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(54) **VOLUMETRIC ULTRASOUND IMAGE DATA REFORMATTED AS AN IMAGE PLANE SEQUENCE**

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(57) **ABSTRACT**

An ultrasound probe acquires a 3D image dataset of a volumetric region of the body. The 3D image data is reformatted into a sequence of successive parallel image planes extending in one of three orthogonal directions through the volume. The sequence of images (**74**, **84**, **94**) is preferably formatted in accordance with the DICOM standard so that a clinician can review the 3D image data as a sequence of DICOM images on an image workstation.

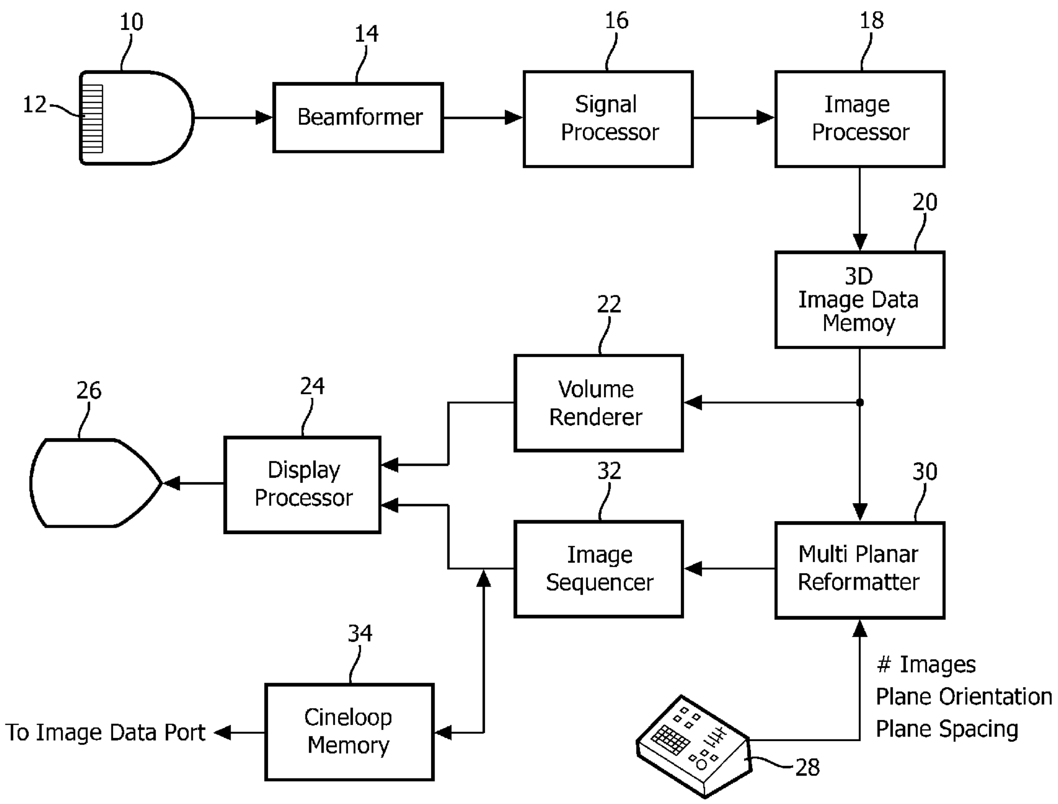
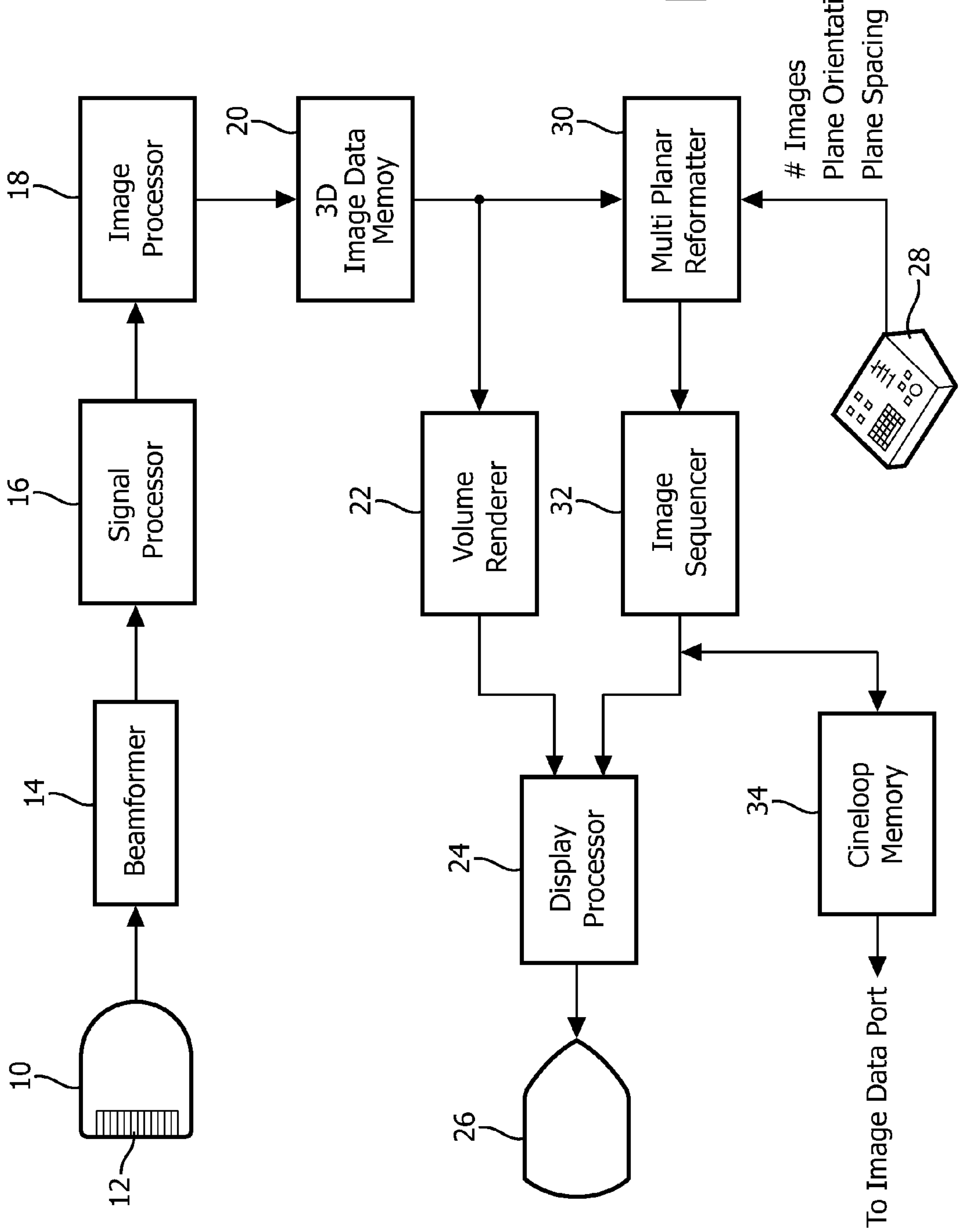


