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(54) Ultrasonic diagnostic apparatus

Ultraschalldiagnostisches Gerät und Verfahren

Dispositif et procédé de diagnostique à ultrasons

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(73) Proprietor: **Aloka Co. Ltd.**
Mitaka-shi
Tokyo, 181-8622 (JP)

(72) Inventor: **Murashita, Masaru**
Mitaka-shi
Tokyo 181-8622 (JP)

(74) Representative: **Heim, Hans-Karl et al**
Weber & Heim
Patentanwälte
Irmgardstrasse 3
81479 München (DE)

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EP 1 419 737 B1

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to an ultrasonic diagnostic apparatus for providing an image of a cavity portion of an organ as a three-dimensional image.

2. Description of Related Art

[0002] Ultrasonic diagnostic apparatuses which transmit and receive ultrasound with respect to a living body and which then provide a three-dimensional image of inside the living body based on a received ultrasonic signal have been known. In general, the three-dimensional image thus obtained is a solid representation of information concerning a brightness value of each voxel. In this case, however, a cavity portion inside an organ cannot be observed. When observing a heart, for example, a cardiac muscle portion is brightly displayed because ultrasound is reflected by the cardiac muscle of the heart, and no information can be obtained regarding a cavity portion inside the organ, such as the characteristics or behavior of a ventricle. Therefore, in order to observe a cavity portion, a processing is conventionally performed in which a cutting plane is specified and an image of the cavity portion is displayed while information concerning regions in front of the plane is eliminated, for example.

[0003] Further, in diagnosis regarding the heart, there is a demand for obtaining a stroke volume of the heart. Conventionally, an approximate stroke volume has been obtained based on a tomogram of the heart or the like. For example, the length of a predetermined portion of the left ventricle is measured and the stroke volume is obtained based on sequential change of this length over time, or, in another example, the cross sectional area of the left ventricle at a certain cutting section is obtained and the stroke volume is calculated based on sequential change in this cross sectional area with time.

[0004] When a cavity portion inside an organ is observed, necessary information is often provided by the state of the inner wall surface of the cavity. Accordingly, when a cavity is observed in such a manner that a cutting plane is specified and information concerning regions in front of the cutting plane is eliminated, as conventionally performed, it is not possible to observe the regions of the cavity which have been eliminated.

[0005] Further, according to the conventional method, a volume of a cavity portion being observed is only an assumed value based on the length of a predetermined part and the area of a predetermined section. Therefore, an accurate volume cannot be obtained.

[0006] US 2002/0072670 A1 discloses a method for analyzing ultrasonic images of the heart. Specially, an automatic border detection of the left ventricle of the heart is described.

[0007] EP 1 008 864 A2 discloses an imaging system with a morphological filter to display human vessels free-dimensional.

[0008] W. Ohyama et al. discloses in "Automatic Left Ventricular Endocardium Detection in Echocardiograms Based on Ternary Thresholding Method" from the pattern recognition, 2000, proceedings 15th international conference on September 3 to 7, 2000 in Los Alamitos, an algorithm which uses two thresholds to determine the left ventricle. The input image is segmented by two thresholds into three regions, and one region of special interest is then binarized with the lower threshold again.

[0009] JP 2000-300555 discloses a method to form an ultrasonic image of vessels in a three-dimensional manner. Therefore, the region of interests is sliced into a plurality of horizontal blocks. Then, an intermediate image is generated for each block. Following, these images of the blocks are combined giving the images nearer to the view point a priority. To extract only blood vessels, a reversal binarization process is performed on the data of the different blocks.

[0010] Out of JP Hei 4-348745 it is known to process ultrasonic image data with a binarization and inversion process. Based on these processes it is possible to display vessels which are filled with a liquid, especially with blood.

[0011] JP Hei 9-131345 teaches a semiautomatic tracking method for determining the volume of a heart, based on a two-dimensional ultrasonic image. Therefore, it is placed a pattern model inside an image of a cardiac cavity. This pattern model is then extracted until it reaches the cardiac walls.

SUMMARY OF THE INVENTION

[0012] The present invention advantageously provides an ultrasonic diagnostic apparatus capable of preferable observation and information acquisition concerning a cavity portion inside an organ.

[0013] An ultrasonic diagnostic apparatus of the present invention inverts and binarizes the brightness value of each voxel regarding three-dimensional data obtained based on a received ultrasonic signal so as to display a cavity portion of an organ, and provides a three-dimensional image of the cavity portion of the organ. Because the brightness value is inverted, it is possible to observe cavity portions where ultrasound reflection is weak. Further, binarization processing enables reliable extraction of the outline surface of the cavity portion being observed.

[0014] It is further possible to provide means for specifying a region of interest for extracting a cavity portion of an organ to be observed with regard to the inverted and binarized data.

