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(54) **ULTRASONIC MONITORING SYSTEM AND METHOD**

(76) Inventor: **Zvi M. Friedman**, Kiriat Bialik (IL)

Correspondence Address:
MCANDREWS HELD & MALLOY, LTD
500 WEST MADISON STREET
SUITE 3400
CHICAGO, IL 60661

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(57) **ABSTRACT**

Apparatus and methods for use in a diagnostic ultrasound system are disclosed. A display device has a first window for displaying live ultrasound images and a second window for displaying a reference cine image. The reference cine image is an image captured prior to the currently displayed live ultrasound images. The images of the first and second windows are synchronized by ECG gating. The apparatus and methods may be employed to image the heart, providing operators with a way to monitor the heart and detect subtle changes in heart condition from the time that a reference image was captured.
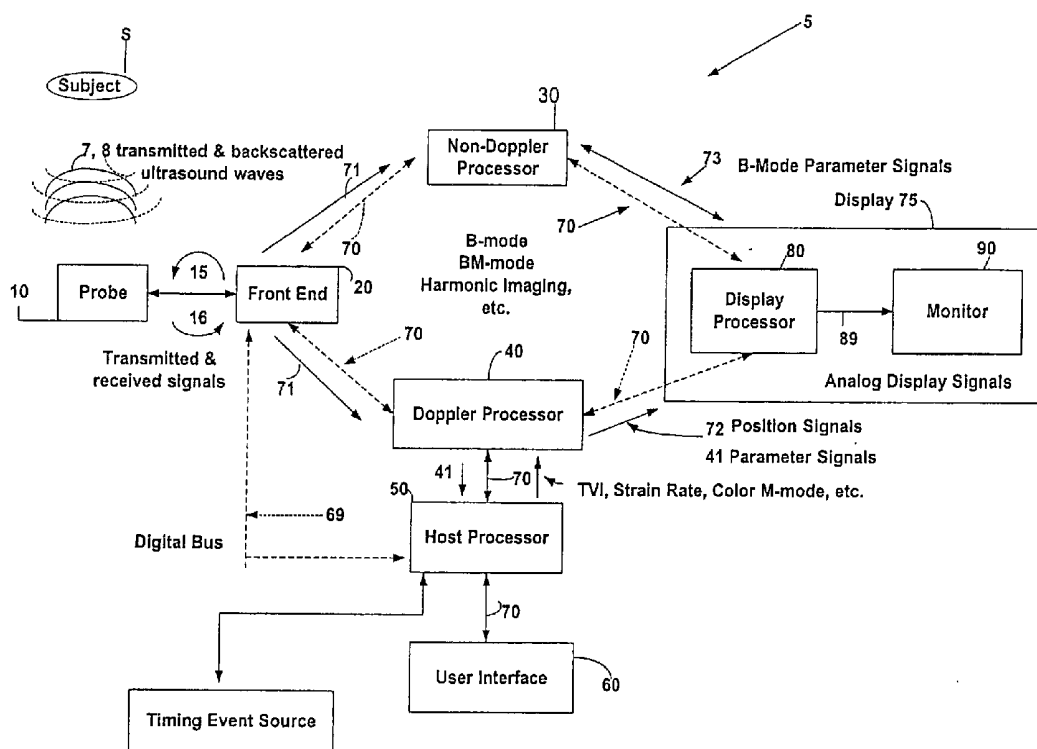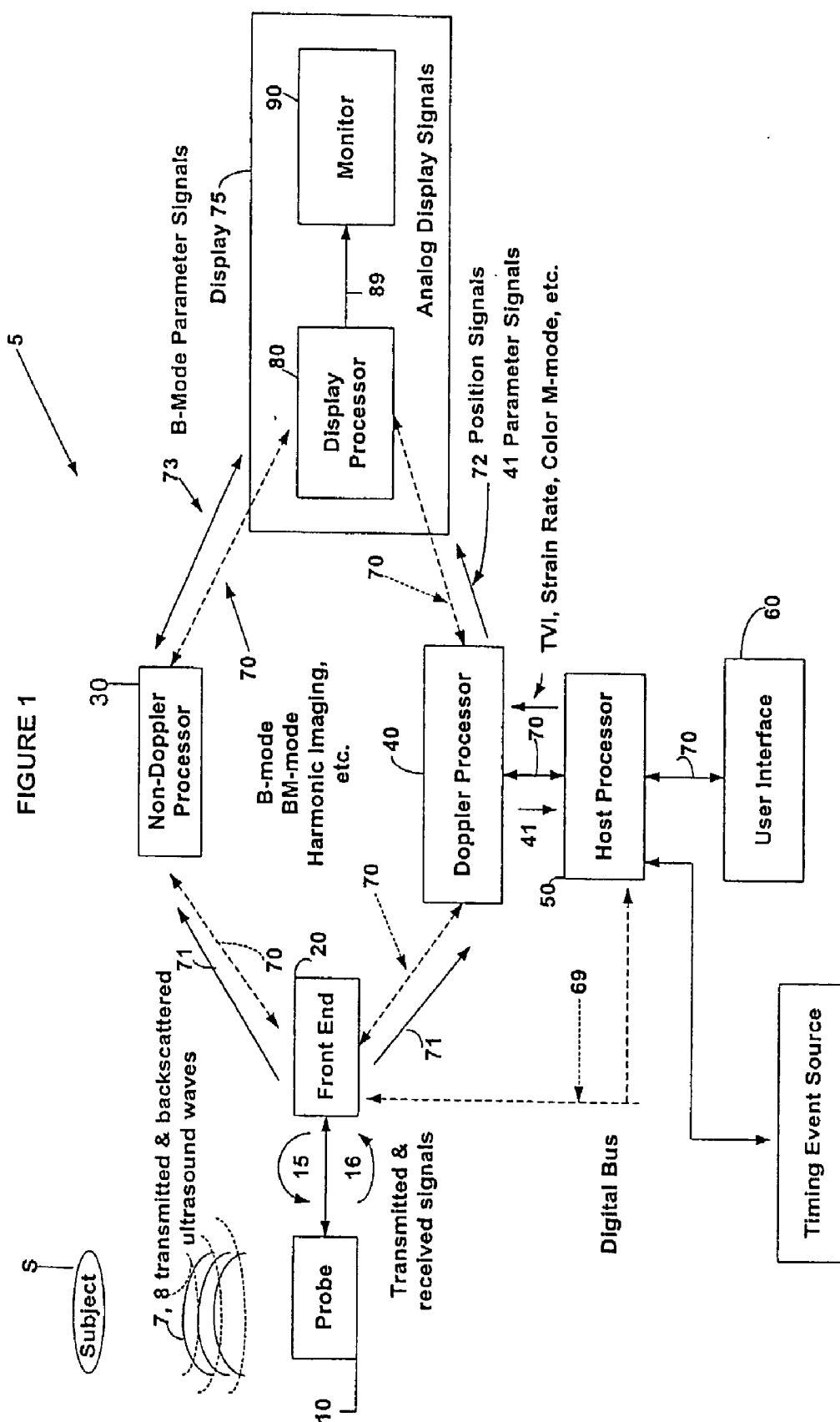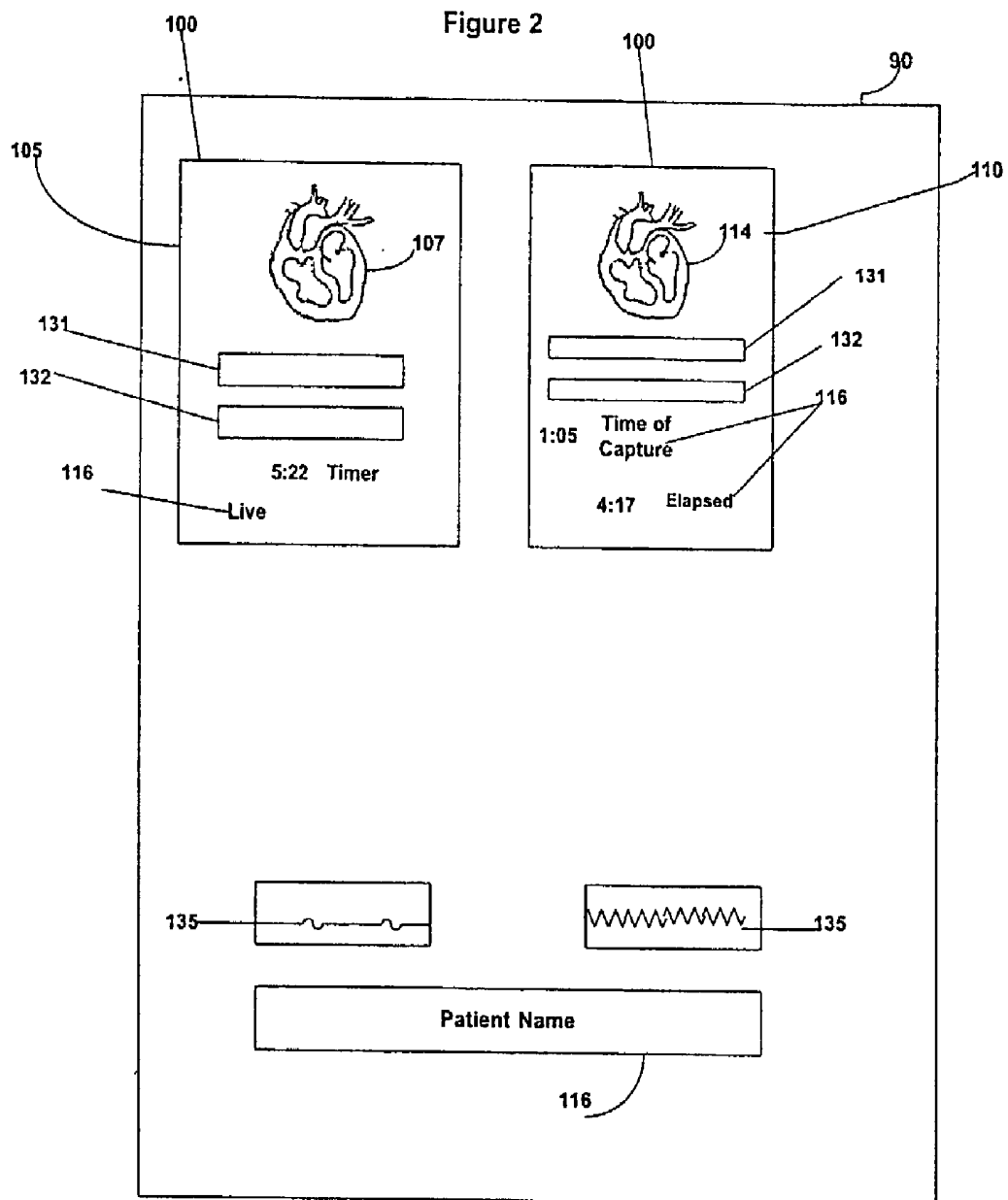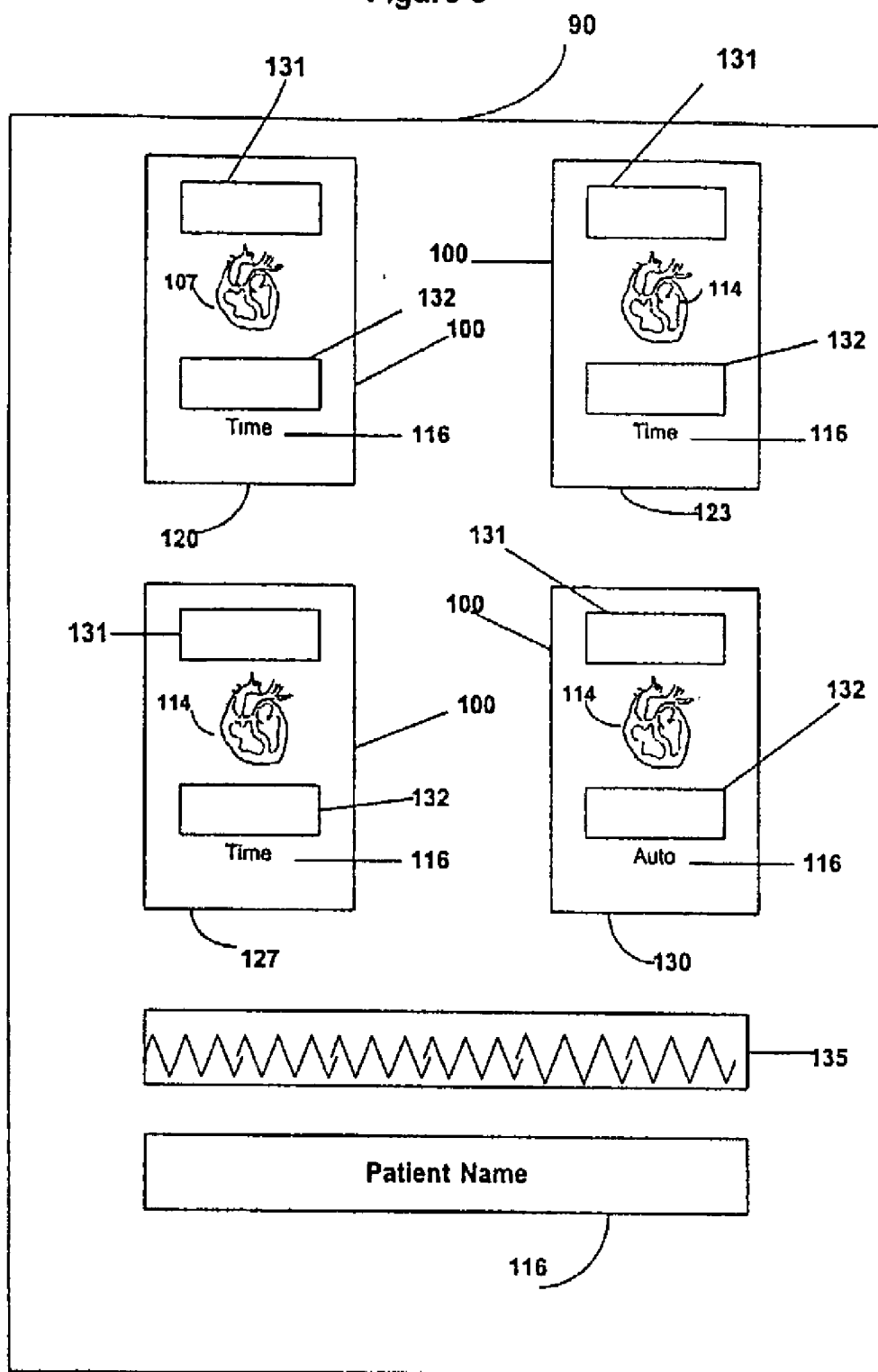
FIGURE 1

