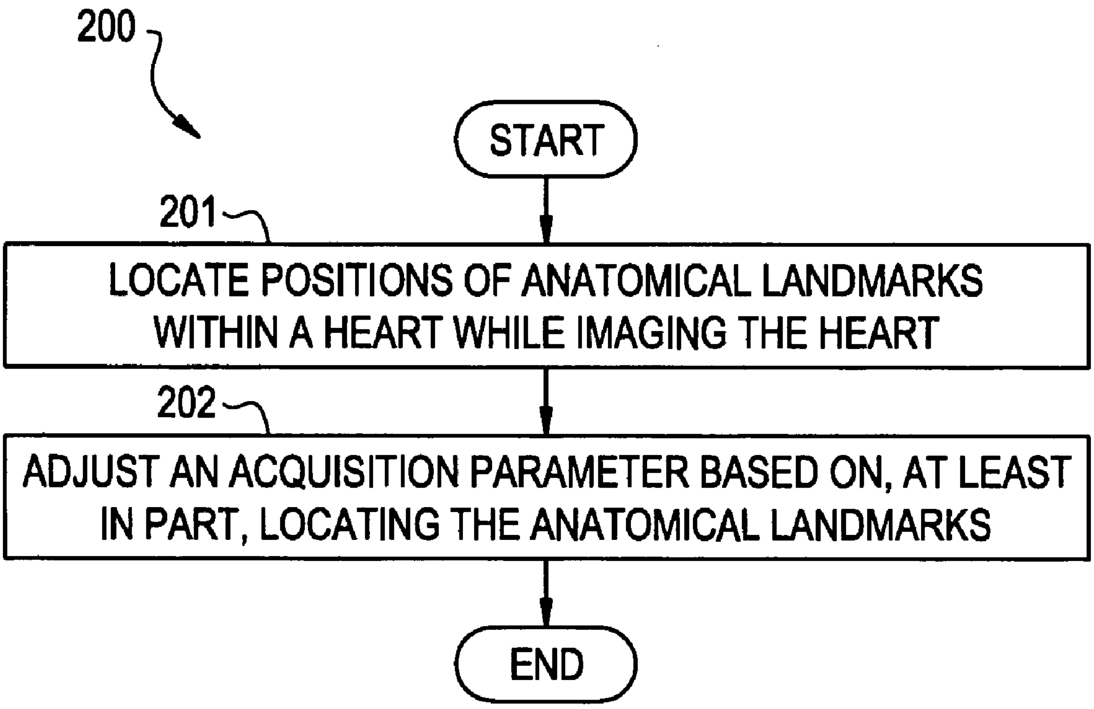
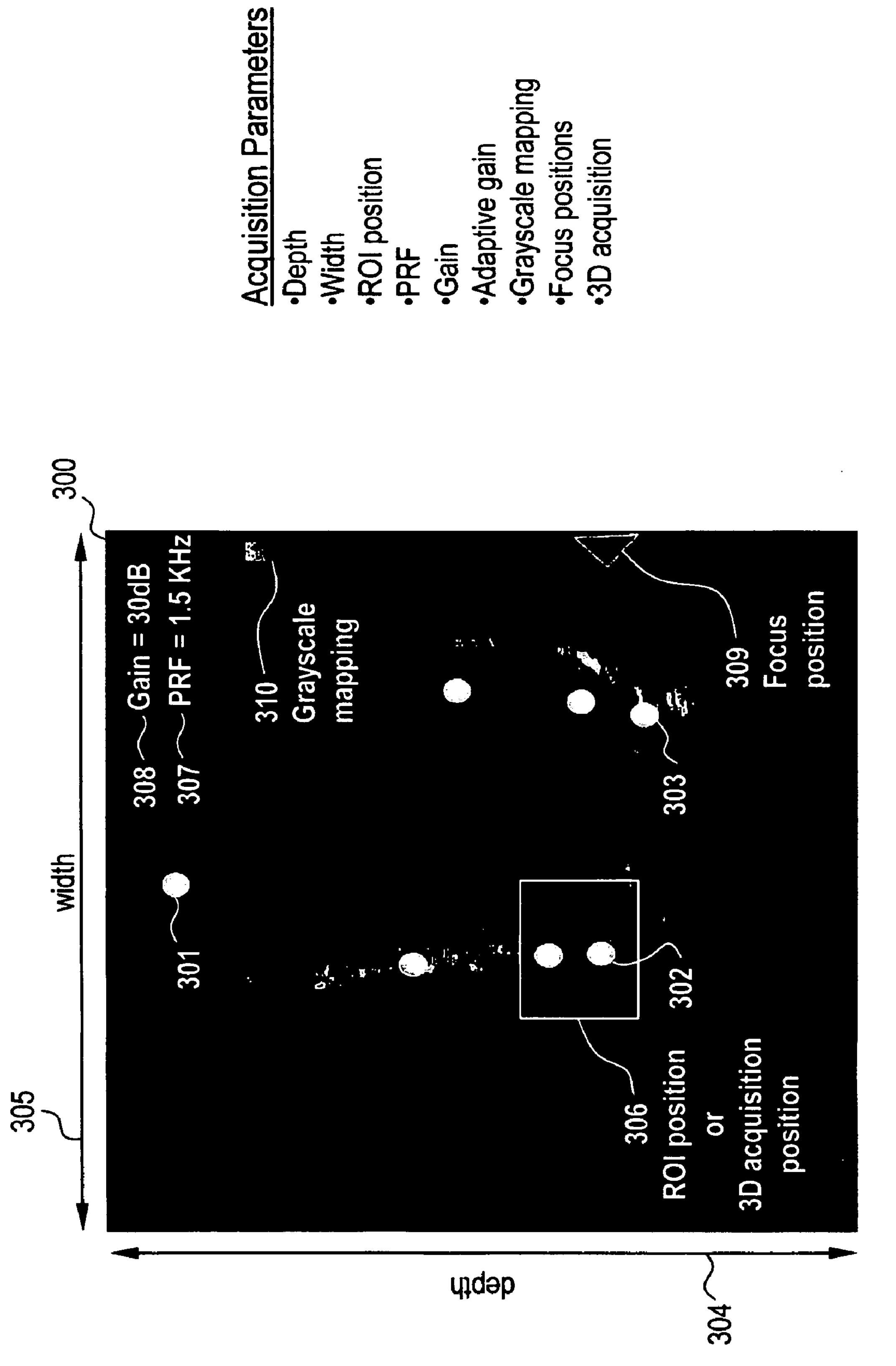