FIG. 1


10
12
14
Beamformer
16
Signal
Processor
18
Image
Processor
20
3D
Image Data
Memoy
22
Volume
Renderer
24
Display
Processor
26
30
Multi Planar
Reformatter
Images
Plane Orientation
Plane Spacing
28
32
Image
Sequencer
34
Cineloop
Memory
To Image Data Port

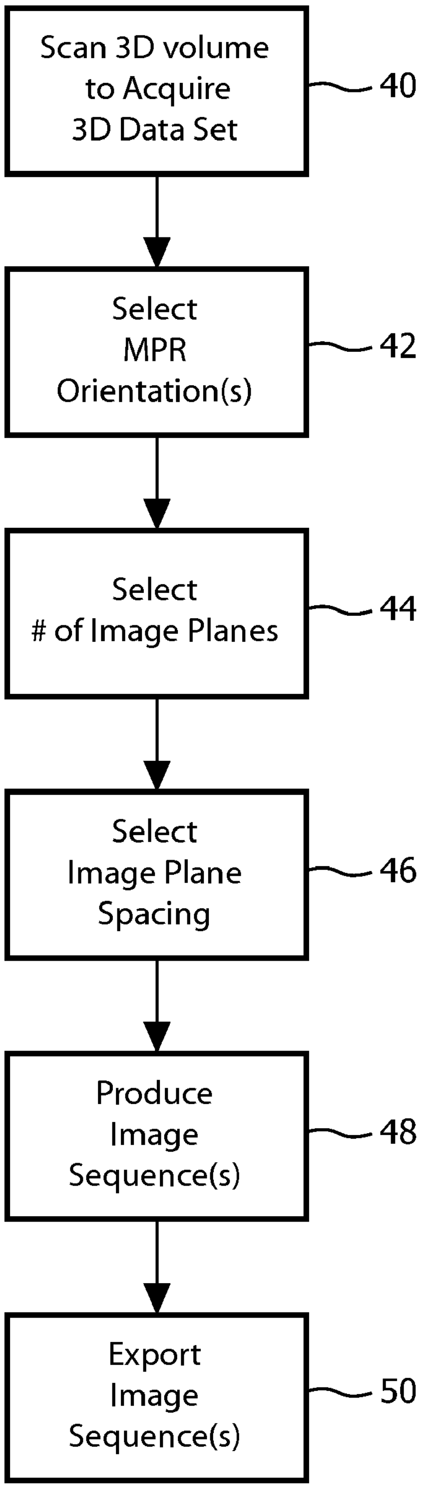

Scan 3D volume to Acquire 3D Data Set
40
Select MPR Orientation(s)
42
Select # of Image Planes
44
Select Image Plane Spacing
46
Produce Image Sequence(s)
48
Export Image Sequence(s)
50

FIG. 2

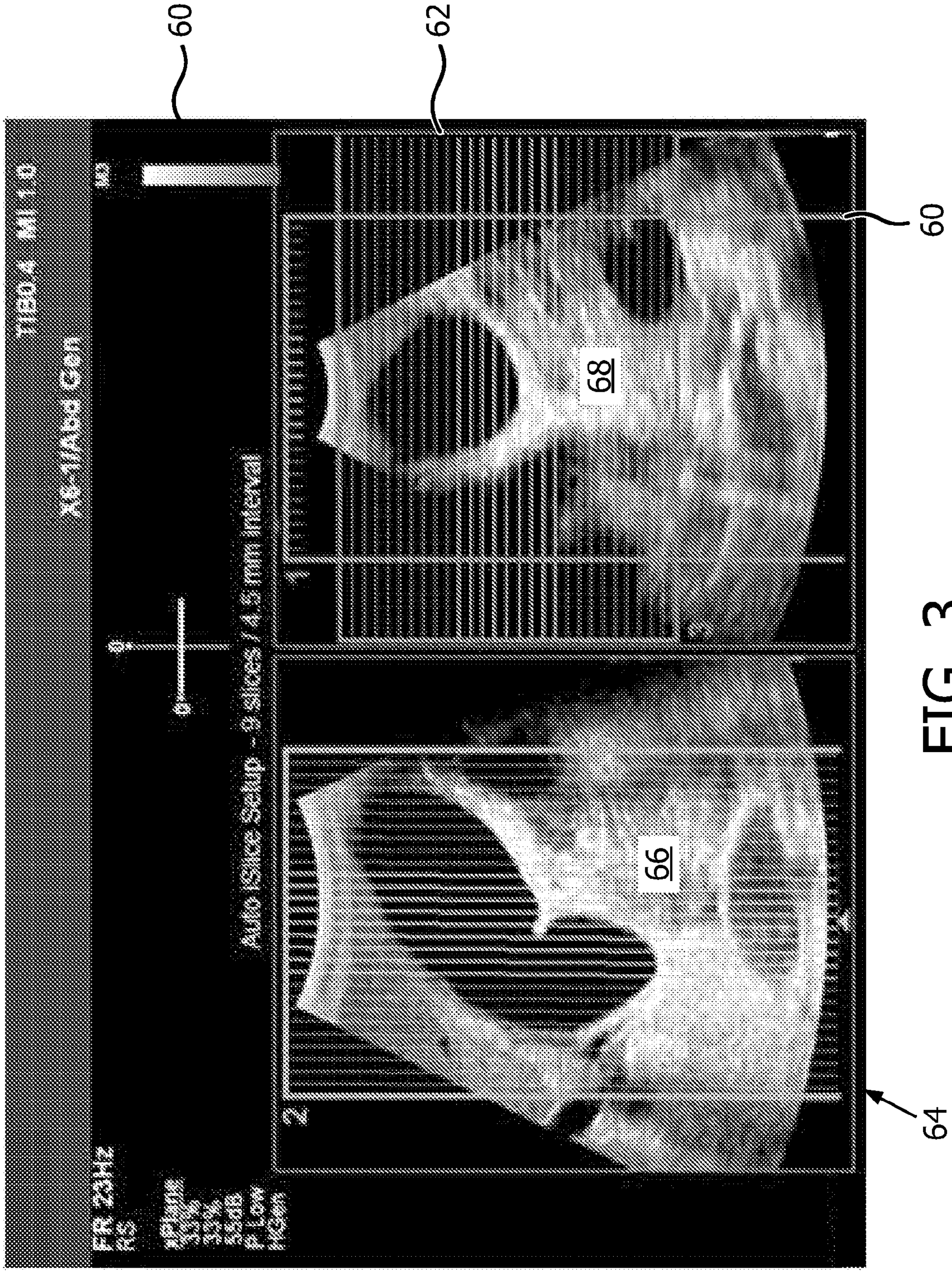

X6-1/Abd Gen
Auto iSlice Setup - 9 slices / 4.5 mm interval
FR 23Hz
RS
60
62
60
64
66
68