Figure 2

Figure 3

ULTRASONIC MONITORING SYSTEM AND METHOD

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 60/316,445, filed Aug. 31, 2001.

BACKGROUND OF INVENTION

[0002] Certain embodiments of the present invention are directed generally to the field of diagnostic ultrasound imaging. More particularly, certain embodiments of the present invention are directed to the field of ultrasonic cardiac monitoring systems and methods.

[0003] When a patient is given anesthesia, there is a risk of myocardial infarction when the patient is in the induction phase or is in the phase of being awakened. One of the first signs of myocardial infarction is a change in left ventricular wall motion. Cardiologists, anesthesiologists, and other medical personnel have a need for early detection of signs of changes in left ventricular wall motion.

[0004] Conventional methods of monitoring patients' cardiac activity include watching the contraction of the left ventricle on an ultrasound diagnostic imaging system that obtains ultrasound data using a TEE probe lowered into the patient's esophagus. Employment of a TEE probe lowered into the patient's esophagus to monitor cardiac activity during surgery is potentially inaccurate because a physician has nothing to compare to the observed data and, therefore, the physician must memorize the previous functioning of the observed heart. Thus, if the difference between the current cardiac activity and previous cardiac activity is subtle, then the physician will not notice the change.

[0005] Another conventional method for monitoring cardiac activity involves using an ultrasound diagnostic imaging system to express general heart function using a single number representing the ejection fraction. The ejection fraction is the fractional change in the observed cross-sectional area of the left ventricle. Greater change in the cross-sectional area of the left ventricle over the cycle of a heartbeat indicates, better health of the heart. Physicians would like to observe changes in the single number representing ejection fraction because changes in that number may represent a significant change in the health of the heart. To obtain the number that represents ejection fraction, an algorithm is used to automatically trace the boundary of the endocardium by distinguishing between blood and heart tissue. Tracing is based on edge detection. Edge detection is performed by detecting sudden high video contrast between the heart muscle and the endocardium cavity, the former being displayed in shades of gray and the latter being displayed in black. Because tracing is based on edge detection, the operator may position a marker, using a track ball or other controller, in the left ventricle prior to tracing. Once the marker is positioned, the endocardium is automatically traced, identifying the inner border of the left ventricle. Tracing, however, may be lost from time to time if the image of the left ventricle is not of high quality because tracing will stop if the algorithm fails to detect the boundary between the endocardium cavity and heart tissue. Also, in some circumstances, tracing is not robust enough for obtaining an accurate number. When tracing is not very robust, tracing has too little contrast to obtain an accurate number to represent the ejection fraction.

[0006] Rather than using a TEE probe or edge detection to detect left ventricle motion, a Doppler method has also been employed to calculate cardiac output. Cardiac output is the volume of the blood that is ejected per unit time from the left ventricle when the left ventricle contracts. Cardiac output can be considered the volume of blood passing through the aorta per unit time, typically expressed in terms of liters per minute. Cardiac output is related to ejection fraction and heart rate. The Doppler method of detecting left ventricle motion requires probe manipulation by an operator, which increases the potential for human error. Measurements made by Doppler are proportional to the cosine of the angle formed between the directional velocity of the flow of blood and the beam direction. Because the angle formed between the directional velocity of the flow of blood and the beam direction changes over time, there is inaccuracy in the Doppler measurements. Also, the cross-sectional area of the vessel being analyzed must be measured, because the volume of blood passing through the vessel equals the cross-sectional area of the vessel multiplied by the velocity. But the cross-section of the vessel changes over time, because the vessel is elastic. Also, the angle from which the vessel is measured changes, changing the measured cross-section of the vessel. For example, the vessel must be measured from an angle perpendicular to the longitudinal axis of the vessel if the measurement is to accurately represent the actual vessel cross-section. If the vessel is not measured from an angle perpendicular to the longitudinal axis of the vessel, then the measurement will be the cross-sectional area of an ellipse, which is greater than the actual cross-sectional area of the vessel. Thus, the use of ultrasound measurements to determine cardiac output is an ineffective method of detecting the subtle changes in left ventricular wall motion that may precede a myocardial infarction.