200
START
201
LOCATE POSITIONS OF ANATOMICAL LANDMARKS WITHIN A HEART WHILE IMAGING THE HEART
202
ADJUST AN ACQUISITION PARAMETER BASED ON, AT LEAST IN PART, LOCATING THE ANATOMICAL LANDMARKS
END

FIG. 3



Acquisition Parameters
•Depth
•Width
•ROI position
•PRF
•Gain
•Adaptive gain
•Grayscale mapping
•Focus positions
•3D acquisition
300
305
width
301
308 Gain = 30dB
307 PRF = 1.5 KHz
310 Grayscale mapping
303
309 Focus position
302
306 ROI position or 3D acquisition position
depth
304

FIG. 4

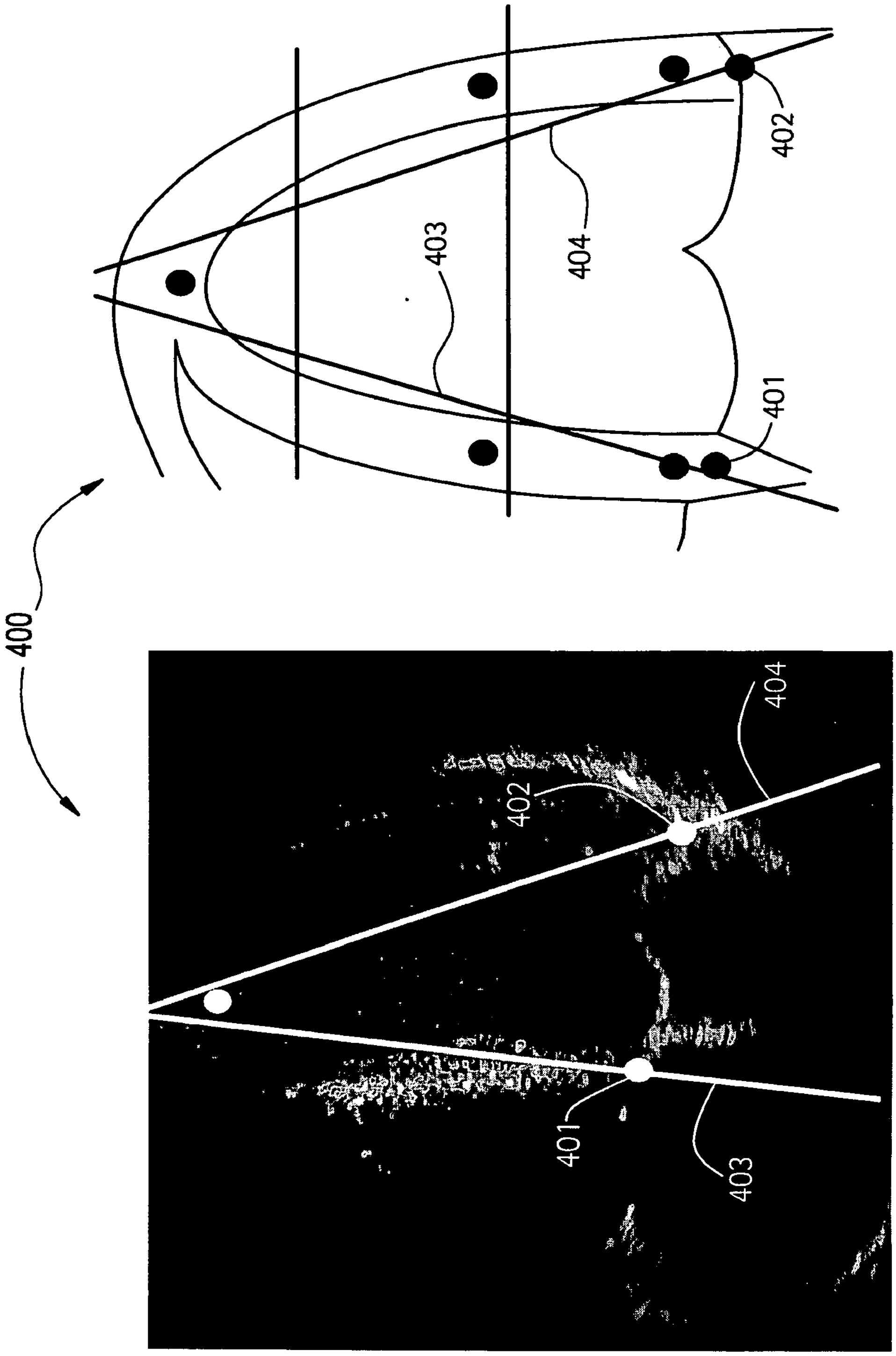


FIG. 5

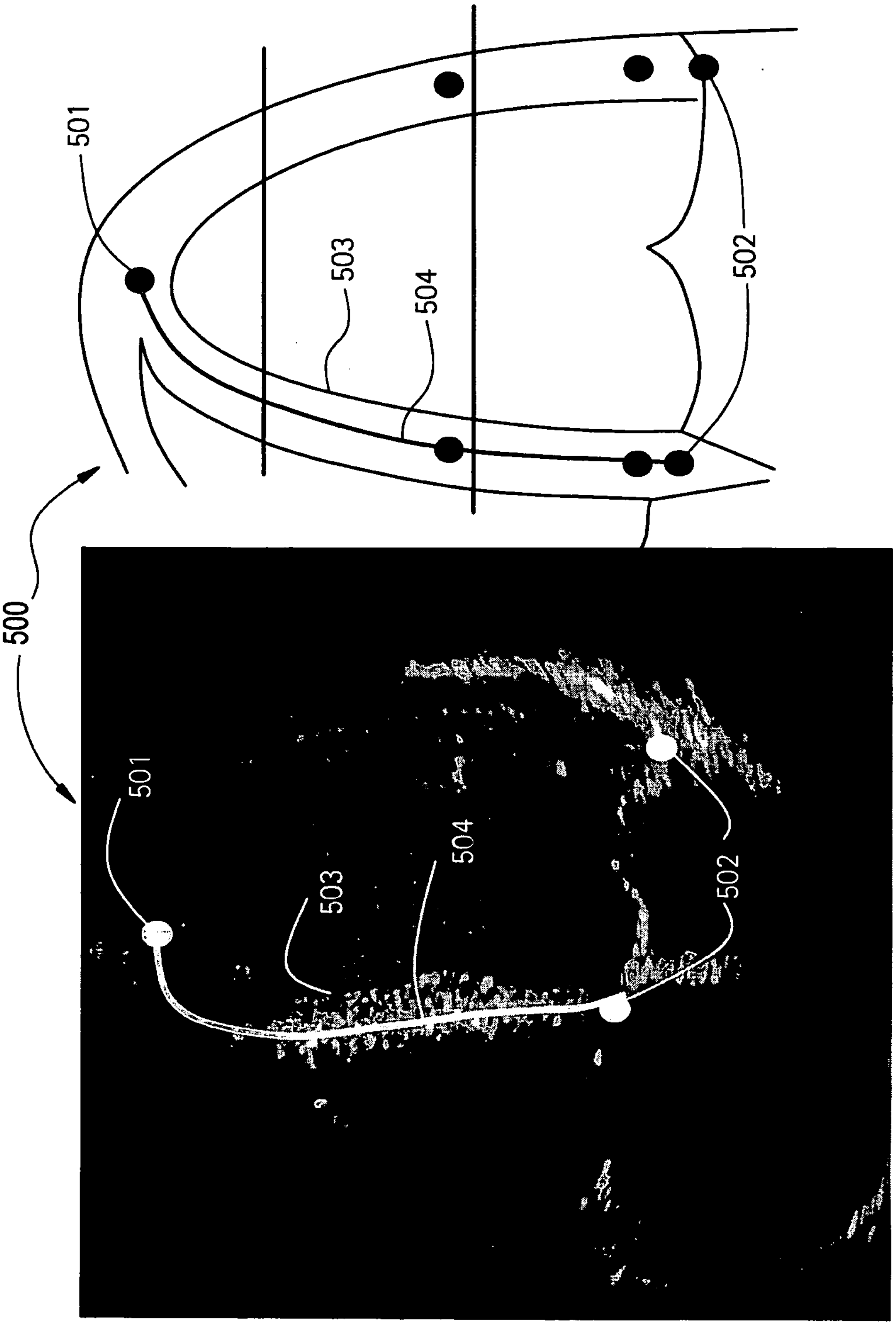


FIG. 6

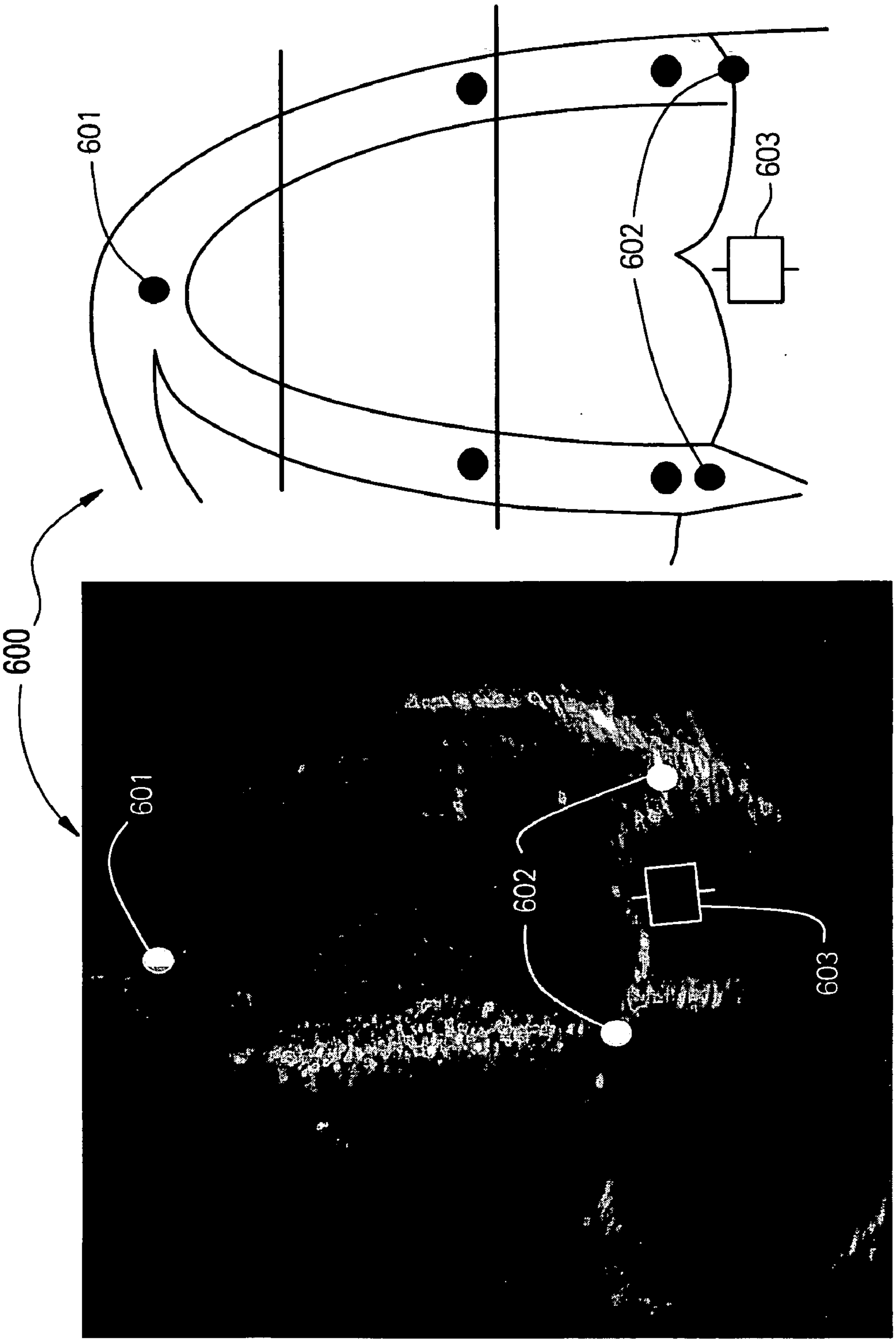
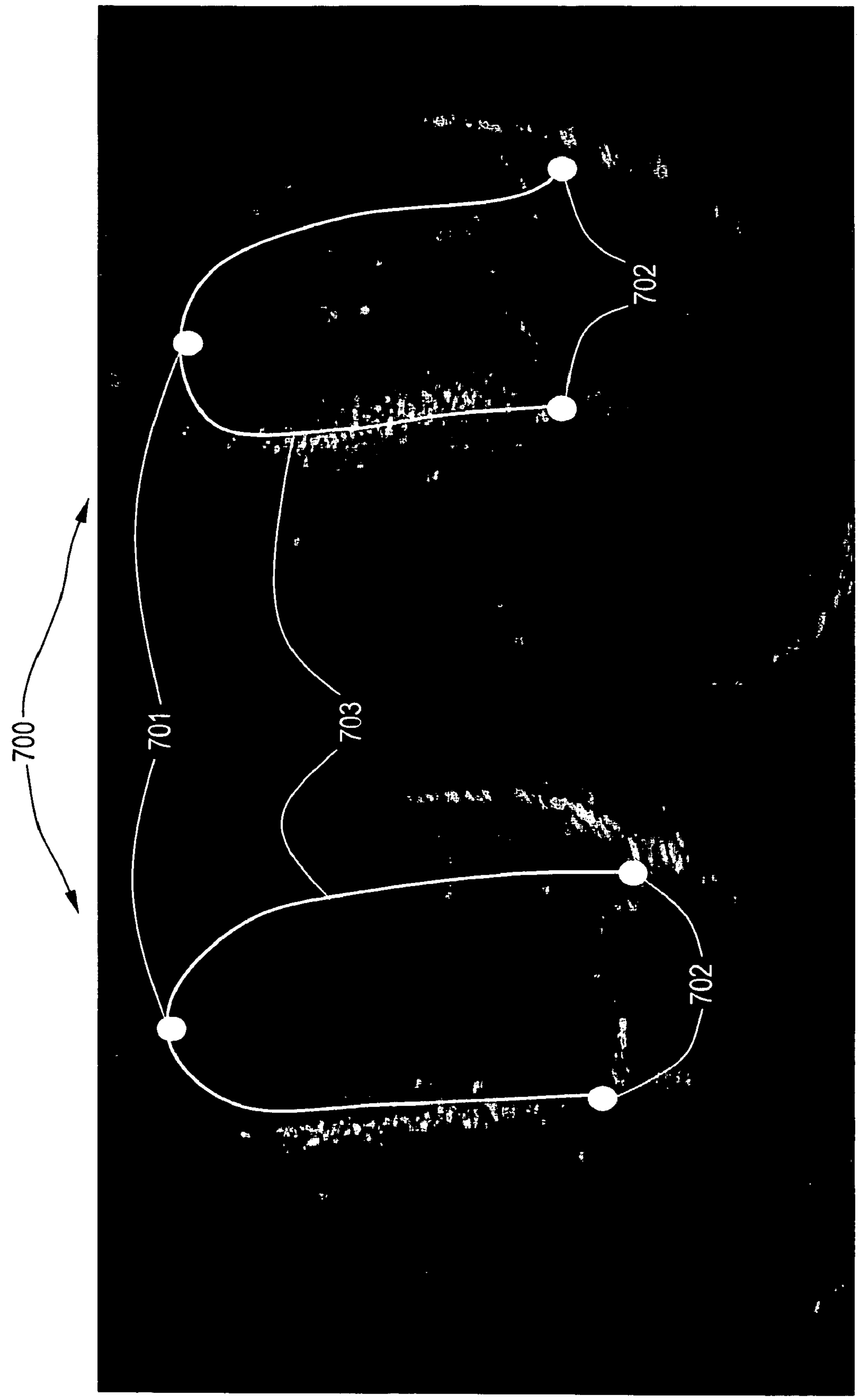


FIG. 7



OPTIMIZING ULTRASOUND ACQUISITION BASED ON ULTRASOUND-LOCATED LANDMARKS

RELATED APPLICATIONS/INCORPORATION BY REFERENCE

[0001] This application is related to, and claims benefit of and priority from, Provisional Application No. 60/606,078 filed Aug. 31, 2004, titled "OPTIMIZING ULTRASOUND ACQUISITION BASED ON ULTRASOUND-LOCATED LANDMARKS", the complete subject matter of which is incorporated herein by reference in its entirety.

