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(54) SIMULTANEOUS ULTRASONIC VIEWING OF 3D VOLUME FROM MULTIPLE DIRECTIONS

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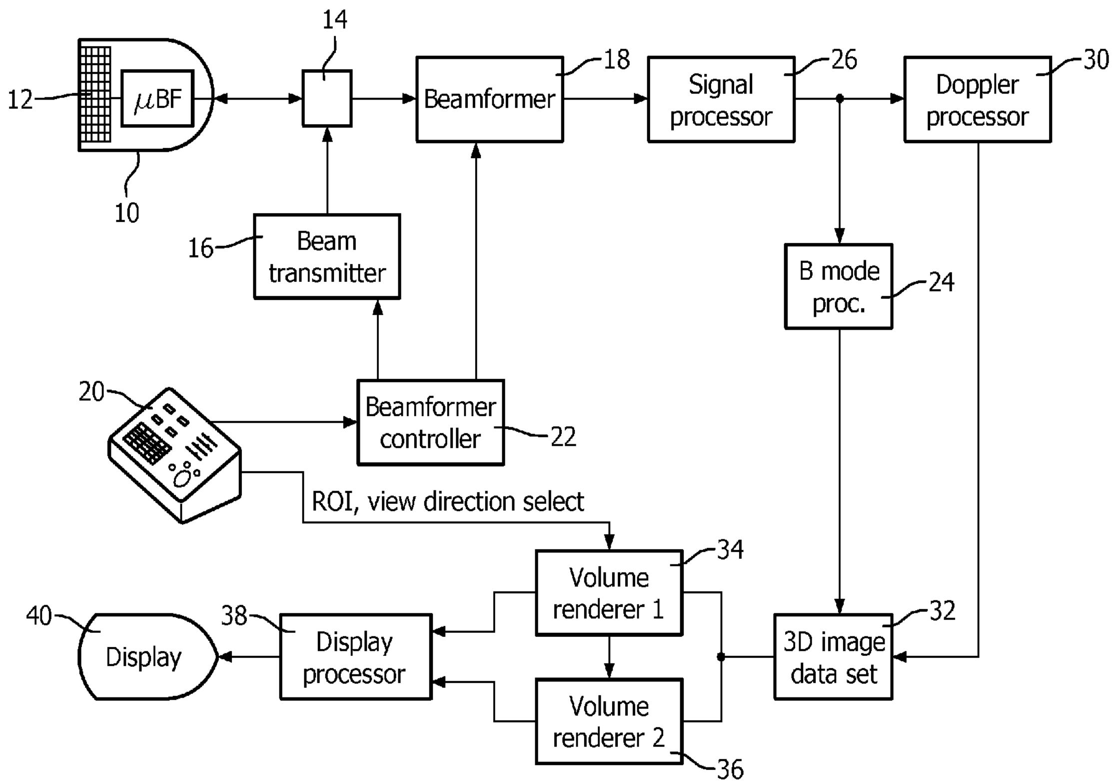
CPC ***A61B 8/483*** (2013.01); ***A61B 8/488*** (2013.01); ***A61B 8/463*** (2013.01)
USPC **600/443**

(57) **ABSTRACT**

An ultrasonic diagnostic imaging system scans a volumetric region of a body. A clinician defines a three dimensional region of interest within the volumetric region. The three dimensional region of interest is viewed from two different viewing directions to give the clinician a sense of the structure, makeup, and orientation of the region of interest. The three dimensional region of interest can be viewed from viewing directions in 180° opposition to each other, orthogonal, or at an intermediate angle. Manipulation of one view of the three dimensional region of interest causes both views to change, as if the clinician were manipulating both views simultaneously in the same way.