FIG. 3

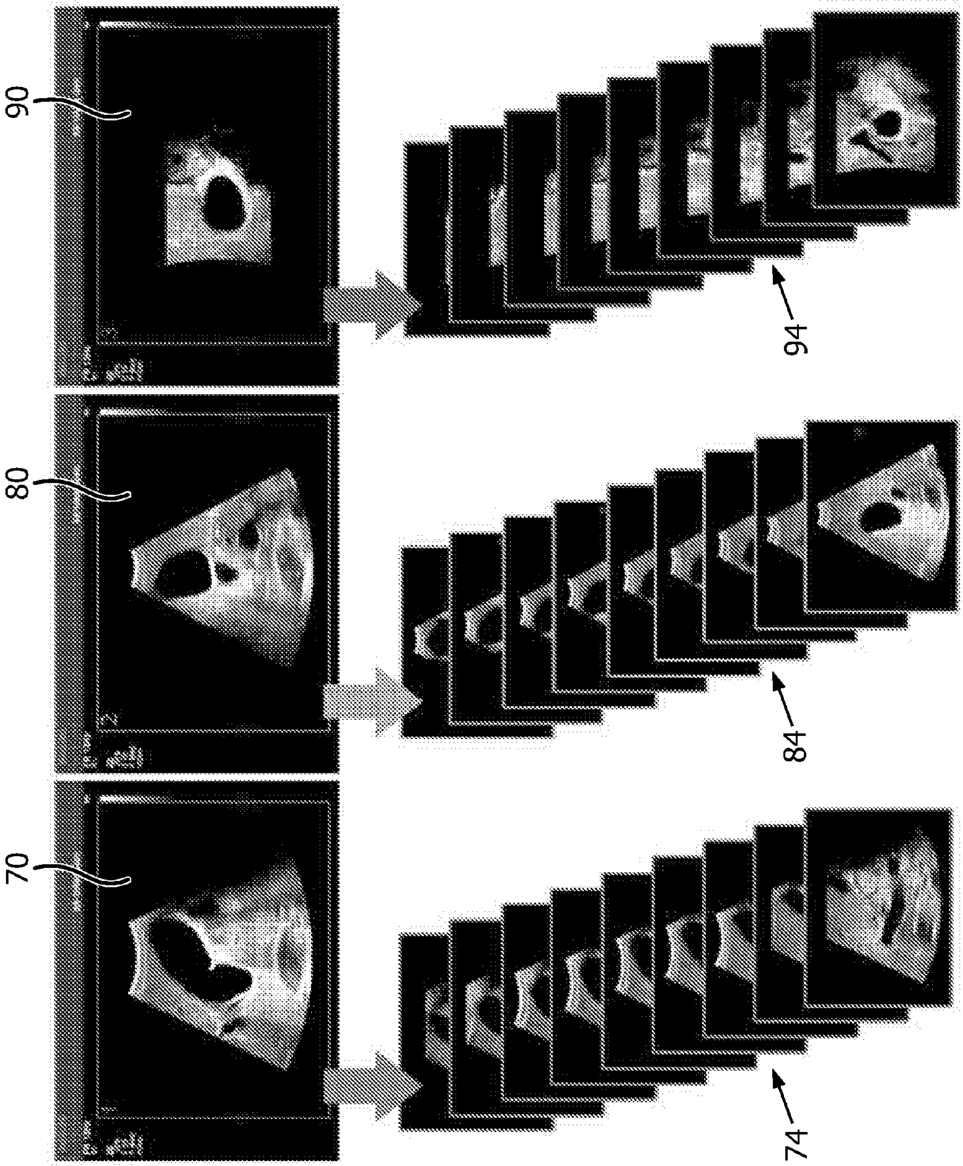


FIG. 4

VOLUMETRIC ULTRASOUND IMAGE DATA REFORMATTED AS AN IMAGE PLANE SEQUENCE

[0001] This invention relates to medical diagnostic ultrasound systems and, in particular, to ultrasound systems for three dimensional (3D) imaging which are capable of exporting volumetric image data as a sequence of planar images.