[0002] The complete subject matter of each of the following U.S. patent applications is incorporated by reference herein in their entirety:

[0003] U.S. patent application Ser. No. 10/248,090 filed on Dec. 17, 2002.

[0004] U.S. patent application Ser. No. 10/064,032 filed on Jun. 4, 2002.

[0005] U.S. patent application Ser. No. 10/064,083 filed on Jun. 10, 2002.

[0006] U.S. patent application Ser. No. 10/064,033 filed on Jun. 4, 2002.

[0007] U.S. patent application Ser. No. 10/064,084 filed on Jun. 10, 2002.

[0008] U.S. patent application Ser. No. 10/064,085 filed on Jun. 10, 2002.

FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0009] [Not Applicable]

BACKGROUND OF THE INVENTION

[0010] Echocardiography is a branch of the ultrasound field that is currently a mixture of subjective image assessment and extraction of key quantitative parameters. Evaluation of cardiac wall function has been hampered by a lack of well-established parameters that may be used to increase the accuracy and objectivity in the assessment of, for example, coronary artery diseases. Stress echo is one example. It has been shown that the subjective part of wall motion scoring in stress echo is highly dependent on operator training and experience. It has also been shown that inter-observer variability between echo-centers is unacceptably high due to the subjective nature of the wall motion assessment.

[0011] Much technical and clinical research has focused on this problem, aimed at defining and validating quantitative parameters. Encouraging clinical validation studies have been reported, which indicate a set of new potential parameters that may be used to increase objectivity and accuracy in the diagnosis of, for instance, coronary artery diseases. Many of the new parameters have been difficult or impossible to assess directly by visual inspection of the ultrasound images generated in real-time. The quantification has typically required a post-processing step with tedious, manual analysis to extract the necessary parameters. Determination of the location of anatomical landmarks in the heart is no exception. Time intensive post-processing techniques or complex, computation-intensive real-time techniques are undesirable.

[0012] A method in U.S. Pat. No. 5,601,084 to Sheehan et al. describes imaging and three-dimensionally modeling portions of the heart using imaging data. A method in U.S. Pat. No. 6.099,471 to Torp et al. describes calculating and displaying strain velocity in real time. A method in U.S. Pat. No. 5,515,856 to Olstad et al. describes generating anatomical M-mode displays for investigations of living biological structures, such as heart function, during movement of the structure. A method in U.S. Pat. No. 6,019,724 to Gronningsaeter et al. describes generating quasi-realtime feedback for the purpose of guiding procedures by means of ultrasound imaging.

BRIEF SUMMARY OF THE INVENTION

[0013] An embodiment of the present invention provides an ultrasound system for imaging a heart and automatically adjusting acquisition parameters after having automatically located anatomical landmarks within the heart. An apparatus is provided in an ultrasound machine for imaging a heart and adjusting certain acquisition parameters based on locating anatomical landmarks within the heart. In such an environment an apparatus for automatically adjusting acquisition parameters comprises a front-end arranged to transmit ultrasound waves into a structure and to generate received signals in response to ultrasound waves backscattered from said structure over a time period. A processor is responsive to the received signals to generate a set of analytic parameter values representing movement of the cardiac structure over the time period and analyzes elements of the set of analytic parameter values to automatically extract position information of the anatomical landmarks and track the positions of the landmarks. A processor is responsive to the tracked anatomical landmark positions and automatically adjusts certain acquisition parameters based on the tracked anatomical landmarks. A display is arranged to overlay indicia corresponding to the position information onto an image of the moving structure to indicate to an operator the position of the tracked anatomical landmarks, and to display the acquisition parameters, if desired.

[0014] A method is also provided in an ultrasound machine or device for imaging a heart and adjusting acquisition parameters based on having previously located certain anatomical landmarks within the heart. In such an environment, a method for automatically adjusting certain acquisition parameters comprises transmitting ultrasound waves into a structure and generating received signals in response to ultrasound waves backscattered from the structure over a time period. A set of analytic parameter values is generated in response to the received signals representing movement of the cardiac structure over the time period. Position information of the anatomical landmarks is automatically extracted and the positions of the landmarks are then tracked. Certain acquisition parameters are automatically adjusted based on the tracked anatomical landmarks. Indicia corresponding to the position information are overlaid onto the image of the moving structure to indicate to an operator the position of the tracked anatomical landmarks, and the adjusted acquisition parameters may also be displayed. Certain embodiments of the present invention relate to automatically adjusting at least one acquisition parameter (e.g., a depth setting, a width setting, an ROI position, a PRF setting, a gain setting, etc.) after automatically locating key anatomical landmarks of the heart, such as the apex and the AV-plane. In least one embodiment adjusting the at least one acquisition parameter is responsive to the at least one anatomical landmark and ultrasound data acquired in regions related to the anatomical landmarks.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] **FIG. 1** is a diagram of an embodiment of an ultrasound machine or device made in accordance with various aspects of the present invention.

[0016] **FIG. 2** is a flowchart of an embodiment of a method performed by the machine or device shown in **FIG. 1**, in accordance with various aspects of the present invention.