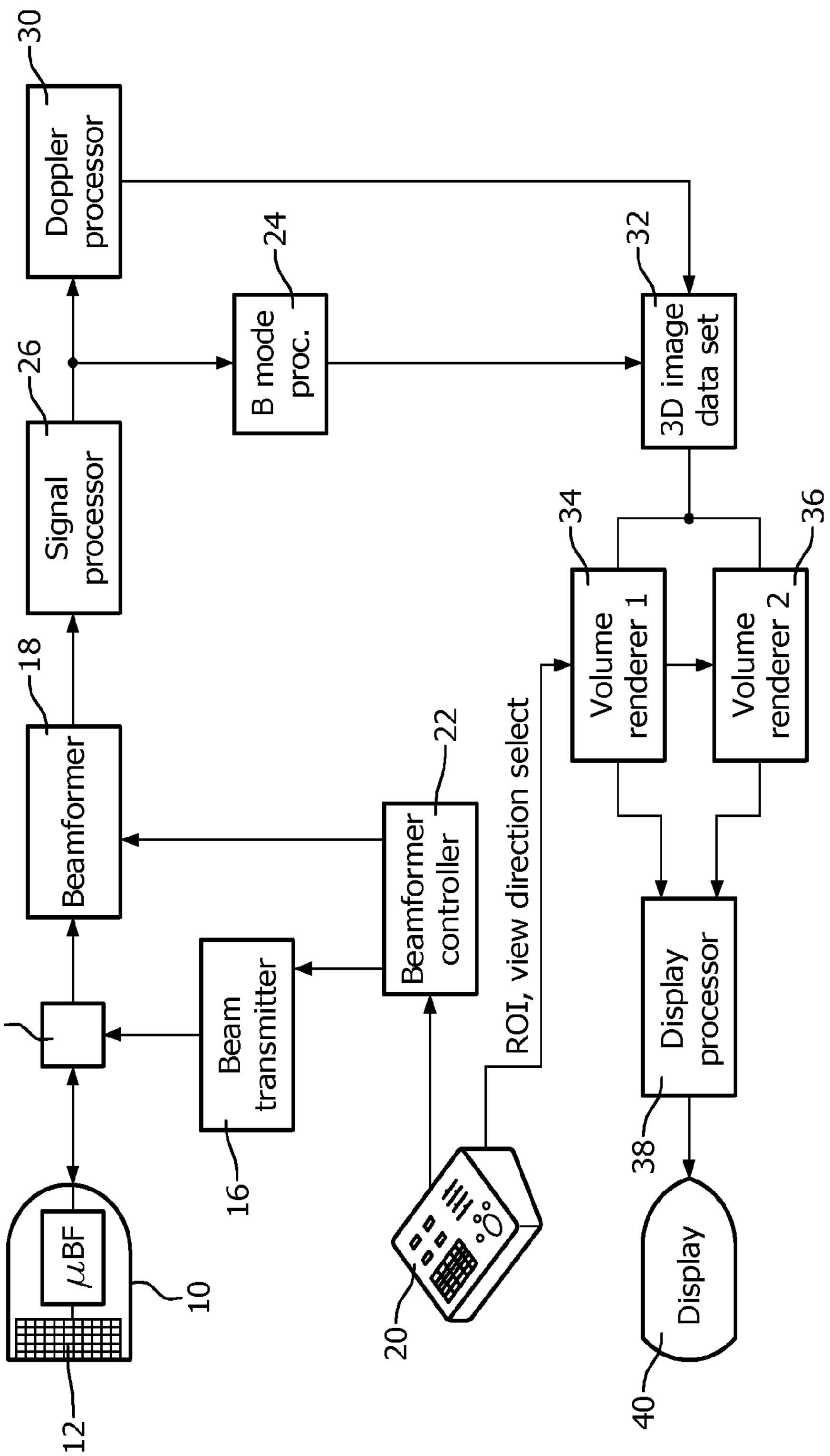

Doppler processor
30
B mode proc.
24
Signal processor
26
3D image data set
32
Beamformer
18
Volume renderer 1
34
Volume renderer 2
36
Beamformer controller
22
ROI, view direction select
14
Beam transmitter
16
Display processor
38
μBF
10
12
20
Display
40