[0015] Also, it is possible to calculate and provide the volume of the cavity portion of the organ based on a three-dimensional image thereof. Further, it is possible to provide data for supporting diagnosis, such as a change of the volume with time and a ratio between the minimum and maximum values of the volume.

[0016] An object organ may be a heart and an object cavity portion may be a left ventricle. Information concerning the cardiac output can be obtained by calculating the volume of the left ventricle.

[0017] An ultrasonic diagnostic apparatus according to the invention is defined in claim 1.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] These and other objects of the invention will be explained in the description below, in connection with the accompanying drawings, in which:

Fig. 1 is a schematic view showing an appearance of an ultrasonic diagnostic apparatus according to an embodiment of the present invention;
Fig. 2 is a block diagram showing a configuration according to the embodiment of the present invention;
Fig. 3 is a view showing an example of an inverted and binarized ultrasonic image;
Fig. 4 is a view showing an example of region of interest for extracting the cardiac cavity portion; and
Fig. 5 is an example image of an extracted cardiac cavity portion which has been binarized and inverted.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0019] A preferred embodiment of the present invention will be described in further detail with reference to the accompanying drawings. Although a heart, particularly a left ventricle, is described as the object of observation in the following example, the present invention is clearly also applicable to other cardiac cavities and to cavity portions of other organs.

[0020] Fig. 1 schematically shows an appearance of an ultrasonic diagnostic apparatus 10 according to an embodiment of the present invention. The ultrasonic diagnostic apparatus 10 has a function of forming a three-dimensional ultrasonic image. The ultrasonic diagnostic apparatus 10 includes an operation panel 14 for performing various operations at a front surface of a main body 12 of the apparatus 10. Further, an ultrasonic probe 16 for transmitting and receiving ultrasound with regard to an object is connected via a cable to the apparatus main body 12. A monitor 17 is provided above the apparatus main body 12 for displaying an ultrasonic image or the like obtained based on a reflection wave received by the ultrasonic probe 16. A circuit board in which a circuit for performing transmission/reception of ultrasonic wave, signal processing of received reflection wave, image processing, or the like is incorporated, is provided within the apparatus main body 12.

[0021] Fig. 2 is a block diagram showing a configuration concerning formation of an ultrasonic image, and specifically shows a configuration related to image processing suitable for displaying a cavity portion of an organ, such, for example, as a cardiac cavity portion including a left ventricle. The ultrasonic probe 16 is capable of scanning in two directions using an ultrasonic beam, which enables formation of a three-dimensional ultrasonic image. A transmission/reception section 18, which corresponds to the ultrasonic probe 16 for three-dimensional image, controls transmission and reception of ultrasonic wave and transmits the received data to a three-dimensional data memory 20 where the data is stored. In an example according to the present embodiment in which the ultrasonic probe 16 is a convex type probe, the three-dimensional data is stored in the form of a polar coordinate system (θ, ϕ, r) based on a main scanning direction θ of the ultrasonic beam, a sub scanning direction ϕ orthogonal to the main scanning direction, and a distance r from the center of curvature of a contact surface of the ultrasonic probe 16. The three-dimensional data may also be stored in another form, such as a form obtained by converting the polar coordinate system, which can be obtained directly from reflection wave information, into another coordinate system, such as, for example, a rectangular coordinate system (x, y, z).

[0022] The data stored in the three-dimensional data memory 20 has a brightness corresponding to the intensity of reflection wave. When a heart is an observation object, the cardiac muscle portion which causes significant reflection has a high brightness, while the cardiac cavity portion which is filled with fluid (blood) only weakly reflects the ultrasound and has a low brightness. When such data is displayed in a typical three-dimensional representation, only the cardiac muscle portion having high brightness is displayed, and the inner cardiac cavity portion being hidden behind the cardiac muscle portion and not displayed. According to the present embodiment, in order to display the cardiac cavity portion, the brightness value is inverted, such that the cardiac muscle portion will have low brightness and the cardiac cavity portion will have high brightness, thereby making it possible to observe the cardiac cavity portion in a three-dimensional representation. An inverted image is created by processing the data stored in the three-dimensional data memory 20 by an inverted image forming section 22. The image processing performed by the inverted image forming section 22 will be described in detail below.

[0023] First, the brightness value of each voxel data in the three-dimensional data memory 20 is binarized in a binarization processing section 24. The threshold value used for binarization may be a predetermined fixed value or may be set by an operator in accordance with an ultrasonic image which is obtained. When the brightness data is based on 64 gray-scale levels, for each voxel, the brightness value is set to 0 when the brightness is lower than the threshold value, and the brightness value is set to 63 when the brightness value equals to or greater than the threshold value. Then, the brightness value is inverted in a brightness value inverting section 26. Because the brightness value has already been binarized, the brightness value is inverted from 0 to 63, or from 63 to 0 due to the inversion. Similar results can be obtained even when the order of performing the binarization and the inversion processing is reversed. When the inversion processing is performed prior to the binarization, in the case of 64 gray-scale levels, a processing is first performed in which the brightness is inverted from 0 to 63, from 1 to 62, from 2 to 61, ... from 63 to 0. Subsequently, the inverted values are binarized using a predetermined threshold value.