[0017] **FIG. 3** is a diagram illustrating using the method of **FIG. 2** in the ultrasound machine of FIG. I to adjust acquisition parameters after having automatically located anatomical landmarks within the heart, in accordance with various embodiments of the present invention.

[0018] FIG 4 illustrates using the method of **FIG. 2** to preset two longitudinal M-modes through two AV-plane locations in accordance with an embodiment of the present invention.

[0019] **FIG. 5** illustrates using the method of **FIG. 2** to preset a curved M-mode within a myocardial segment from the apex and down to the AV-plane in accordance with an embodiment of the present invention.

[0020] **FIG. 6** illustrates using the method of **FIG. 2** to preset a Doppler sample volume relative to detected anatomical landmarks in accordance with an embodiment of the present invention.

[0021] **FIG. 7** illustrates using the method of **FIG. 2** to define a set of points within myocardial segments to perform edge detection in accordance with an embodiment of the present invention.

[0022] The foregoing summary, as well as the following detailed description of certain embodiments of the present invention, will be better understood when read in conjunction with the appended drawings. It should be understood, however, that the present invention is not limited to the arrangements and instrumentality shown in the attached drawings.

DETAILED DESCRIPTION OF THE INVENTION

[0023] An embodiment of the present invention enables the automatic adjusting of acquisition parameters, after locating and tracking certain anatomical landmarks of the heart, for subsequent acquisition of certain clinically relevant information. Moving cardiac structure and blood is monitored to accomplish the function. As used herein, structure means non-liquid and non-gas matter, such as cardiac wall tissue for example. An embodiment of the present invention helps establish improved, real-time visualization and assessment of wall function parameters of the heart. The moving structure is characterized by a set of analytic parameter values corresponding to anatomical points within a myocardial segment of the heart. The set of analytic parameter values may comprise, for example, tissue velocity values, time-integrated tissue velocity values, B-mode tissue intensity values, tissue strain rate values, blood flow values, and mitral valve inferred values.

[0024] **FIG. 1** depicts a diagram of an embodiment of an ultrasound machine **5** made in accordance with various aspects of the present invention. A transducer **10** is used to transmit ultrasound waves into a subject by converting electrical analog signals to ultrasonic energy and to receive ultrasound waves backscattered from the subject by converting ultrasonic energy to analog electrical signals. A front-end **20**, comprising a receiver, transmitter, and beamformer, is used to create the necessary transmitted waveforms, beam patterns, receiver filtering techniques, and demodulation schemes that are used for the various imaging modes. Front-end **20** performs the functions by converting digital data to analog data and vice versa. Front-end **20** interfaces at an analog interface **15** to transducer **10** and interfaces over a digital bus **70** to a non-Doppler processor **30** and a Doppler processor **40** and a control processor **50**. Digital bus **70** may comprise several digital sub-buses, each sub-bus having its own unique configuration and providing digital data interfaces to various parts of the ultrasound machine **5**.

[0025] Non-Doppler processor **30** comprises amplitude detection functions and data compression functions used for imaging modes such as B-mode, B M-mode, and harmonic imaging. Doppler processor **40** comprises clutter filtering functions and movement parameter estimation functions used for imaging modes such as tissue velocity imaging (TVI), strain rate imaging (SRI), and color M-mode. The processors, **30** and **40**, accept digital signal data from the front-end **20**, process the digital signal data into estimated parameter values, and pass the estimated parameter values to processor **50** and a display **75** over digital bus **70**. The estimated parameter values may be created using the received signals in frequency bands centered at the fundamental, harmonics, or sub-harmonics of the transmitted signals in a manner known to those skilled in the art.

[0026] Display **75** comprises scan-conversion functions, color mapping functions, and tissue/flow arbitration functions, performed by a display processor **80** which accepts digital parameter values from processors **30**, **40**, and **50**, processes, maps, and formats the digital data for display, converts the digital display data to analog display signals, and passes the analog display signals to a monitor **90**. Monitor **90** accepts the analog display signals from display processor **80** and displays the resultant image to the operator on monitor **90**.

[0027] A user interface **60** allows user commands to be input by the operator to the ultrasound machine **5** through control processor **50**. User interface **60** comprises a keyboard, mouse, switches, knobs, buttons, track ball, and on screen menus.

[0028] A timing event source **65** is used to generate a cardiac timing event signal **66** that represents the cardiac waveform of the subject. The timing event signal **66** is input to ultrasound machine **5** through control processor **50**.

[0029] Control processor **50** is in at least one embodiment, the central processor of the ultrasound machine **5** and interfaces to various other parts of the ultrasound machine **5** through digital bus **70**. Control processor **50** executes the various data algorithms and functions for the various imaging and diagnostic modes. Digital data and commands may be transmitted and received between control processor **50** and other various parts of the ultrasound machine **5**. As an alternative, the functions performed by control processor **50** may be performed by multiple processors, or may be integrated into processors **30**, **40**, or **80**, or any combination thereof. As a further alternative, the functions of processors **30**, **40**, **50**, and **80** may be integrated into a single PC backend.

[0030] Once certain anatomical landmarks of the heart are identified, (e.g., the AV-planes and apex as described in U.S. patent application Ser. No. 10/248,090 filed on Dec. 17, 2002) certain acquisition parameters may be automatically adjusted by the ultrasound system **5** in order to optimize subsequent acquisition of clinically relevant information, in accordance with various aspects of the present invention. The various processors of the ultrasound machine **5** described above may be used to adjust and position the various acquisition parameters.