FIG. 1

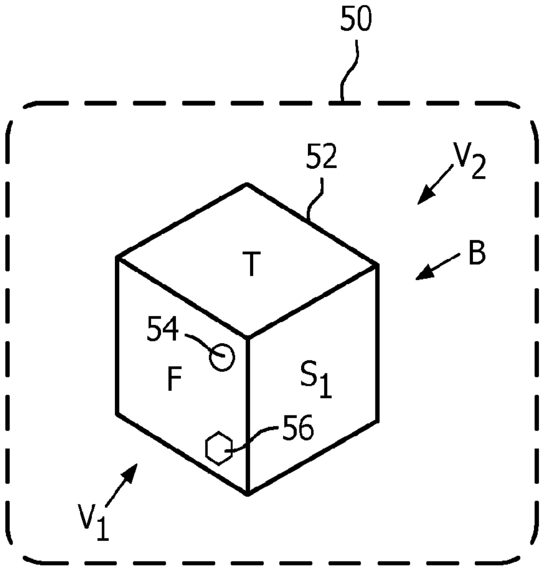


FIG. 2

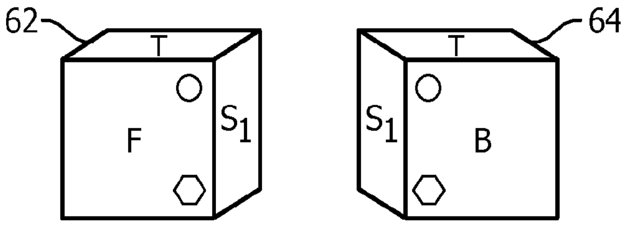


FIG. 3a

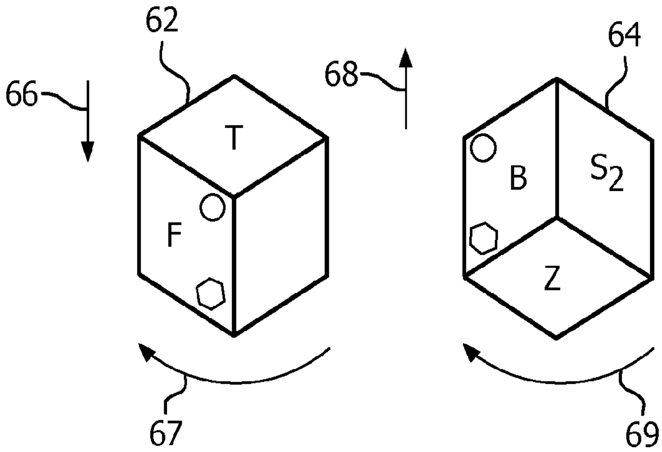


FIG. 3b

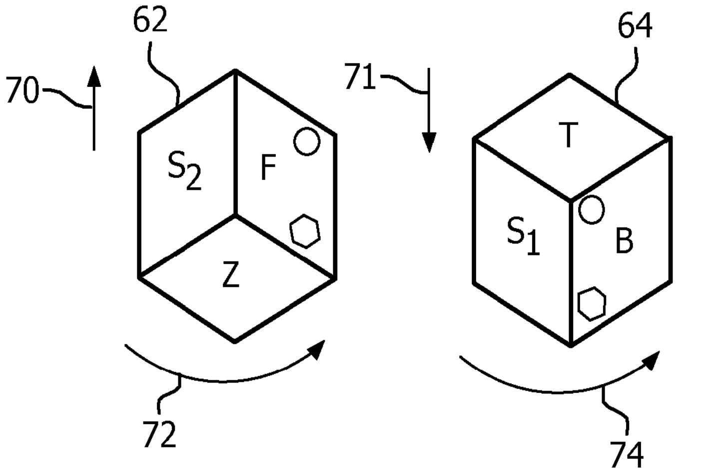


FIG. 3c

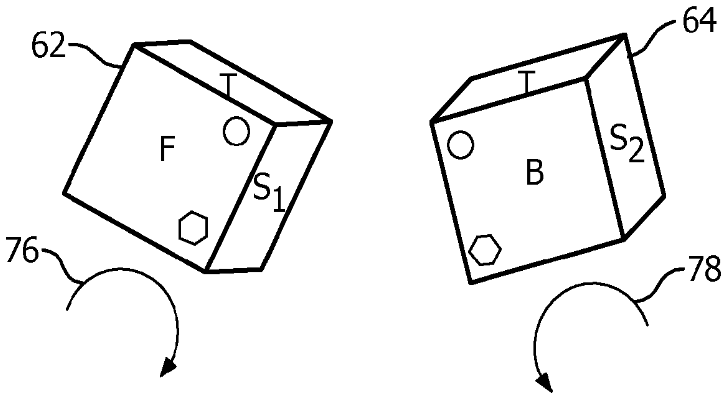


FIG. 3d

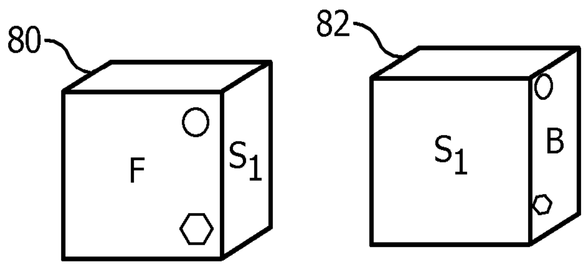


FIG. 4

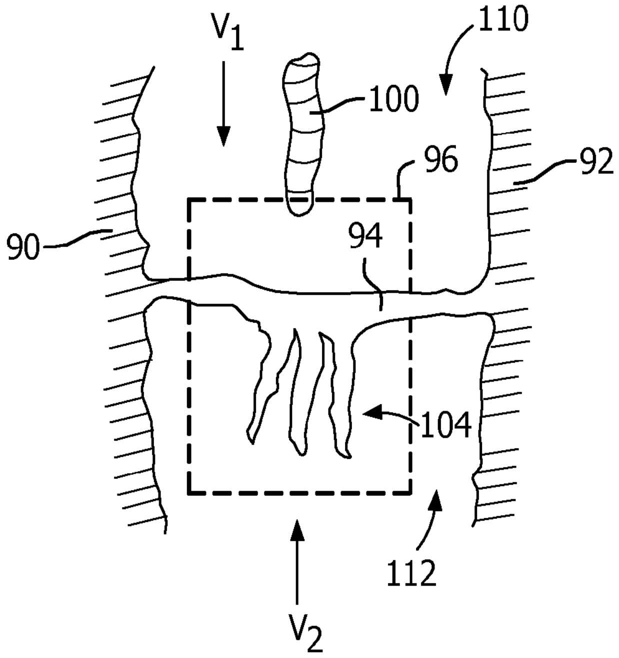


FIG. 5a

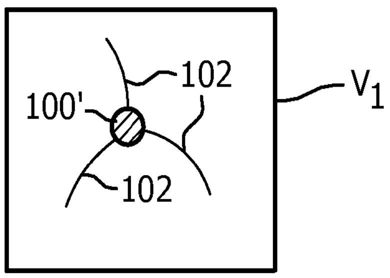


FIG. 5b

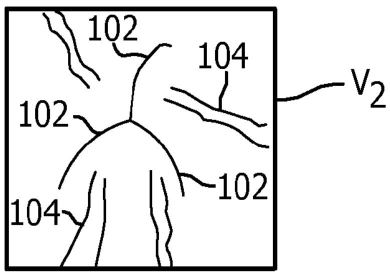


FIG. 5c

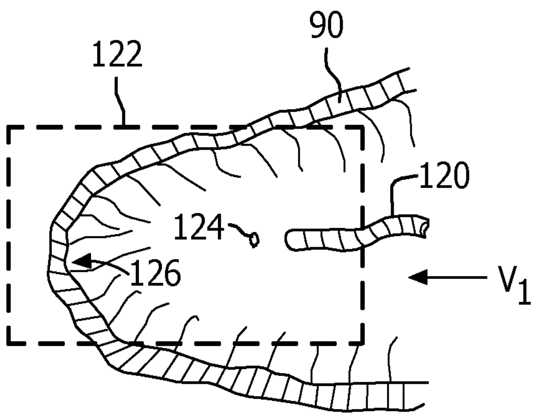


FIG. 6a

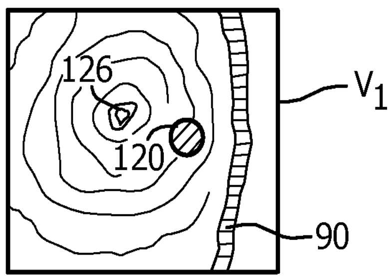


FIG. 6b

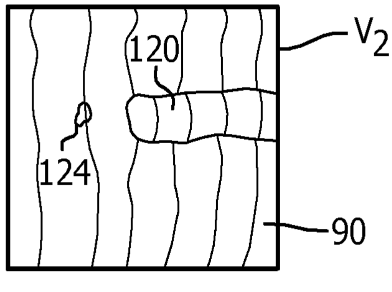


FIG. 6c

SIMULTANEOUS ULTRASONIC VIEWING OF 3D VOLUME FROM MULTIPLE DIRECTIONS

[0001] This invention relates to medical diagnostic ultrasound systems and, in particular, to ultrasonic imaging systems which display a 3D volume in simultaneous views from multiple directions.

[0002] Ultrasonic diagnostic imaging system have traditionally been used to image a plane of the body in real time. A probe with a one dimensional (1D) array transducer or mechanically swept single element transducer can be operated to repeatedly scan a plane of the body to produce real time image sequences for live display of the anatomy. Recently two dimensional (2D) array transducers and mechanically swept 1D arrays have been developed for scanning a volumetric region of the body. Such probes can be used to produce three dimensional (3D) images of the volume being scanning, also in real time. A display technique commonly used for 3D display of ultrasonically scanned volumes is called kinetic parallax, in which a 3D data set of the volume is rendered from a series of different viewing directions. As the operator moves a control on the ultrasound system to change the viewing direction, the volume rendering processor renders the volume in a newly selected viewing direction and the progression of different directions gives the appearance of a 3D volume moving on the display screen. Individual planes can be selected from a three dimensional data set for viewing, a technique known as multiplanar reconstruction (MPR).