[0024] Fig. 3 shows an example image based on binarized and inverted data. In Fig. 3 is shown a state in which conversion from a polar coordinate system to a rectangular coordinate system has been performed. The surfaces which have an appearance similar to side surfaces of a quadrangular pyramid correspond to a portion where, perhaps due to the influence of a rib or the like, no reflection wave of ultrasound exists, and have appeared by inversion of the brightness values. The portion which seems to bulge in the middle of the drawing represents the cardiac cavity.

[0025] Although not shown in Fig. 3, when the binarized data is displayed without any processing, the display is inferior because the contrast is too high, and the noise is emphasized. It is therefore preferable to apply image processing such as the following to the binarized and inverted data so as to form and display a clear and useful image. First, noise removal is performed in a noise removing section 28. For example, on a θ-ϕ plane, with regard to eight voxels surrounding a certain target voxel, when at least five voxels have a brightness value of 63 (in the case of 64 gray-scale), the brightness value of the target voxel is set to 63. When four or less voxels have a brightness value of 63, the target voxel maintains its brightness value. Further, when at least five voxels surrounding the target voxel have a brightness value of 0, the brightness value of the target pixel is set to 0. When four or less voxels have a brightness value of 0, the target voxel maintains its brightness value. The noise removing processing which is performed on a θ-ϕ plane in the above description may also be performed on a θ-r plane or aϕ-r plane. Further, the brightness value of a target voxel may be determined based on brightness values of 26 voxels three dimensionally surrounding the target voxel.

[0026] Subsequently, a smoothing processing is performed in a smoothing section 30. Because the binarized data is, as described above, not preferable, an image processing for obtaining a smooth display is performed. For example, smoothing can be achieved by determining the brightness value of a certain voxel to be an average of brightness values of the certain voxel and the surrounding voxels. In order to calculate the average value, 9 voxels within one plane or 27 voxels in a three-dimensional plane may be used. With such smoothing processing, voxels with a middle tone are generated, resulting in a smooth display. Further, in an interpolating section 32, interpolation between lines (in the θ direction) and between frames (in the ϕ direction) is performed.

[0027] Finally, extraction of a cardiac cavity portion is performed in a cardiac cavity portion extracting section 34. As also shown in Fig. 3, in an image which has been binarized and inverted, displayed images other than that of the cardiac cavity portion which is the object of observation obstruct observation of the cardiac cavity portion being observed. Therefore, the cardiac cavity portion is extracted using a general shape thereof. Fig. 4 shows an example of region of interest for extracting the cardiac cavity portion. Because the shape of the cardiac cavity portion can be outlined by a substantial ellipsoid, the region of interest is set to a substantial ellipsoid. In Fig. 4, the upper left view is a plan view of an ellipsoid, the lower left view is a front view thereof, the upper right view is a side view thereof, and the lower right view is a perspective view thereof. The shape (the length of a longer axis, the length of shorter axis, and so on) and the position of the ellipsoid is determined such that the cardiac cavity portion can be preferably extracted. Although the region of interest is preferably a substantial ellipsoid when a cardiac cavity portion is extracted, when other site is extracted, it is preferable that the region of interest having a shape in accordance with that target site is used for extraction.

[0028] A selector 36 selects either the original three-dimensional data or the extracted data of a cardiac cavity portion which has been binarized and inverted, according to an operator's instruction, and transmits the selected data to a converting section 38. The converting section 38 performs data conversion from a polar coordinate system to a rectangular coordinate system and also data conversion for two-dimensional display. When data stored in the three-dimensional data memory 20 is already converted to a rectangular coordinate system, only the data conversion for displaying three-dimensional data two-dimensionally is performed in the converting section 38. Then, a display is created on the monitor 17 using the converted data.

[0029] Further, a volume calculating section 40 calculates the volume of the cardiac cavity portion based on the data of the cardiac cavity portion extracted by the cardiac cavity portion extracting section 34. Because the extracted cardiac cavity portion is a solid model, the volume can be obtained with higher degree of accuracy than when the volume is assumed from the length of a part of the cardiac cavity portion or from a cross sectional area in one section of the cardiac cavity portion. In addition, information supporting a diagnosis, such as, for example, a change of the volume with time, the maxim and minimum values of the volume, and a stroke volume corresponding to the difference between the maxim and minimum volumes, are also calculated. All or some portion of the calculated data is displayed on the monitor 17.