SUMMARY OF INVENTION

[0007] One embodiment of the present invention is an apparatus for displaying a plurality of images in a diagnostic ultrasound system. The apparatus may comprise a display device having a first window for displaying a live ultrasound image and a second window for displaying a reference cine image. The images displayed in the first and second windows are synchronized by ECG gating. The images may be cardiac images. The reference image makes it easy for an operator to compare the current condition of the heart or other imaged region with the condition of that region at the time the reference image was captured.

[0008] The reference image may be captured and recaptured automatically at predetermined intervals. Alternatively, the reference image may be captured when the operator elects to capture the image, in which case the reference cine image is repeated until the operator elects to capture a new reference image. The reference cine image may be continuously updated so that the reference cine image lags behind the live ultrasound image by a predetermined amount of time.

[0009] Alternative embodiments include a plurality of windows for displaying reference images. Embodiments having a plurality of windows for displaying reference

images permit an operator to have a plurality of reference views of an area of interest that is displayed as a live ultrasound image in the first window.

[0010] A method in accordance with one embodiment of the present invention comprises the steps of displaying a live ultrasound image, displaying a reference cine image, and synchronizing, by ECG gating, the live ultrasound image and the reference cine image. The live ultrasound image and the reference cine image may be images of the heart. In a further embodiment, the method comprises the additional step of displaying a second reference cine image, wherein a view of the heart displayed in the first reference cine image is different from a view of the heart displayed in the second reference cine image. The reference cine image or images may be captured manually or may be captured and re-captured at a pre-determined interval. Alternatively, the reference cine image or images may be continuously updated so that the reference cine image or images lag behind the live ultrasound image by a pre-determined amount of time.

BRIEF DESCRIPTION OF DRAWINGS

[0011] The foregoing summary, as well as the following detailed description of the preferred embodiments of the present invention, will be better understood when read in conjunction with the appended drawings. For the purpose of illustrating the preferred embodiments of the present invention, there is shown in the drawings, embodiments which are presently preferred. It should be understood, however, that the present invention is not limited to the arrangements and instrumentality shown in the attached drawings.

[0012] FIG. 1 is a block diagram of an ultrasound system formed in accordance with an embodiment of the present invention.

[0013] FIG. 2 is a schematic diagram of a display system formed in accordance with one embodiment of the present invention.

[0014] FIG. 3 is a schematic diagram of a display system formed in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION

[0015] FIG. 1 is a schematic block diagram of a medical diagnostic ultrasound system 5. A probe 10 connected to the ultrasound system 5 is used to transmit ultrasound waves 7 into a subject S by converting electrical signals 15 into ultrasound energy. The probe 10 converts backscattered ultrasonic energy 8 to analog electrical signals 16. A front-end subsystem 20 comprising a receiver, transmitter, and beamformer is used to create transmitted waveforms, beam patterns and receiver filtering techniques that are used for various imaging modes. The front-end subsystem 20 inter-faces at an analog interface to the probe 10 and interfaces at a digital interface over a digital bus 70 with a non-Doppler processor 30 and a Doppler processor 40 and interfaces over a digital bus 69 with a host processor 50. The digital buses 69 and 70 may comprise several digital sub-buses, each sub-bus having a unique configuration and providing digital data interfaces to various parts of the ultrasound system 5.

[0016] The non-Doppler processor 30 performs an ampli-tude detection function and data compression functions used

for imaging modes such as B-mode, M-mode and harmonic imaging. The non-Doppler processor 30 and the Doppler processor 40 accept received signal digital data 71 from the front-end subsystem 20, process the signal digital data 71 into sets of signal values, and pass the signal values to the host processor 50 and/or a display 75 over the digital bus 69.