[0003] It is at times desirable to view a volumetric region of interest (ROI) from different directions. With a conventional viewer this must be done by viewing the ROI from one direction, then turning or rotating the 3D ROI so that it can be seen from the second direction. A comparison of the two views must be done by remembering what was seen in the first view, then moving the view to the second direction and making the comparison based on the recollection of the first view. For comparison of subtle anatomical differences, it would be preferable not to rely on memorization, or moving the views back and forth to try to make the diagnosis. It would be preferable to be able to see both views simultaneously so that the clinician is seeing both views at the same time while making the diagnosis.

[0004] In accordance with the principles of the present invention, a diagnostic ultrasound system is described which enables a clinician to view a volume from multiple external viewing perspectives at the same time. When the clinician manipulates one view, the manipulation is applied to the second view so that both views are changed in unison, as the clinician would expect the views to change if both were altered in the same way. Either or both views can also be interrogated by MPR viewing. A system of the present invention is particularly useful for guiding an invasive device such as a needle or a catheter inside the body.

[0005] In the drawings:

[0006] FIG. **1** illustrates in block diagram form an ultrasonic diagnostic imaging system constructed in accordance with the principles of the present invention.

[0007] FIG. **2** shows a cubic ROI and two different viewing orientations.

[0008] FIGS. **3***a*-**3***d* illustrate simultaneous changes of two viewing orientations of the cubic ROI of FIG. **2** by manipulation of one of the views.

[0009] FIG. **4** illustrates two simultaneous views of the cubic ROI of FIG. **2** from orthogonal viewing orientations.

[0010] FIGS. **5***a*-**5***c* illustrate simultaneous views from different directions of a volumetric ROI including a heart valve.

[0011] FIGS. **6***a*-**6***c* illustrate simultaneous views of a catheter procedure from orthogonal viewing directions.

[0012] Referring first to FIG. **1**, an ultrasonic diagnostic imaging system constructed in accordance with the principles of the present invention is shown in block diagram form. An ultrasound probe **10** capable of three dimensional imaging includes a two dimensional array transducer **12** which transmits electronically steered and focused beams over a volumetric region and receives single or multiple receive beams in response to each transmit beam. Groups of adjacent transducer elements referred to as "patches" or "subarrays" are integrally operated by a microbeamformer (μBF) in the probe **12**, which performs partial beamforming of received echo signals and thereby reduces the number of conductors in the cable between the probe and the main system. Suitable two dimensional arrays are described in U.S. Pat. No. 6,419,633 (Robinson et al.) and in U.S. Pat. No. 6,368,281 (Solomon et al.) Microbeamformers are described in U.S. Pat. No. 5,997,479 (Savord et al.) and U.S. Pat. No. 6,013,032 (Savord). The transmit beam characteristics of the array are controlled by a beam transmitter **16**, which causes the apodized aperture elements of the array to emit a focused beam of the desired breadth in a desired direction through a volumetric region of the body. Transmit pulses are coupled from the beam transmitter **16** to the elements of the array by means of a transmit/receive switch **14**. The echo signals received by the array elements and microbeamformer in response to a transmit beam are coupled to a system beamformer **18**, where the partially beamformed echo signals from the microbeamformer are processed to form fully beamformed single or multiple receive beams in response to a transmit beam. A suitable beamformer for this purpose is described in the aforementioned Savord '032 patent.

[0013] The receive beams formed by the beamformer **18** are coupled to a signal processor **26** which performs functions such as filtering and quadrature demodulation. The echo signals of the processed receive beams are coupled to a Doppler processor **30** and/or a B mode processor **24**. The Doppler processor **30** processes the echo information into Doppler power or velocity information signals. For B mode imaging the receive beam echoes are envelope detected and the signals logarithmically compressed to a suitable dynamic range by the B mode processor **24**. The echo and Doppler signals from the scanned volumetric region are processed to form one or more 3D image datasets which are stored in a 3D image dataset buffer **32**. The 3D image data may be processed for display in several ways. One way is to produce multiple 2D planes of the volume. This is described in U.S. Pat. No. 6,443,896 (Detmer). Such planar images of a volumetric region are produced by a multi-planar reformatting as is known in the art. In accordance with the present invention, the three dimensional image data may also be rendered to form perspective or kinetic parallax 3D displays by volume renderers **34** and **36**. The resulting images, which may be B mode, Doppler or both as described in U.S. Pat. No. 5,720,291 (Schwartz), are coupled to a display processor **38**, from which they are displayed on an image display **40**. User control of the beamformer controller **22**, the selection of an ROI, the selection of directions in which the ROI is to be viewed, and other functions of the ultrasound system are provided through a user interface or control panel **20**.