[0030] Fig. 5 shows an example of an image of the extracted cardiac cavity portion. The viewing point can be changed by user operation of the operation panel 14, so that the rear side in the display of Fig. 5 can also be observed.

[0031] While in the foregoing embodiment, processing in which the brightness value is both inverted and binarized is performed, it is also possible to display data which has only been inverted, and has not been binarized.

[0032] As described above, a cavity portion of an organ, which normally has a low brightness, is made bright by inverting the brightness value of an obtained ultrasonic image, and three-dimensional display of the cavity portion is performed. As a result, the shape of the cavity portion can be easily understood and the accuracy of calculating the volume of the cavity portion can be increased.

[0033] While the preferred embodiment of the present invention has been described using specific terms, such description is for illustrative purposes only, and it is to be understood that changes and variations may be made without departing from the scope of the appended claims.

Claims

1. An ultrasonic diagnostic apparatus for transmitting and receiving an ultrasonic wave with regard to a living body and providing a three-dimensional image of an organ based on the received ultrasonic wave, the apparatus being further configured to perform the following steps:

   a) inverting a brightness value of each voxel regarding three-dimensional data obtained by a received ultrasonic signal so as to display a cavity portion of the organ,
   b) before or after inversion of the brightness value of each voxel, binarizing the brightness value,
   c) after inversion and binarization, performing a noise removal processing on the inverted and binarized data, wherein the brightness value of a target voxel is determined based on brightness values of 26 voxels three-dimensionally surrounding said voxel,
   d) after the noise removal processing, performing a smoothing processing on the data, wherein the brightness value of a voxel is determined to be an average of the brightness values of said voxel and the surrounding voxels,
   e) following, extracting the cavity portion of the organ with regard to the binarized and inverted data using a region of interest having a three-dimensional shape in accordance with that of the cavity portion of the organ,
   f) determining the shape of the region of interest such that the cavity portion of the organ can be extracted, and
   g) providing a three-dimensional image of the extracted cavity portion of the organ based on the inverted, binarized, noise removed and smoothed data.

2. An ultrasonic diagnostic apparatus according to claim 1,
   comprising means for specifying a region of interest with regard to the inverted data.

3. An ultrasonic diagnostic apparatus according to any one of claims 1 to 2
   further configured for calculating
   a volume of the cavity portion of the organ and providing that volume based on the three-dimensional image of the cavity portion.

4. An ultrasonic diagnostic apparatus according to claim 3
   further configured for calculating
   data for supporting diagnosis and providing that data based on a result of the calculation of the volume of the cavity portion.

5. An ultrasonic diagnostic apparatus according to any one of claims 1 to 4
   wherein
   the organ to be observed is a heart.

6. An ultrasonic diagnostic apparatus according to claim 5,
   wherein
   the cavity portion to be observed is the left ventricle.

Patentansprüche

1. Ultraschall-Diagnose-Gerät zum Senden und Empfangen einer Ultraschallwelle bezüglich eines lebenden Körpers und zum Aufbereiten eines dreidimensionalen Bildes eines Organs auf der Basis der empfangenen Ultraschallwelle,
   wobei das Gerät des weiteren so konfiguriert ist um die folgenden Schritte durchzuführen:

   a) Invertieren eines Helligkeitswertes jedes Foxels im Hinblick auf dreidimensionale Daten, die durch ein empfangenes Ultraschallsignal erhalten werden, derart um einen Hohlraumbereich des Organes darstellen zu können,
   b) Binärdarstellung des Helligkeitswertes vor oder nach der Invertierung des Helligkeitswertes jedes Foxels,
   c) Durchführung eines Störgeräusch-Entfernungsprozesses im Hinblick auf die invertierten und der Binärdarstellung unterzogenen Daten nach der Invertierung und Binärdarstellung, wobei der Helligkeitswert eines Ziel-Foxels auf der Basis von Helligkeitswerten von 26 Foxel bestimmt ist, die dreidimensional das entsprechende Foxel umgeben,
   d) Durchführung eines Glättungsverfahrens im Hinblick auf die Daten nach dem Störgeräusch-

Entfernungsschritt, wobei der Helligkeitswert eines Foxels als Durchschnitt der Helligkeitswerte des entsprechenden Ziel-Foxels und der umgebenden Foxel bestimmbar ist,

e) nachfolgende Extrahierung des Hohlraumbereiches des Organs in Bezug auf die binärisierten und invertierten Daten unter Verwendung eines interessierenden Bereichs, der eine dreidimensionale Form entsprechend der des Hohlraumbereichs des Organs hat,

f) Bestimmung der Form des interessierenden Bereichs derart, dass der Hohlraumbereich des Organs extrahiert werden kann, und

g) Aufbereitung eines dreidimensionalen Bildes des extrahierten HohlraumBereichs des Organs auf der Grundlage der invertierten, binärisierten, störgeräuschentfernten und geglätteten Daten.