[0017] The display 75 includes a display processor 80 that performs a scan-conversion function, color mapping function, and tissue/flow arbitration functions based on the digital signals 41 and 73 from the non-Doppler processor 30 and the Doppler processor 40. Digital data 72, representing a location of a pattern of indicia, is accepted from host processor 50. The display processor 80 processes, maps, and formats the digital data 72 accepted from the host processor 50 for display, converts the digital display data to analog display signals 89, and passes these analog display signals 89 to a monitor 90. The monitor 90 accepts the analog display signals 89 from the display processor 80 and dis-plays a resultant image 87 to the operator on the monitor 90.

[0018] A user interface 60 allows user commands to be input by the operator to the ultrasound system 5. The user interface 60 comprises a keyboard, mouse, switches, knobs, buttons, track ball, and on screen menus. The host processor 50 is the main, central processor of the ultrasound system 5. The ultrasound system 5 has been described as an example of an ultrasound system compatible with certain embodi-ments of the present invention. Embodiments of the present invention may be used in connection with ultrasound sys-tems other than the ultrasound system S.

[0019] In FIG. 2 is shown an embodiment of the present invention comprising a display device, such as the monitor 90, having two windows 100. The display processor 80 (FIG. 1) has the capability of providing the monitor 90 with a plurality of windows 100. For example, in order to provide a plurality of windows 100, the display processor 80 may provide to the monitor 90 compound dynamic images pro-duced by computer image manipulation. A first window 105 displays live ultrasound images 107. A second window 110 displays a reference cine image 114. The images 107, 114 may be images of the heart. The two windows 105, 110 are ECG gated to the ECG of the live ultrasound images 107 for synchronization.

[0020] The reference cine image 114 is an image captured earlier than the live images 107 currently being displayed. The reference cine image 114 may be captured at one time by the operator and then repeatedly displayed until the operator captures a reference image to replace it. Capture performed by an operator is called manual capture. With manual capture, the same cine image of a heart cycle, for example, keeps playing over and over while the live images 107 in the first window 105 are displayed until the operator captures a replacement reference cine image. The operator may perform capture, for example, by pressing a button on the user interface 60 (FIG. 1).

[0021] Alternatively, the second window 110 displays a reference cine image 114 that is automatically captured. An automatically captured image is a cine image that is updated or re-captured by the ultrasound system after a pre-deter-mined amount of time passes. The operator may enter a number to indicate how much time must pass between updates of the reference image in the second window 110.

[0022] As seen in FIG. 2, an operator may annotate the windows with information 116. Annotations may include

patient information. The window **100** that displays live images **107** may have a timer indicating how long that image **107** has been running. For example, the live image **107** of **FIG. 2** has been running for five minutes and **22** seconds. The window **100** displaying a reference image **114** may have a number indicating the time at which the reference cine image **114** was captured, the time being the time that had been displayed with the live image **107** of the first window **105** when the reference image **114** was captured. For example, the reference image **114** in **FIG. 2** was captured when the live image **107** had been running for one minute and five seconds. The reference image **114** of **FIG. 2** has been running for four minutes and **17** seconds. If the reference image **114** is an automatic reference image, then the time of capture shown in that window **100** will be updated each time that the reference cine image **114** is updated (i.e., automatically captured). Additionally or alternatively, the time displayed in connection with either the manual or the automatic reference images **114** may be the time elapsed since the most recent capture (as noted above, an example of elapsed time of four minutes and **17** seconds is shown for the reference image **114** of **FIG. 2**). Although not shown in the Figures, for the automatic reference images **114**, the pre-determined time between automatic captures may also be displayed.

[0023] In other embodiments the display screen may have more than two windows **100**. For example, **FIG. 3** shows an example of a display with four windows **100**. A first window **120** displays live ultrasound images **107**. Second and third windows **123, 127**, respectively, may be manually captured reference images **114** of a cardiac cycle showing different views such as the long axis and short axis. A fourth window **130** may be an automatically captured reference cine image **114** of a cardiac cycle. All four windows **120,123, 127**, and **130** are ECG gated to the ECG of the live images **107** for synchronization. The windows shown in **FIG. 3** may display annotations, capture times, elapsed times, and other times, as described in connection with the embodiment of **FIG. 2**. An annotation **131** describes the view of the displayed image in the window **100** in which the annotation **131** is located. For example, the annotation **131** may read "Long Axis" in a window **100** displaying a long axis view, and a different annotation **131** may read "Short Axis" in a window **100** displaying a short axis view. Other information may be included, additionally or alternatively, in the annotation **131**, such as whether the image in the window **100** is a view of the heart during inhalation or whether the image is a view of the heart during exhalation. In **FIG. 3**, the annotation "Time" is not used to indicate a single particular type of time display but rather indicates that one or more of a variety of time display formats may be displayed. For example, an operator may select the desired time display, whether it be elapsed time, time of capture, or some other time display.