[0014] A clear understanding of manipulation of simultaneous views of a 3D ROI may be had with reference to FIGS. **2-4**. In these drawings a cubic ROI **52** located in a volumetric region **50** is used for clarity of illustration. As seen in FIG. **2**, the cubic ROI **52** has a front face F, a top face T, side faces S_1 and S_2, and back (B) and bottom (Z) faces, the latter three not visible in FIG. **2**. The 3D ROI **52** has two passageways extending from the front face to the back face, one drawn as a circular passageway **54** and the other drawn as a hexagonal passageway **56**. Two viewing directions V_1 and V_2 are also shown in FIG. **2**, which view the 3D ROI from the front F and the back B, respectively.

[0015] FIGS. **3***a*-**4** show simultaneous 3D views of the 3D ROI formed by simultaneous operation of volume renderer1 and volume renderer2 in accordance with the principles of the present invention. The two 3D views are displayed to the clinician simultaneously on the display **40** as illustrated in these drawings. Volume renderer1 renders the 3D ROI as viewed looking toward the front face F and volume renderer2 renders the 3D ROI as viewed looking toward the back face B. The viewing directions used for rendering are thus opposed to each other by 180°. In the front face view **62** of FIG. **3***a* the viewing direction is slightly to the right of and above the front face of the 3D ROI so that the top T and side S_1 faces can be seen. For the back face view **64** the viewing direction is slightly to the left of and above the back face B so that the side S_1 and top T faces can also be seen in this view. Slight variation from exactly 180° views can be used as shown in FIG. **3***a*, or both views can be exactly 180° in opposition as shown in FIG. **4**. As FIG. **3***a* illustrates, the passageways **54**,**56** extending through the 3D ROI are seen on the right side of the front face F and on the left side of the back face B as a clinician would expect to see them.

[0016] In FIG. **3***b* the clinician has manipulated a control of the user interface such as a trackball on the control panel **20** or a softkey control on the display screen to rotate the 3D ROI **62** on the left side of the display slightly to the left as indicated by arrow **67**. The clinician has also manipulated a user control to tilt the 3D ROI slightly downward as indicated by arrow **66** so that more of the top face T can be seen. As the clinician manipulates the left 3D ROI **62** in this way, the 3D ROI view **64** on the right moves in correspondence, as if the clinician manipulated the right view to move in the same way. The right view **64** from the back of the 3D ROI rotates the same amount to the left as indicated by the arrow **69** and tilts upward by the same amount (arrow **68**) as the tilt of the left 3D ROI view, causing more of the bottom face Z to be visible. Thus, by manipulating one view of the 3D ROI, the corresponding adjustments are made to the other view of the 3D ROI. The clinician has the sense of moving one 3D ROI with the control adjustments and seeing the resulting change in both views of the front and back of the 3D ROI as if clinician were seeing the same ROI and its motion from two different views.

[0017] FIG. **3***c* illustrates the front and back 3D ROI views **62** and **64** after the clinician has rotated the ROI to the right (as indicated by arrows **72** and **74**) and tilted the front view of the ROI up (as indicated by arrows **70**) so that the bottom face Z is visible. As the drawing indicates, the back view **64** moves in a corresponding manner. The upward tilt **70** of the ROI as seen from the front is seen as a downward tilt from the back as indicated by arrow **71**, causing the top face T to be more visible from the back. Both the left and right views move in unison as the clinician adjusts the orientation of one of the views.

[0018] FIG. **3***d* illustrates the result of rotating the left view to tilt the right side of the 3D ROI **62** downward. As this happens, the rear view **64** of the 3D ROI tilts down on the left side as indicated by arrow **78**. This is how the clinician would expect the right view to behave when rotating the left view: the S_1 face side tilts down in both views. The same result can be obtained by tilting the right view **64** downward on the left side, which causes the corresponding effect of tilting the right side of view **62** down to the right. Thus, moving the ROI in one of the views causes the same movement of the other view, which is seen from the different viewing orientation.

[0019] FIG. **4** shows two views of a 3D ROI, with the left view **80** looking at the 3D ROI from the front face F and the right view **82** looking at the 3D ROI from the side face S. As in the previous examples, manipulating one of the views of the 3D ROI will cause the same motion of the 3D ROI in the other view but as seen from a different viewpoint. The two views of the 3D ROI can thus be at a 180° angle to each other as shown in FIGS. **3***a*-**3***d*, or at a 90° angle to each other as shown in FIG. **4**, or at any other intermediate angle between the views, e.g., between 0° and 180°.