2. Ultraschall-Diagnose-Gerät nach Anspruch 1, mit Mitteln zur Spezifizierung eines interessierenden Bereiches bezüglich der invertierten Daten.

3. Ultraschall-Diagnose-Gerät nach einem der Ansprüche 1 bis 2, des weiteren zur Berechnung eines Volumens des Hohlraumbereichs des Organs konfiguriert und zur Aufbereitung dieses Volumens auf der Basis des dreidimensionalen Bildes des Hohlraumbereichs.

4. Ultraschall-Diagnose-Gerät nach Anspruch 3, des weiteren zur Berechnung von Daten zur diagnostischen Unterstützung konfiguriert und zum Aufbereiten der Daten auf der Basis eines Ergebnisses der Berechnung des Volumens des Hohlraumbereiches.

5. Ultraschall-Diagnose-Gerät nach einem der Ansprüche 1 bis 4, wobei das Organ, das beobachtet ist, das Herz ist.

6. Ultraschall-Diagnose-Gerät nach Anspruch 5, wobei der Hohlraumbereich, der beobachtet ist, der linke Ventrikel ist.

Revendications

1. Appareil de diagnostic à ultrasons destiné à émettre et recevoir une onde ultrasonore en relation avec un corps vivant et à fournir une image tridimensionnelle d'un organe sur la base de l'onde ultrasonore reçue, l'appareil étant configuré en plus pour réaliser les étapes suivantes:

(a) inversion d'une valeur de luminosité de chaque voxel concernant les données tridimensionnelles obtenues par un signal ultrasonore reçu afin d'afficher une portion de cavité de l'organe,

(b) avant ou après l'inversion de la valeur de luminosité de chaque voxel, binarisation de la valeur de luminosité,

(c) après inversion et binarisation, réalisation d'un traitement d'élimination des bruits sur les données inversées et binarisées, dans lequel la valeur de luminosité d'un voxel cible est déterminée sur la base des valeurs de luminosité de 26 voxels entourant tridimensionnellement ledit voxel,

(d) après le traitement d'élimination des bruits, réalisation d'un traitement de lissage sur les données, dans lequel la valeur de luminosité d'un voxel est déterminée comme étant une moyenne des valeurs de luminosité dudit voxel et des voxels l'entourant,

(e) ensuite, extraction de la portion de cavité de l'organe en relation avec les données binarisées et inversées en utilisant une région d'intérêt ayant une forme tridimensionnelle en accord avec celle de la portion de cavité de l'organe,

(f) détermination de la forme de la région d'intérêt de façon que la portion de cavité de l'organe puisse être extraite, et

(g) fourniture d'une image tridimensionnelle de la portion de cavité extraite de l'organe sur la base des données inversées, binarisées, dont les bruits ont été éliminés, et lissées.

2. Appareil de diagnostic à ultrasons selon la revendication 1, comprenant des moyens de spécification d'une région d'intérêt en relation avec les données inversées.

3. Appareil de diagnostic à ultrasons selon l'une quelconque des revendications 1 à 2, configuré en plus pour calculer un volume de la portion de cavité de l'organe et fournir ce volume sur la base de l'image tridimensionnelle de la portion de cavité.

4. Appareil de diagnostic à ultrasons selon la revendication 3, configuré en plus pour calculer des données pour aider à un diagnostic et fournir ces données sur la base d'un résultat du calcul du volume de la portion de cavité.

5. Appareil de diagnostic à ultrasons selon l'une quelconque des revendications 1 à 4, dans lequel l'organe à observer est un coeur.

6. Appareil de diagnostic à ultrasons selon la revendication 5, dans lequel la portion de cavité à observer est le ventricule gauche.