[0024] The reference images **114** allow an operator to readily compare the live image **107** of the heart with past images of the heart. Reference images **114** may be particularly helpful soon after a patient has been given a fluid or other treatment that affects heart function. An annotation **132** may be used to display the amount of time that has elapsed since administration of anesthesia was initiated. With the reference image or images **114**, operators can determine whether the wall of the heart has moved after the treatment or whether other subtle changes may have occurred. Reference images **114** and live images **107** may be employed to

monitor areas of the human body other than the heart, however, ECG triggering would still be employed to synchronize such images **114** and **107**.

[0025] The positions of the live images **107** and the one or more reference images **114** may be determined by the operator. Thus, although shown on the left in **FIG. 2**, and in the upper left in **FIG. 3**, the live ultrasound images **107** may be shown in a different window **100**, and a reference cine image **114** may be displayed in the left window (or upper left window in the embodiment of **FIG. 3**).

[0026] Any window **100** that is not displaying the live ultrasound image **107** may display either a manual reference image **114** or an automatic reference image **114**. Thus, although **FIG. 3** displays two manually captured reference windows **114** and one automatically captured reference window **114**, embodiments of the present invention may have any combination of manually captured and automatically captured reference windows **114**. Thus, an embodiment with a total of four windows **100** may comprise three manually captured reference windows **114**, or three automatically captured reference windows **114**, or other combinations of reference windows **114**. The display device may also display data **135** such as a blood pressure graph, an ECG graph, and a breathing monitor.

[0027] All images (live images **107** and reference cine images **114**) may be stored to an archiving system for review postoperatively. With a large enough amount of memory, the automatic reference images **114** could be updated continuously so that the automatic reference images **114** remain behind (i.e., lag behind) the live image **107** by a pre-determined amount of time. As time would pass, the memory or buffer storing the cine image would be updated so that the displayed automatic reference image **114** would be continuously changed to correspond to what the live image **107** had been at the pre-determined time earlier. If an image buffer can hold cine images of a duration equal to the pre-determined amount of time that the automatic reference image **114** is supposed to lag behind the live image **107**, then the image buffer would be able to update the automatic reference images **114** continuously. If there is not enough memory to make such adjustments (or updates) to the automatic reference cine images **114**, then the automatic reference cine images **114** will simply repeat until the pre-selected time has elapsed and a new reference cine image **114** is automatically captured. The pre-selected time may be determined by the operator.

[0028] Memory for storing the live and reference images **107, 114**, respectively, may be provided by a computer. Images may be compressed to save memory, if desired. To conserve memory usage, images may be gated to only the contractility portion of the heart cycle. The windows **100** would then display only the contractility portion of the heart cycle which, for many applications, is the portion of the heart cycle of most interest to operators. The image **107** and reference image **114** data may be transmitted to remote locations over the Internet. Data compression techniques such as those mentioned above can facilitate transmission over the Internet.

[0029] While the invention has been described with reference to a preferred embodiment, 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 a diagnostic ultrasound system, an apparatus for displaying a plurality of images comprising:

a display device having a first window for displaying a live ultrasound image and a second window for displaying a reference cine image;

wherein the images displayed in the first and second windows are synchronized by ECG gating.

2. The apparatus of claim 1, wherein the images displayed in the first and second windows are images of a heart.

3. The apparatus of claim 2, and comprising a third window:

wherein the third window displays a reference cine image of the heart;

wherein a view of the heart displayed in the second window is different from a view of the heart displayed in the third window; and

wherein the images displayed in the first, second, and third windows are synchronized by ECG gating.

4. The apparatus of claim 1, wherein the reference cine image is captured manually.

5. The apparatus of claim 4, wherein the display device displays an amount of time that has elapsed since capture of the reference cine image.

6. The apparatus of claim 1, wherein the reference cine image is captured and recaptured at a pre-determined interval.

7. The apparatus of claim 6, wherein the display device displays at least one of an amount of time that has elapsed since capture of the reference cine image and an amount of time since initiating administration of anesthesia.

8. The apparatus of claim 1, wherein the display device has a window for displaying medical data.

9. The apparatus of claim 8, wherein the medical data displayed includes one of ECG data, blood pressure data, and a breathing monitor.

10. The apparatus of claim 1, and comprising a window for displaying annotations.

11. The apparatus of claim 1, and comprising third and fourth windows, wherein:

the third and fourth windows display reference cine images;

at least one of the reference cine images is captured and re-captured at a pre-determined interval;

at least one of the reference cine images is captured manually; and

the images displayed in the first, second, third, and fourth windows are synchronized by ECG gating and are images of a heart.

12. The apparatus of claim 1, wherein the reference cine image is continuously updated so that the reference cine image lags behind the live ultrasound image by a pre-determined amount of time.