[0031] **FIG. 2** depicts a flow chart of an embodiment of a method **200** performed by the machine **5** of **FIG. 1** in accordance with various aspects of the present invention. In step **201**, positions of anatomical landmarks (e.g., the AV-plane and apex) are identified or located within the heart while imaging the heart. In step **202**, an acquisition parameter is automatically adjusted based on, at least in part, having located and identified the positions of the anatomical landmarks. In least one embodiment adjusting the at least one acquisition parameter is responsive to the at least one anatomical landmark and ultrasound data acquired in regions related to the anatomical landmarks.

[0032] As defined herein, acquisition parameters include, for example, at a depth setting of an ultrasound image, a width setting of an ultrasound image, a position of a region-of-interest (ROI), a pulse-repetition-frequency (PRF) setting of the ultrasound machine, a gain setting of the ultrasound machine, an adaptive gain setting of the ultrasound machine, at least one transmit focus position of the ultrasound machine, and a position of a **3**D acquisition region or some combination.

[0033] **FIG. 3** is a diagram illustrating using the method **200** of **FIG. 2** in the ultrasound machine **5** of **FIG. 1** to adjust acquisition parameters after having automatically located anatomical landmarks within the heart, in accordance with various embodiments of the present invention. **FIG. 3** shows a displayed B-mode image **300** of a heart also displaying the locations of anatomical landmarks of the heart and various acquisition parameters. The displayed anatomical landmarks include an apex location **301**, a first AV-plane location **302**, and a second AV-plane location **303**. The displayed acquisition parameters include a depth setting **304** for the B-mode image **300**, a width setting **305** for the B-mode image **300**, a positioned region-of-interest (ROI) or 3D acquisition region **306**, a pulse-repetition-frequency (PRF) setting **307** of the ultrasound machine **5**, a gain setting **308** of the ultrasound machine **5**, a positioned transmit focus **309** of the ultrasound machine **5**, and a grayscale mapping **310** for the B-mode image **300**.

[0034] For example, the depth **304** and/or width **305** may be adjusted by the ultrasound machine **5** based on the locations of the apex **301** and the AV-planes **302** and **303** to yield an appropriate B-mode view relative to actual heart dimensions. For example, the depth **304** and width **305** settings may be adjusted such that the displayed B-mode image of the heart is actual size. The appropriate depth and width settings are calculated from the relative positions of the apex and AV-plane locations.

[0035] As another example, after detecting, the AV-plane **302** for example, a color flow ROI **306** may be automatically positioned over the AV-plane **302** to visualize mitral flow near the AV-plane location. Alternatively, as part of locating the AV-plane **302**, for example, the highest tissue velocities in the region around the AV-plane **302** may be determined and used to automatically adjust the PRF setting **307** such that the highest velocity may be resolved in, for example, a tissue velocity imaging (TVI) ROI **306**.

[0036] As a further example, a gain setting, adaptive gain setting, and/or gray scale mapping may be adjusted to obtain a known transfer function at identified anatomical locations within the image **300**. Such an approach serves to standardize the grayscale mapping and is beneficial for the visual appearance of the image and for the reduction of variance in subsequent automated procedures that may be performed such as, for example, edge detection.

[0037] The position of a transmit focus **309** may be automatically adjusted to, for example, follow the position (in depth) of the AV-plane **303**. As a result, a best lateral resolution of the AV-plane **303** may be maintained. Alternatively, multiple transmit focus positions may be adjusted over the depth of the image **300** between, for example, the apex **301** and the AV-plane **302** in order to maximize image quality between the two.

[0038] One of the primary applications of cardiac 3D is that of rendering heart valves. The identification of AV-plane locations may be used to improve a **3**D acquisition of a heart valve by positioning an acquisition ROI (e.g., **306**) in a more optimal location.

[0039] **FIG. 4** depicts a diagram that illustrates using method **200** of **FIG. 2** to preset two longitudinal M-modes through two AV-plane locations, extracting information, in accordance with an embodiment of the present invention. **FIG. 4** illustrates how two longitudinal M-modes **403** and **404** may be preset through the two AV-plane locations **401** and **402** in order to display the longitudinal AV-motion in two M-modes within the heart **400**, in accordance with an embodiment of the present invention.

[0040] **FIG. 5** depicts a diagram illustrating using method **200** of **FIG. 2** to preset a curved M-mode within a myocardial segment from apex down to the AV-plane, extracting information, in accordance with an embodiment of the present invention. **FIG. 5** illustrates how a curved M-mode **504** from apex **501** down to the AV-plane **502** in the middle of myocardium **503** may be preset using the landmarks alone or in combination with local image analysis to keep the curve **504** inside myocardium **503** within the heart **500**, in accordance with an embodiment of the present invention.

[0041] **FIG. 6** depicts a diagram illustrating using methods **200** of **FIG. 2** to preset a Doppler sample volume relative to detected anatomical landmarks, extracting information, in accordance with an embodiment of the present invention. **FIG. 6** illustrates how a sample volume **603** for

Doppler measurements may be preset relative to the detected landmarks **601** (apex) and **602** (AV-plane) within the heart **600**. Such a technique may be applied to PW and CW Doppler, for inspection of blood flow and measurement of myocardial function.

[0042] In accordance with at least one embodiment of the present invention, a region-of-interest (ROI) may be preset with respect to the anatomical landmarks extracting information from these clinically relevant locations. The extracted information may include one or more of Doppler information over time, velocity information over time, strain rate information over time, strain information over time, M-mode information, deformation information, displacement information, and B-mode information.

[0043] The locations of the M-modes, curved M-modes, sample volumes, and ROI's may be tracked in order to follow the motion of the locations, in accordance with an embodiment of the present invention. Further, indicia may be overlaid onto the anatomical landmarks and/or the clinically relevant locations to clearly display the positions of the landmarks and/or locations.