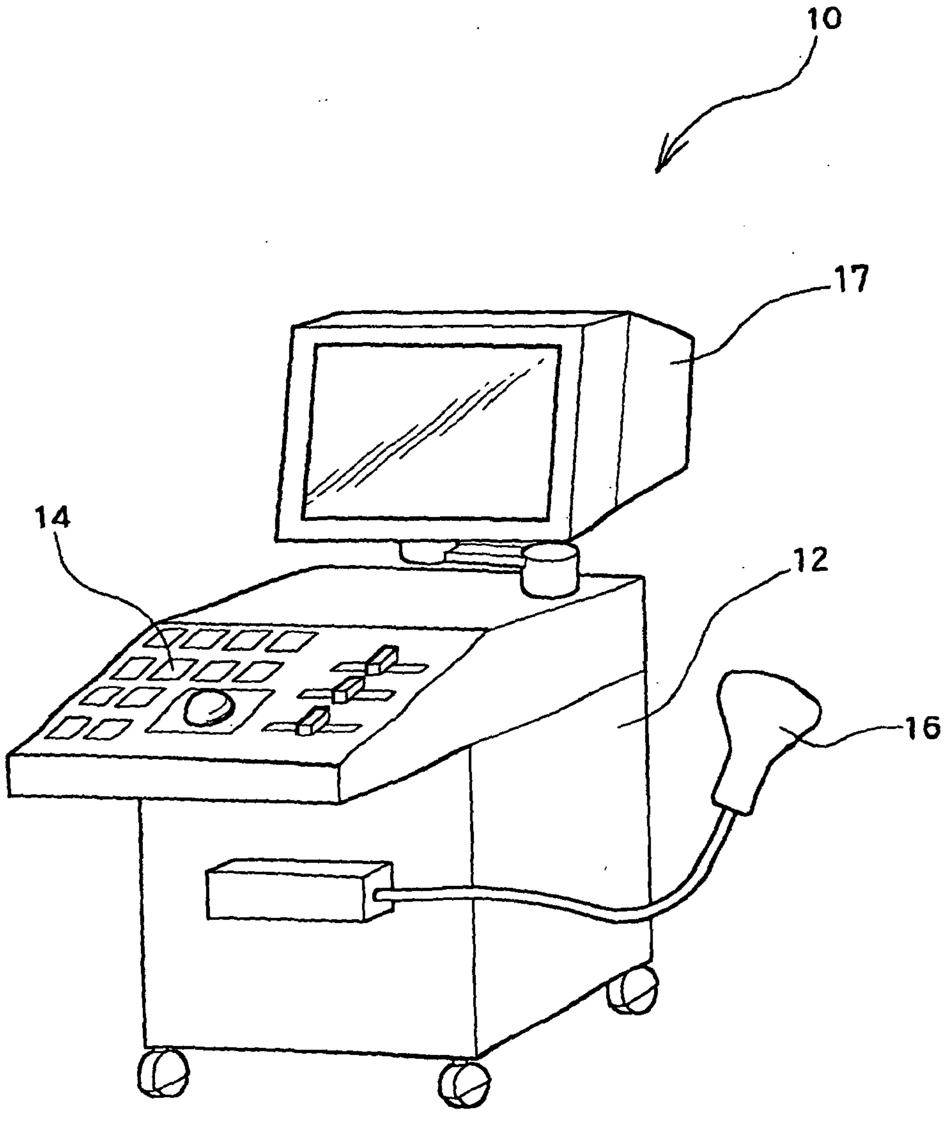

Fig. 1

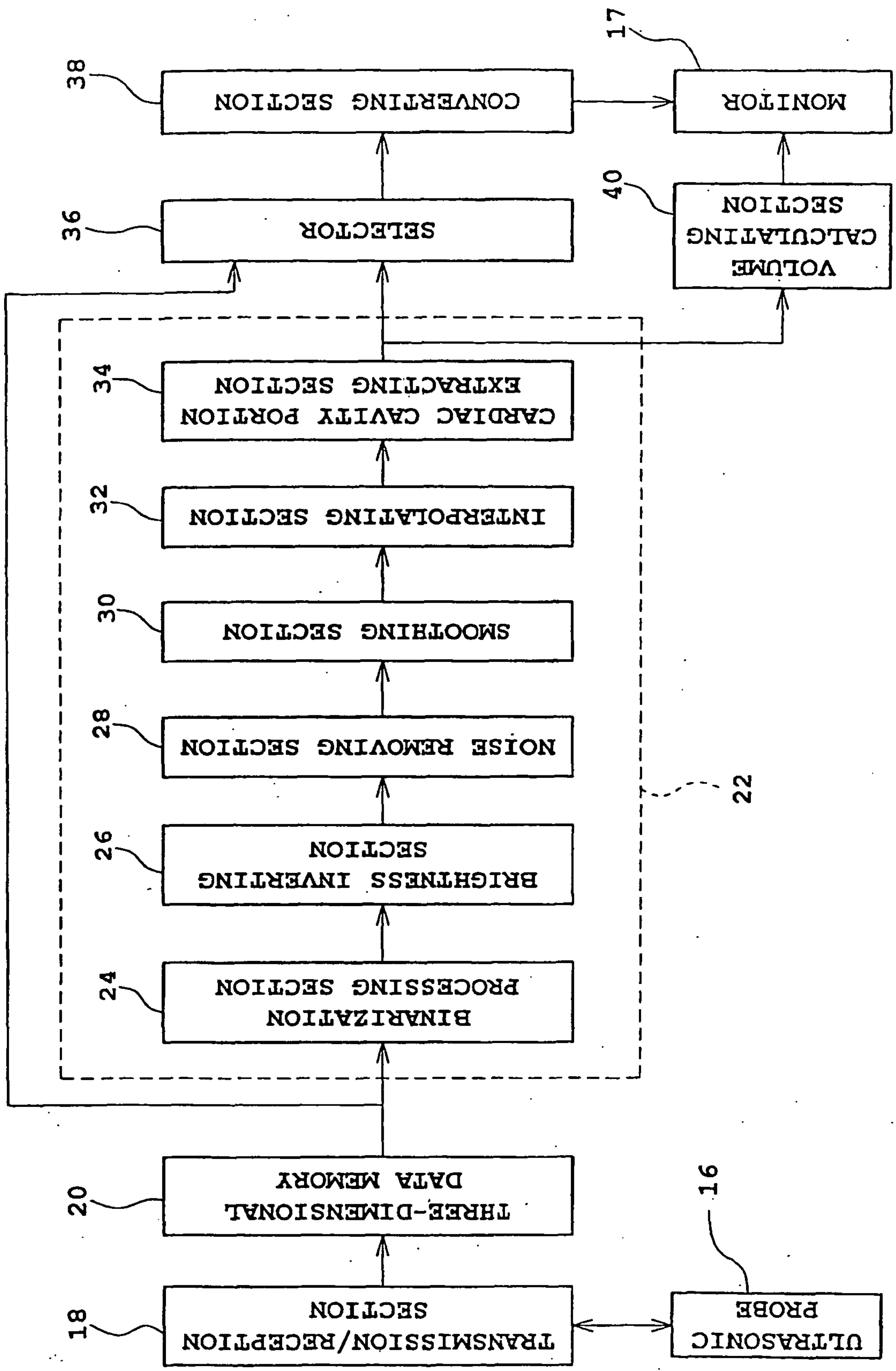
CONVERTING SECTION
MONITOR
SELECTOR
VOLUME CALCULATING SECTION
CARDIAC CAVITY PORTION EXTRACTING SECTION
INTERPOLATING SECTION
SMOOTHING SECTION
NOISE REMOVING SECTION
BRIGHTNESS INVERTING SECTION
BINARIZATION PROCESSING SECTION
THREE-DIMENSIONAL DATA MEMORY
TRANSMISSION/RECEPTION SECTION
ULTRASONIC PROBE
16
17
18
20
22
24
26
28
30
32
34
36
38
40