13. In a diagnostic ultrasound system, an apparatus for displaying a plurality of images of the heart comprising:

a display device having a first window for displaying a live ultrasound image of the heart, a second window for displaying a reference cine image of a first view of the heart, and a third window for displaying a reference cine image of a second view of the heart;

wherein the images displayed in the first, second, and third windows are synchronized by ECG gating.

14. In a diagnostic ultrasound system, an apparatus for displaying a plurality of images of the heart comprising:

a display device having a first window for displaying a live ultrasound image of the heart and a second window for displaying a reference cine image of the heart;

wherein the images displayed in the first and second windows are synchronized by ECG gating;

wherein the reference cine image is captured and re-captured at a predetermined interval; and

wherein the display device displays at least one of an amount of time that has elapsed since capture of the reference cine image and an amount of time that has elapsed since initiating administration of anesthesia.

15. In a diagnostic ultrasound system, an apparatus for displaying a plurality of images of the heart comprising:

a display device having a first window for displaying a live ultrasound image of the heart, a second window for displaying a reference cine image of a first view of the heart, and a third window for displaying a reference cine image of a second view of the heart;

wherein the images displayed in the first, second, and third windows are synchronized by ECG gating; and

wherein at least one of the reference cine images is continuously updated so that the at least one reference cine image lags behind the live ultrasound image by a pre-determined amount of time.

16. A method for displaying a plurality of images in a diagnostic ultrasound system, the method comprising:

displaying a live ultrasound image;

displaying a reference cine image; and

synchronizing, by ECG gating, the live ultrasound image and the reference cine image.

17. The method of claim 16, wherein the live ultrasound image and the reference cine image are images of the heart.

18. The method of claim 17, and comprising the step of:

displaying a second reference cine image;

wherein a view of the heart displayed in the first reference cine image is different from a view of the heart displayed in the second reference cine image.

19. The method of claim 17, and comprising the step of capturing the reference cine image manually.

20. The method of claim 17, and comprising the step of capturing and re-capturing the reference cine image at a pre-determined interval.

21. The method of claim 16, and comprising the step of displaying at least one of an amount of time that has elapsed since capture of the reference image and an amount of time that has elapsed since initiating administering anesthesia.

22. The method of claim 16, and comprising the step of displaying medical data, wherein the medical data includes one of ECG data, blood pressure data, and a breathing monitor.

23. The method of claim 16, and comprising the step of continuously updating the reference cine image so that the reference cine image lags behind the live ultrasound image by a pre-determined amount of time.

24. The method of claim 16, and comprising the steps of:

displaying second and third reference cine images;

capturing at least one of the reference cine images manually; and

capturing and re-capturing at least one of the reference cine images at a pre-determined interval.

25. The method of claim 16, and comprising the step of displaying annotations.

26. A method for displaying a plurality of images of the heart in a diagnostic ultrasound system, the method comprising:

displaying a live ultrasound image of the heart;

displaying a first reference cine image of the heart;

displaying a second reference cine image of the heart; and

synchronizing, by ECG gating, the live ultrasound image and the first and second reference cine images;

wherein a view of the heart displayed in the first reference cine image is different from a view of the heart displayed in the second reference cine image.

27. A method for displaying a plurality of images of the heart in a diagnostic ultrasound system, the method comprising:

displaying a live ultrasound image of the heart;

capturing and re-capturing a reference cine image of the heart at a predetermined interval;

displaying the reference cine image of the heart;

displaying an amount of time that has elapsed since capture of the reference cine image; and

synchronizing, by ECG gating, the live ultrasound image and the reference cine image.

28. A method, for displaying a plurality of images of the heart in a diagnostic ultrasound system, the method comprising:

displaying a live ultrasound image of the heart;

displaying a first reference cine image of the heart;

displaying a second reference cine image of the heart, wherein a view of the heart displayed in the first reference cine image is different from a view of the heart displayed in the second reference cine image;

synchronizing, by ECG gating, the live ultrasound image and the first and second reference cine images; and

continuously updating at least one of the first and second reference cine images so that the at least one reference cine image lags behind the live ultrasound image by a pre-determined amount of time.

* * * * *

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摘要(译)

公开了用于诊断超声系统的装置和方法。显示装置具有用于显示实时超声图像的第一窗口和用于显示参考电影图像的第二窗口。参考电影图像是在当前显示的实况超声图像之前捕获的图像。通过ECG门控同步第一和第二窗口的图像。该装置和方法可用于对心脏成像，从而为操作者提供监测心脏的方法并从捕获参考图像的时间检测心脏状况的细微变化。