[0044] **FIG. 7** depicts a diagram illustrating using method **200** of **FIG. 2** to define a set of points within myocardial segments performing edge detection to extract information about the associated endocardium, in accordance with an embodiment of the present invention. Automatic edge detection of the endocardium remains a challenging task. **FIG. 7** illustrates how the techniques discussed herein (i.e., similar to the curved M-mode localization) may be used to either define a good ROI for the edge detection, or provide an initial estimate that may be used to search for the actual boundary with edge detection algorithms such as active contours. **FIG. 7** illustrates two views of a heart **700** identifying the apex **701** and the AV-plane **702**. A contour **703**, estimating the approximate inside of myocardial segments in the heart **700** based on the anatomical landmarks, is drawn as the apex and AV-plane locations are tracked. Edge detection of the endocardium may then be performed using edge detection techniques using the contour as a set of starting points.

[0045] In accordance with an alternative embodiment of the present invention, other locations within a heart such as, for example, lower parts of mid segments and basal segments, may also be identified and used to adjust certain acquisition parameters.

[0046] While the invention has been described with reference to certain embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from its scope. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

1. In an ultrasound device for generating an image responsive to moving cardiac structure and blood within a heart of a subject, a method comprising:

locating at least one anatomical landmark within the cardiac structure and generating position information of said at least one anatomical landmark; and

adjusting at least one acquisition parameter based on, at least in part, locating said at least one anatomical landmark.

2. The method of claim 1 wherein adjusting said at least one acquisition parameter is responsive to said at least one anatomical landmark and ultrasound data acquired in regions related to said anatomical landmarks.

3. The method of claim 1 wherein said at least one anatomical landmark comprises at least one of an apex of said heart and an AV-plane of said heart.

4. The method of claim 1 wherein said acquisition parameter comprises a depth setting of an ultrasound image.

5. The method of claim 1 wherein said acquisition parameter comprises a width setting of an ultrasound image.

6. The method of claim 1 wherein said acquisition parameter comprises a position of a region-of-interest (ROD.

7. The method of claim 1 wherein said acquisition parameter comprises a pulse-repetition-frequency (PRF) setting of the ultrasound device.

8. The method of claim 1 wherein said acquisition parameter comprises a gain setting of the ultrasound device.

9. The method of claim 1 wherein said acquisition parameter comprises an adaptive gain setting of the ultrasound device.

10. The method of claim 1 wherein said acquisition parameter comprises a grayscale mapping of said ultrasound machine.

11. The method of claim 1 wherein said acquisition parameter comprises at least one transmit focus position of the ultrasound device.

12. The method of claim 1 wherein said acquisition parameter comprises a position of a 3D acquisition region.

13. In an ultrasound device for generating an image responsive to moving cardiac structure and blood within a heart of a subject, an apparatus comprising:

a front-end arranged to transmit ultrasound waves into said moving cardiac structure and blood and to generate received signals in response to ultrasound waves backscattered from said moving cardiac structure and blood;

at least one processor responsive to said received signals to locate at least one anatomical landmark within said cardiac structure and generate position information of said at least one anatomical landmark and adjust at least one acquisition parameter based on, at least in part, locating said at least one anatomical landmark.

14. The method of claim 12 wherein said at least one processor is responsive to said at least one anatomical landmark and ultrasound data acquired in regions related to said anatomical landmarks when adjusting said at least one acquisition parameter.

15. The apparatus of claim 13 further comprising a display processor and monitor to process said position information and display indicia overlaying at least one of said at least one anatomical landmark.

16. The apparatus of claim 13 further comprising a display processor and monitor to process and display said at least one acquisition parameter.

17. The apparatus of claim 13 wherein said at least one anatomical landmark comprises at least one of an apex of said heart and an AV-plane of said heart.

18. The apparatus of claim 13 wherein said at least one acquisition parameter comprises at least one of a depth setting of an ultrasound image, a width setting of an ultrasound image, a position of a region-of-interest (ROI), a pulse-repetition-frequency (PRF) setting of the ultrasound device, a gain setting of the ultrasound device, an adaptive gain setting of the ultrasound device, at least one transmit focus position of the ultrasound device, a grayscale mapping of said ultrasound image, and a position of a 3D acquisition region.

19. The apparatus of claim 13 wherein said at least one processor comprises at least one of a Doppler processor, a non-Doppler processor, a control processor, and a PC back-end.

20. The apparatus of claim 13 further comprising at least one transducer connected to said front-end to convert electrical signals to said ultrasound waves.

21. The apparatus of claim 13 comprising at least one transducer connected to said front-end to convert said ultrasound signals to electrical signals.

22. The apparatus of claim 13 further comprising at least one user interface connecting to said at least one processor to control operation of the ultrasound device.

* * * * *

专利名称(译)	基于超声定位地标优化超声采集		
公开(公告)号	US20060058674A1	公开(公告)日	2006-03-16
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[标]申请(专利权)人(译)	通用电气公司		
申请(专利权)人(译)	通用电气公司		
当前申请(专利权)人(译)	通用电气公司		
[标]发明人	OLSTAD BJORN		
发明人	OLSTAD, BJORN		
IPC分类号	A61B8/02		
CPC分类号	A61B8/06 A61B8/13 A61B8/0883 A61B8/08		
优先权	60/606078 2004-08-31 US		
外部链接	Espacenet USPTO		

摘要(译)

公开了一种超声设备，其包括用于响应于移动心脏结构和血液而生成图像的方法和设备，以及用于至少部分地基于定位心脏内的至少一个解剖标志来调整至少一个采集参数的方法和设备。响应于从心脏接收的信号，至少一个处理器定位心脏结构内的解剖标志，生成解剖标志的位置信息，并调整至少一个采集参数。可以将地标和采集参数显示给超声设备的用户。