[0020] FIGS. **5***a*-**5***c* illustrate a clinical application of an ultrasound system of the present invention. In this example a catheter **100** has been threaded into an atrium **110** of a heart in preparation for passage through a mitral or tricuspid valve **94** and into a ventricle **112**. The heart valve **94** is seen to be attached to the myocardial walls **90** and **92** on opposite sides of the heart. Extending from the valve leaflets in the ventricle are chordate tendineae **104**, cord-like tendons that attach the valve leaflets to papillary muscles in the ventricle. An ultrasound system of the present invention is used to guide the catheter procedure by imaging the heart as illustrated in FIG. **5***a* and defining within such a volumetric region a 3D ROI **96**. As FIG. **5***a* illustrates, this 3D ROI extends into the heart chambers on both sides of the valve and includes the valve through which the catheter **100** is to be inserted. With the 3D ROI defined in this way, the 3D ROI is viewed simultaneously from both the face in the atrium **110** and the face in the ventricle as shown in FIGS. **5***b* and **5***c*. In the view V_1 from the atrium **110** as shown in FIG. **5***b*, the clinician can see the catheter **100'** as it approaches the slits **102** between the valve leaflets. On the other side of the valve the V2 view of FIG. **5***c* views the slits **102** of the valve leaflets through which the catheter will soon appear, and the chordate tendineae **104** extending back from the valve leaflets. By viewing the valve **94** from both sides in 3D, the clinician can guide the catheter **100** toward the center of the heart valve **94**, and view its insertion through the heart valve as the catheter appears on the ventricular side of the valve **94**.

[0021] FIGS. **6***a*-**6***c* illustrate another example of a clinical procedure performed with an ultrasound system of the present invention. In this example the 3D ROI is viewed in two orthogonal viewing directions V_1 and V_2. In this example a catheter **120** is being guided to perform a clinical procedure on a spot **124** on the wall of the myocardium **90** of a heart. A 3D ROI is delineated as shown by outline **122** in FIG. **6***a*, which includes the catheter **120**, the spot **124** which is to be treated, and the far side **126** of the heart chamber in which the procedure is to be performed. This 3D ROI **122** is viewed in two orthogonal viewing directions, V_1 as shown in FIG. **6***a*, and in a second direction looking into the plane of the FIG. **6***a* drawing. FIG. **6***b* illustrates the 3D ROI **122** as viewed from direction V_1. In this view the catheter **120** can be axially seen alongside the wall **90** of the myocardium and approaching the far end **126** of the heart chamber in which the catheter is located. The orthogonal V2 view is shown in FIG. **6***c*. In this view the catheter **120** is seen approaching point **124** at which the procedure is to be performed and is in an orientation approximately parallel to the heart wall **90**. The two orthogonal views give the clinician a sense of how the catheter is proceeding along the heart wall, its spacing from the heart wall, and how much further the catheter needs to be extended to reach the point **124** at which the procedure is to be performed.

1. An ultrasonic diagnostic imaging system comprising:
- an ultrasound probe operable to scan a volumetric region of a body which produces echo signals from three dimensions of the region;
- a signal processor, responsive to the echo signals from the volumetric region, which produces a 3D image data set of the region;
- a volume renderer coupled to receive the 3D image data set and produce two 3D views, a first 3D view and a second 3D view, of the region as if the region were being simultaneously viewed from two different viewing directions;
- a first user control which selects the two different viewing directions; and
- a display, responsive to the volume renderer, which simultaneously displays the two 3D views,
- wherein the first and second 3D views are manipulable on the display such that moving an orientation of the first 3D view causes movement of an orientation of the second 3D view.

2. The ultrasonic diagnostic imaging system of claim **1**, wherein the two different viewing directions further comprise views of the region as seen from directions oriented 180° with respect to each other.

3. The ultrasonic diagnostic imaging system of claim **1**, wherein the two different viewing directions further comprise views of the region as seen from directions oriented 90° with respect to each other.

4. The ultrasonic diagnostic imaging system of claim **1**, wherein the two different viewing directions further comprise views of the region as seen from directions oriented at an angle between 0° and 180° with respect to each other.

5. The ultrasonic diagnostic imaging system of claim **1**, further comprising a second user control operable by a user to select a 3D region of interest (ROI) within the volumetric region, wherein the volume renderer produces two 3D views of the ROI as if the ROI were being simultaneously viewed from two different viewing directions.