Fig.2

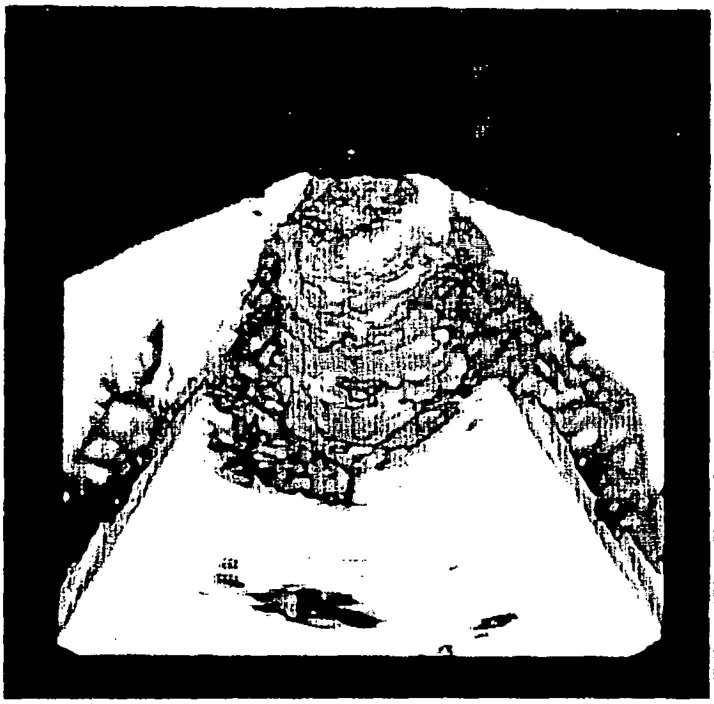

Fig.3

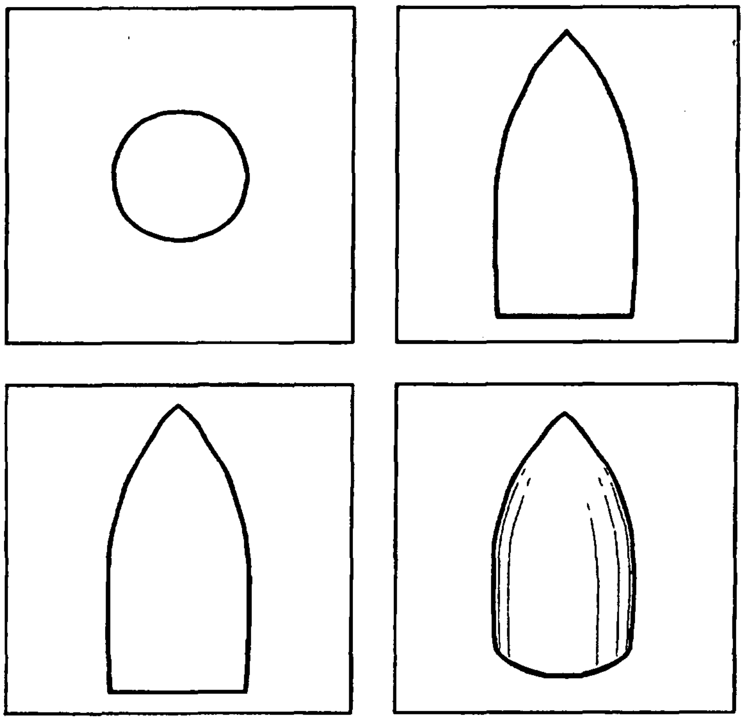

Fig. 4

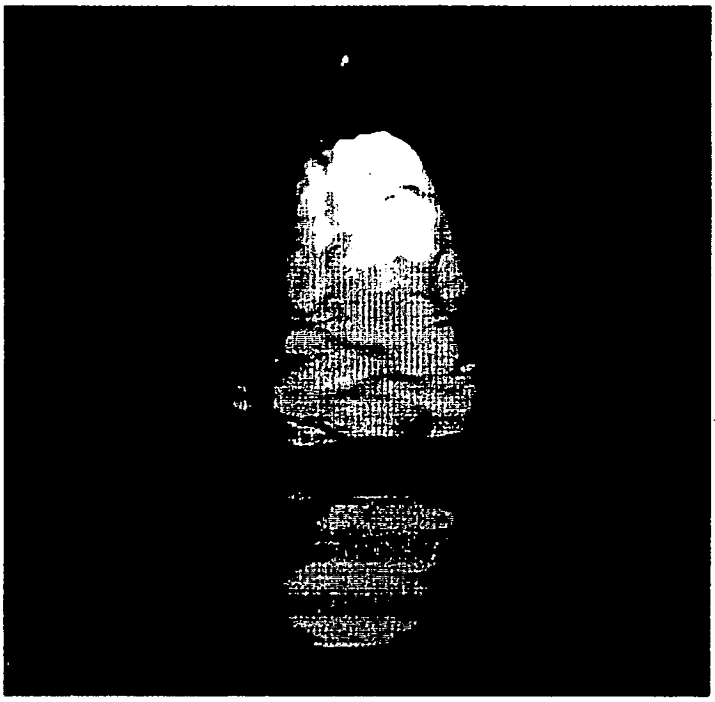

Fig.5

REFERENCES CITED IN THE DESCRIPTION

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- JP 9131345 A **[0011]**

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申请(专利权)人(译)	ALOKA CO.LTD.		
当前申请(专利权)人(译)	ALOKA CO.LTD.		
[标]发明人	MURASHITA MASARU		
发明人	MURASHITA, MASARU		
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外部链接	Espacenet		

摘要(译)

在能够形成三维超声图像的超声诊断设备中，可以显示器官的整个空腔部分而没有任何部分不可见。基于相对于对象器官发送和接收的超声波获得的三维超声图像数据被存储在存储器20中。关于所存储的数据，在二值化处理部分24中使用二值化处理部分24对每个体素的亮度值进行二值化。预定的阈值。然后，在亮度值反转部分26中进一步反转二值化亮度值。因此，在反转之前具有低亮度的器官的空腔部分具有高亮度，并且在反转之前具有高亮度的器官的壁部分，阻碍观察内腔部分现在具有低亮度。因此，可以获得待观察的空腔部分的实线表示，从而便于观察。

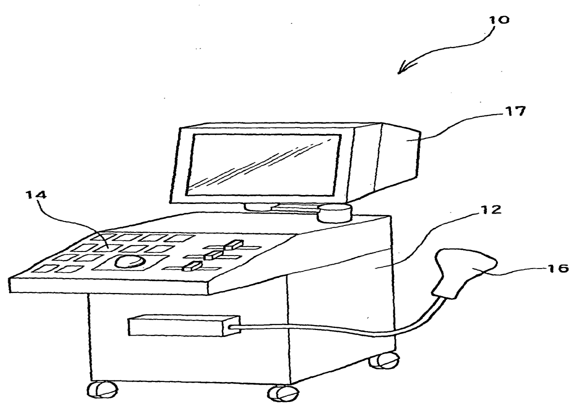

Fig. 1