[0002] Ultrasonic diagnostic imaging has traditionally scanned two-dimensional cross-sectional images of anatomy of the body. As the technology has developed, ultrasound can now scan and image three dimensional volumes, in both still images and real time. The 3D datasets of a scanned volume can be successively rendered as three dimensional views, rapidly enough for the clinician to observe the motion of the anatomy in real time movement. But radiologists and cardiologists are still more familiar with seeing the standard 2D planar images of anatomy and many are still not comfortable with diagnosing anatomy in 3D, a challenge made more difficult by the tissue clutter which often surrounds and obscures the region of interest at the center of the volume being imaged. As a result, many physicians prefer to see planar 2D image "slices" of a 3D volume. Once a 3D volume image dataset has been captured, a technique called multiplanar reformatting enables the clinician to select one or more cut planes through the volume for viewing as 2D images. In the typical user interface the clinician can position three orthogonal lines in the volume image. Each line represents the position of one of three orthogonal image planes through the volume, an x-y plane (azimuth vs. depth), a y-z plane (depth vs. elevation, generally referred to as a C plane), and an x-z plane (azimuth vs. elevation). As the lines are repositioned, 2D images of the corresponding cut planes are formed by the voxels of the dataset intercepted by the cut planes. See U.S. Pat. No. 6,572,547 (Miller et al.), which illustrates the use of such cut planes to visualize the tip of a catheter from the three different imaging perspectives.

[0003] A further limitation of three dimensional imaging is that the datasets of 3D images are formatted differently by various ultrasound imaging system vendors, as the vendors try to process and accommodate the storage of the large (3D) datasets inherent in three dimensional imaging. In an effort to align these different proprietary approaches, a working group of the DICOM Standards Committee published Supplement 43 to the standard in April, 2009 directed specifically to a DICOM standard for storing 3D ultrasound images. However implementation of this standard for 3D ultrasound images has not been rapid, and the plans of different vendors for converting imaging systems such as PACS systems to the new 3D standard remain largely unknown. Accordingly there remains a need to provide 3D image data in a standardized format which readily lends itself to transport and use on other medical image platforms which have not implemented the DICOM standard for 3D ultrasound images.

[0004] In accordance with the principles of the present invention, an ultrasound system is described which reformats 3D image data as one or more sequences of 2D images in respective cut plane directions which can be ported to other imaging platforms and replayed and diagnosed as a standardized 2D real time image sequence. A user interface provides selection of the cut plane direction, the spacing of the planes, and/or the number of images in the sequence. The volume is then reformatted into planar images in the selected cut plane direction(s) and stored as one or more image sequences, enabling replay of each sequence on most conventional medical imaging platforms, preferably as 2D DICOM image sequences.

[0005] In the drawings:

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

[0007] FIG. **2** illustrates a sequence for acquiring a 3D dataset and reformatting the data as one or more planar image sequences in accordance with the present invention.

[0008] FIG. **3** illustrates lines over a 3D image indicating position of cut planes in accordance with the present invention.

[0009] FIG. **4** illustrates the formation of three planar image sequences from a volumetric image dataset in accordance with the present invention.

[0010] Referring to FIG. **1**, an ultrasound system constructed in accordance with the principles of the present invention is shown in block diagram form. An ultrasound probe **10** with an array transducer **12** transmits ultrasound waves into the body of a patient and receives echoes from a volumetric region in response. Several techniques are known for ultrasonically scanning a volumetric region of the body. One is to move an ultrasound probe containing a one-dimensional array transducer over the skin in a direction normal to the image plane of the probe. The probe will thus acquire a succession of substantially parallel image planes as the probe is moved, and the image data of the image planes comprises a 3D image dataset. This manual technique, referred to as freehand scanning, is described in U.S. Pat. No. 5,474,073 (Schwartz et al.) A second technique is to mechanically oscillate the transducer array back and forth inside a compartment of the probe. The probe will thus acquire the same data from a succession of substantially parallel image planes as in the freehand technique, but in this case the mechanical oscillation of the transducer array may be rapid enough to produce real time 3D images. The third approach is to use a probe with a two-dimensional array transducer, from which beams can be electronically scanned in three dimensions by phased array beam steering. A 3D probe with a two-dimensional array for this purpose is described in U.S. Pat. No. 5,993,390 (Savord et al.) This third approach advantageously uses a probe with no moving parts, and electronic beam steering can be done rapidly enough to scan even the heart with real time imaging. Each of these scanning techniques is capable of producing a 3D image dataset suitable for use with the present invention.