6. The ultrasonic diagnostic imaging system of claim **5**, further comprising an invasive object which can be seen on the display when manipulated in the volumetric region;
- wherein the region of interest further contains anatomy of interest,
- wherein the system is configured to visualize the invasive object can be visualized moving away from a viewer in the first 3D view one of the 3D views when manipulated in a first direction in relation to the anatomy of interest, and
- wherein the system is further configured to simultaneously visualize the invasive object is simultaneously visualized moving toward the viewer in the second 3D view other of the 3D views when manipulated in the first direction in relation to the anatomy of interest.

7. The ultrasonic diagnostic imaging system of claim **5**, further comprising an invasive object which can be seen on the display when manipulated in the volumetric region;
- wherein the region of interest further contains anatomy of interest, wherein the system is configured to visualize the invasive object can be visualized moving toward or away from a viewer in the first 3D view one of the 3D views when manipulated in a first direction in relation to the anatomy of interest, and
- wherein the system is further configured to simultaneously visualize the invasive object is simultaneously visualized moving laterally with respect to the viewer in the second 3D view other of the 3D views when manipulated in the first direction in relation to the anatomy of interest.

8. The ultrasonic diagnostic imaging system of claim **1**, further comprising a third user control, coupled to the volume renderer, which is operable to change the orientation of the volumetric region as seen from the two different viewing directions.

9. The ultrasonic diagnostic imaging system of claim **8**, wherein the third user control is operable to change the orientation of the volumetric region as seen from a first of the two different viewing directions,
- wherein the orientation of the volumetric region as seen from the other of the two different viewing directions is changed in correspondence to the change applied to the first viewing direction,
- wherein a user sees a single change in the orientation of the volumetric region as it would appear from two different viewing directions of the volumetric region.

10. The ultrasonic diagnostic imaging system of claim **9**, wherein the system is configured such that the change in the orientation of the two 3D views of the volumetric region produced by manipulation of the third user control is visualized in real time.

11. The ultrasonic diagnostic imaging system of claim **8**, wherein the third user control is further operable to tilt the two 3D views up or down, turn the two 3D views left or right, or rotated the two 3D views clockwise or counter-clockwise.

12. The ultrasonic diagnostic imaging system of claim **11**, wherein the system is configured such that further comprising:
- when the third user control is operated to tilt one of the 3D views up, the other 3D view tilts down correspondingly;
- when the third user control is operated to turn one of the 3D views to the left, the other 3D view turns to the left correspondingly; and
- when the third user control is operated to rotate one of the two 3D views clockwise, the other 3D view rotates counter-clockwise correspondingly.

13. The ultrasonic diagnostic imaging system of claim **1**, wherein the volume renderer further comprises:
- a first volume renderer which produces a 3D view of the volumetric region from a first viewing direction, and
- a second volume renderer which produces a 3D view of the volumetric region from a second viewing direction.

14. The ultrasonic diagnostic imaging system of claim **13**, wherein the two 3D views further comprise kinetic parallax renderings.

15. The ultrasonic diagnostic imaging system of claim **14**, wherein the 3D image data set further comprises B mode or Doppler image data.

* * * * *

patsnap

专利名称(译)	从多个方向同时超声波观察3D体积		
公开(公告)号	[US20140358004A1](US20140358004A1)	公开(公告)日	2014-12-04
申请号	US14/372029	申请日	2013-02-11
[标]申请(专利权)人(译)	大卫普拉特 WATKINS STEPHEN		
申请(专利权)人(译)	普拉特，DAVID 沃特金斯STEPHEN ADAMS，DAVID FRANK		
当前申请(专利权)人(译)	皇家飞利浦N.V.		
[标]发明人	PRATER DAVID WATKINS STEPHEN ADAMS DAVID FRANK		
发明人	PRATER, DAVID WATKINS, STEPHEN ADAMS, DAVID FRANK		
IPC分类号	A61B8/08 A61B8/00		
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优先权	61/597931 2012-02-13 US		
外部链接	Espacenet USPTO		

摘要(译)

超声诊断成像系统扫描身体的体积区域。临床医生在体积区域内定义三维感兴趣区域。从两个不同的观察方向观察三维感兴趣区域，以使临床医生感知感兴趣区域的结构，构成和取向。可以从彼此相反180°的观察方向，正交或中间角度观察感兴趣的三维区域。操纵三维感兴趣区域的一个视图导致两个视图改变，好像临床医生以相同方式同时操纵两个视图。