[0011] The echo signals received by the individual transducer elements of the array **12** are processed by a beamformer **14** to form coherent echo signals relating to specific points in the body. The echo signals are processed by a signal processor **16**. Signal processing may include separation of harmonic echo signal components for harmonic imaging and clutter removal, for example. The processed signals are arranged into images of a desired format such as a trapezoidal sector or a cube by an image processor **18**. The 3D image data is organized by its x-y-z coordinates in the volumetric region and stored in an image memory **20**. The 3D image data is rendered into a three-dimensional image by a volume renderer **22**. A series of volume rendered images may be dynamically displayed in kinetic parallax so that the user may rotate, re-orient and reposition the volume from different viewing perspectives as described in U.S. Pat. No. 6,117,080 (Schwartz). The images are processed for display by a display processor **24** which can overlay the 3D image with graphics, and the image is displayed on an image display **26**.

[0012] A 3D volumetric image can also be examined by "slicing through" the volume and displaying a particular slice as a 2D image. The location of the slice in the volume is selected by user manipulation of a control on a user control interface **28**. The user control will select a particular 2D plane in the 3D volume as described above, and a multi-planar reformatter **30** selects the planar data of the 3D dataset which have coordinates in the selected plane. The 2D image of the selected plane is shown on the display **26**, either alone or in conjunction with the 3D image. As previously described, the user control interface can present the user with three differently colored lines or cursors, each of which can select a plane of a respective mutually orthogonal orientation. The user can thus simultaneously view three orthogonal planes through the 3D volume, as described in U.S. Pat. No. 6,572,547 (Miller et al.), for example.

[0013] In accordance with the principles of the present invention, the image data of a 3D volume is arranged in a sequence of images of sequential, parallel planes of the volume. The sequence of images may be stored as a sequence of frames within an ultrasound DICOM multi-frame image, which can be stored and replayed on most medical image workstations and PACS systems in the manner of a 2D image sequence stored in an ultrasound DICOM multi-frame image. A clinician can thereby view the image data of the 3D volume as a sequence of cut planes through the volume. The clinician can replay the image sequence rapidly, giving the impression of "swimming through" the volume. Or, the clinician can step through the sequence slowly or pick out a particular image in a plane which cuts through a region of interest for diagnosis. The 3D volume data can thus be reviewed as 2D images with which the clinician is more comfortable and familiar than a 3D volume image.

[0014] In the implementation of FIG. **1**, the user operates the user control interface to select the orientation of the planes of the 2D image sequence (or sequences) to be created. Standard 2D images have an azimuth (x) dimension and a depth (y) dimension and the clinician may, for example, want to have the cut planes oriented in a succession of x-y planes, each with a different z (elevation) coordinate in the volume. This selection is applied to the multi-planar reformatter **30**, which selects a sequence of x-y image planes of the 3D dataset. This sequence of x-y cut plane images is coupled to an image sequencer **32**, which processes the images as a succession of 2D images. The image sequence can have a proprietary (custom) format used by the particular ultrasound system, but preferably the 2D images are processed in compliance with the DICOM standard for two-dimensional medical images. With DICOM standard formatting, the image sequence can be replayed and viewed on a wide variety of medical image platforms. The 2D image sequence is stored in a Cineloop® memory **34** as a sequence or "loop" of 2D images. The image sequence can be sent to other imaging systems and platforms by way of the image data port of the ultrasound system. An image sequence of the present invention can be ported to an image review workstation in another department of a hospital over the hospital's image data network, for instance.

[0015] In a preferred implementation of the present invention the user can specify and select additional parameters of the 2D image sequence of the 3D volume. As shown in FIG. **1**, the user control interface **28** uses the same or other user controls to specify other characteristics of a 2D image sequence, including selecting the number of images of the sequence and the plane-to-plane spacing of the cut planes of the sequence. The user controls may also provide the ability for the user to select a particular sub-volume of the 3D volume for the cut planes. For example, the user may select just the central one-third of the volume for the 2D image sequence. As another example, the entire 3D volume is to be reformatted into 2D image planes in a sequence of 100 image planes. The multi-planar reformatter takes this selection and distributes the 100 cut planes at equal intervals over the volume in the selected orientation. As another example, the user selects a 2 mm plane-to-plane spacing, and the multi-planar reformatter cuts the 2D image planes at 2 mm intervals through the volume in the selected orientation.

[0016] FIG. **2** illustrates a process for producing and exporting a 2D image sequence of a 3D volume in accordance with the present invention. In step **40** the clinician scans a volumetric region of the body to acquire a 3D dataset. In step **42** the clinician observes the rendered 3D image and selects one or more plane orientations for one or more image sequences into which the volume is to be sliced by the multi-planar reformatter. The clinician may select two sequences, for example, one with the cut planes having x-y coordinates and another with the cut planes having y-z coordinates. In a constructed embodiment the selection of the plane orientation for a sequence is done by selecting and viewing a particular MPR image plane. The other images of the sequence will then be formatted in planes parallel to the selected plane. In step **44** the clinician selects the number of image planes of each sequence. The clinician may select 50 planes for the x-y plane sequence and 20 planes for the y-z plane sequence, for example. In step **46** the clinician selects the image plane spacing. The clinician may select a 1 mm spacing for the x-y planes and a 2 mm spacing for the y-z planes, for example. If the inter-plane spacing of this step is too large for the number of planes selected in step **44**, the system will notify the user of the conflict so that the user can select one parameter or the other. If the inter-plane spacing selected is too small for the full volume, the system will distribute the number of plane selected with the selected inter-plane spacing about the center of the volume, where users most frequently position the region of interest. Alternatively, the user may specify a sub-region of the volume over which the planes are to be distributed. In the constructed embodiment there is no need to perform steps **44** and **46**; the ultrasound system automatically produces planes of image data from one side of the 3D volume to the other, and produces image planes at the smallest plane-to-plane spacing permitted by the ultrasound system. In step **48** the multi-planar reformatter and the image sequencer produce the specified image sequence(s). In step **50** the image sequence(s) are exported to an image workstation as an ultrasound DICOM multi-frame image for review and diagnosis.

[0017] FIG. **3** is an image display on the screen of display **26** which illustrates a grid of cut plane lines which show the user the planes which will be reformatted into sequences of 2D images. On the left side of the display screen **60** is an ultrasound image **66** which is oriented in the x-y plane. Overlaying this image **66** is a grid of vertical lines **64**, which indicate a series of cuts through the volume in the y-z (elevation) direction. This grid **64** shows the user that the portion of the volume spanned by these thirty cut planes will be reformatted into a sequence of thirty 2D images in the y-z dimension. On the right side of the display is a second image **68** through the volume in the x-y dimension which is overlaid with a grid of horizontal lines **62**. This grid **62** shows the user that a sub-region of the volume extending from near the top of the image down to about two-thirds of the full image depth will be reformatted into a sequence of thirty C-plane images, that is, images which are each in the x-z dimension and are at successive depths (y-direction increments) of the volume. The grid **62** is backed by a graphical box **60** which at the top indicates with small tick-marks the locations of the cut planes in the y-z dimension which is set over the left-side image **66**. Thus, the user can see at a glance the relative locations of the two sets of orthogonal grid lines and cut planes.

[0018] The user is also given the ability to rotate or tilt a grid **62**,**64** and thereby create cut plane lines which are tilted or rotated with respect to the nominal orientation of purely horizontal or vertical cut planes.

[0019] FIG. **4** illustrates three image sequences **74**, **84**, **94** which are produced by an implementation of the present invention. The display screen **70** on the left side of FIG. **4** shows an ultrasound image **72** cut through the volume in the x-y dimension, and an image sequence **74** of 2D images which are in successive x-y planes through the volume and 3D dataset. In the center of FIG. **4** is a display screen **80** showing an image **84** in the y-z plane and below this image is an image sequence **84** of images in successive y-z cut planes through the volume and 3D dataset. On the right side of FIG. **4** is a display screen **90** showing a C-plane (x-z dimension) **92** and below it is a sequence **94** of images cut through successive x-z planes of the volume and 3D dataset. The three image sequences show images cut through mutually orthogonal planes of the volume and 3D dataset, one which progresses in the z direction, a second which progresses in the x direction, and the third which progresses in the y direction. The user can export one, two, or all three image sequences as DICOM images to an image workstation for further analysis and diagnosis.

[0020] Since each cut plane is through the full 3D image dataset, each 2D cut plane image thus intersects and contains all of the image data acquired for the particular reformatted image. In a preferred embodiment the 2D images are in Cartesian coordinates and each image sequence is of successive cut planes in a respective orthogonal Cartesian coordinate direction. The 2D images are thus suitable for measurement and quantification to the same degree as a standard 2D image acquired by conventional means by a one-dimensional array transducer.

What is claimed is:

1. An ultrasonic diagnostic imaging system which produces three dimensional (3D) image data of a volumetric region of a body comprising:

an ultrasound probe operable to acquire a 3D image dataset of the volumetric region;

an image data reformatter, responsive to the 3D image dataset, which produces a plurality of parallel 2D images of cut planes which are normal to a selected direction through the 3D image dataset;

an image sequencer, responsive to the 2D images, which produces a sequence of 2D images which can be replayed as a 2D image sequence of a standard format;

a data port, coupled to the image sequencer, by which the sequence of 2D images can be transferred to another imaging system; and

a display operable for viewing the 2D image sequence.

2. The ultrasonic diagnostic imaging system of claim **1**, wherein image sequencer is further operable to produce a sequence of 2D images which is in accord with the DICOM format.

3. The ultrasonic diagnostic imaging system of claim **2**, wherein the other imaging platform is operable to replay the sequence of 2D images as a DICOM image sequence.

4. The ultrasonic diagnostic imaging system of claim **1**, further comprising a Cineloop memory which is operable to store the sequence of 2D images produced by the image sequencer as an image Cineloop,

wherein the sequence of 2D images can be replayed on the display.

5. The ultrasonic diagnostic imaging system of claim **4**, wherein the sequence of 2D images can be replayed from the Cineloop memory as a real time image sequence, or can be played and stopped to view a particular one of the 2D images on the display.

6. The ultrasonic diagnostic imaging system of claim **1**, further comprising a user control interface operable by a user of the imaging system to select the normal direction through the 3D dataset.

7. The ultrasonic diagnostic imaging system of claim **6**, wherein selection of the normal direction comprises selecting a 2D image plane through the 3D dataset,

wherein the images of the sequence of 2D images are parallel to the plane of the selected 2D image plane.

8. The ultrasonic diagnostic imaging system of claim **6**, wherein the user control is further operable by a user to select up to three orthogonal normal directions for up to three orthogonal 2D image datasets,

wherein the image data reformatter and the image sequencer are responsive to the selection of up to three orthogonal normal directions for the production of up to three sequences of 2D images from the 3D dataset.

9. The ultrasonic diagnostic imaging system of claim **6**, wherein the user control interface is further operable by the user to select the spacing of the cut planes.

10. The ultrasonic diagnostic imaging system of claim **9**, wherein the user control interface is further operable by the user to select the number of cut planes,

wherein the number of cut plane is equal to the number of 2D images of the sequence produced by the image sequencer.

11. The ultrasonic diagnostic imaging system of claim **6**, wherein the user control interface is further operable by the user to select the number of cut planes,

wherein the number of cut plane is equal to the number of 2D images of the sequence produced by the image sequencer.

12. The ultrasonic diagnostic imaging system of claim **1**, further comprising a volume renderer, responsive to the 3D image dataset, for producing a rendered 3D ultrasound image,

wherein the display is further operable to display the rendered 3D ultrasound image.

13. The ultrasonic diagnostic imaging system of claim **1**, further comprising a display processor, coupled to the display, which produces a graphic overlaying an ultrasound image acquired by the probe that indicates the spatial locations of a sequence of 2D image planes.

14. The ultrasonic diagnostic imaging system of claim **13**, wherein the graphic further comprises a grid of cut plane lines, and further comprising a user control by which a user can adjust at least one of the number of cut planes of the grid, the spacing of the cut planes of the grid, and the position of the cut planes relative to the spatial location of the volumetric region.

15. The ultrasonic diagnostic imaging system of claim **14**, further comprising a user control by which a user can rotate or tilt the cut planes through the volumetric region.

* * * * *

patsnap

专利名称(译)	体积超声图像数据被重新格式化为图像平面序列		
公开(公告)号	US20130012820A1	公开(公告)日	2013-01-10
申请号	US13/636613	申请日	2011-03-17
[标]申请(专利权)人(译)	皇家飞利浦电子股份有限公司		
申请(专利权)人(译)	皇家飞利浦电子N.V.		
当前申请(专利权)人(译)	皇家飞利浦电子N.V.		
[标]发明人	BROWN JIMMY RAY BRADLEY KEVIN		
发明人	BROWN, JIMMY RAY BRADLEY, KEVIN		
IPC分类号	A61B8/13		
CPC分类号	A61B8/465 A61B8/466 A61B8/469 A61B8/483 G06F19/321 G01S7/52073 G01S7/52074 G01S15/8993 A61B8/523 G16H30/20 G16H30/40		
优先权	61/316471 2010-03-23 US		
其他公开文献	US10235497		
外部链接	Espacenet USPTO		

摘要(译)

超声探头获取身体的体积区域的3D图像数据集。将3D图像数据重新格式化为一系列连续的平行图像平面，这些平面图像平面在通过该体积的三个正交方向之一上延伸。优选地，图像序列（74,84,94）根据DICOM标准格式化，使得临床医生可以将3D图像数据作为图像工作站上的DICOM图像序列进行查看。