



(11) **EP 2 338 419 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention
of the grant of the patent:
01.02.2017 Bulletin 2017/05

(51) Int Cl.:
A61B 8/12 (2006.01) G06T 7/00 (2017.01)

(21) Application number: **10252188.7**

(22) Date of filing: **22.12.2010**

(54) **Fast anatomical mapping using ultrasound images**

Schnelle anatomische Abbildung mit Ultraschallbildern

Cartographie anatomique rapide utilisant des images à ultrasons

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**

(30) Priority: **23.12.2009 US 646225**

(43) Date of publication of application:
29.06.2011 Bulletin 2011/26

(73) Proprietor: **Biosense Webster (Israel), Ltd.
Yokneam 20692 (IL)**

(72) Inventors:
• **Altmann, Andres Claudio
Haifa 34614 (IL)**
• **Kilim, Nahum
Haifa 35439 (IL)**
• **Goldberg, Aviva
Hadera 38505 (IL)**

(74) Representative: **Small, Gary James
Carpmaels & Ransford LLP
One Southampton Row
London WC1B 5HA (GB)**

(56) References cited:
**EP-A1- 1 750 216 EP-A2- 1 929 956
WO-A1-2005/030057 WO-A2-2005/112773
US-A- 5 682 895 US-A1- 2002 102 023
US-A1- 2003 153 823 US-B1- 6 443 894
US-B1- 6 968 299**

- **SPECHTARETAL: "Surface segmentation using
a modified ball-pivoting algorithm", IMAGE
PROCESSING, 2004. ICIP '04. 2004
INTERNATIONAL CONFERENCE ON
SINGAPORE 24-27 OCT. 2004, PISCATAWAY, NJ,
USA,IEEE, vol. 3, 24 October 2004 (2004-10-24),
pages 1931-1934, XP010786145, DOI:
DOI:10.1109/ICIP.2004.1421457 ISBN:
978-0-7803-8554-2**

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Description

FIELD OF THE INVENTION

[0001] The present invention relates generally to ultrasound imaging, and specifically to methods and systems for three-dimensional (3D) reconstruction of anatomical structures based on ultrasound images.

BACKGROUND OF THE INVENTION

[0002] A variety of devices and methods for intracardiac ultrasonic imaging are known in the art. For example, Biosense Webster Inc. (Diamond Bar, California) offers the CartoSound™ system and SoundStar™ catheter for producing 3D ultrasound images in real time. The SoundStar catheter, which is inserted through the vascular system into the heart, contains a position sensor and a phased array of ultrasound transducers. The Carto-Sound system processes the signals from the position sensor and the ultrasound transducers to generate 3D images of the heart chambers.

[0003] Several methods are known in the art for non-contact reconstruction of the endocardial surface using intracardiac ultrasonic imaging. For example, PCT International Publication WO 00/19908, describes a steerable transducer array for intracardiac ultrasonic imaging. The array forms an ultrasonic beam, which is steered in a desired direction by an active aperture. U.S. Patent 6,004,269, describes an acoustic imaging system based on an ultrasound device that is incorporated into a catheter. The ultrasound device directs ultrasonic signals toward an internal structure in the heart to create an ultrasonic image.

[0004] As another example, PCT International Publication WO 99/55233, describes a method for delineating a 3-D surface of a patient's heart. A 3-D mesh model is developed using training data, to serve as an archetypal shape for a population of patient hearts. Multiple ultrasound images of the patient's heart are taken in different image planes. Anatomical locations are manually identified in each of the images. The mesh model is rigidly aligned with the images in respect to the predefined anatomical locations.

[0005] This sort of manual assistance in delineating contours is common in methods for 3D reconstruction based on ultrasound images. For example, U.S. Patent Application Publication 2006/0241445, describes a method for modeling of an anatomical structure, in which a plurality of ultrasonic images of the anatomical structure are acquired using an ultrasonic sensor, at a respective plurality of spatial positions of the ultrasonic sensor. Location and orientation coordinates of the ultrasonic sensor are measured at each of the plurality of spatial positions. Contours-of-interest that refer to features of the anatomical structure are marked in one or more of the ultrasonic images. A three-dimensional (3D) model of the anatomical structure is constructed, based on the con-

tours-of-interest and on the measured location and orientation coordinates Document WO2005112773 A2 discloses the preambles of claim 1 and 8 and the corresponding subject-matter of claim 18.

SUMMARY OF THE DISCLOSURE

[0006] Embodiments of the present invention that are described hereinbelow provide fast, accurate methods for reconstructing 3D surfaces from collections of 2D ultrasound images.

[0007] There is therefore provided, in accordance with an embodiment of the present invention, a method according to claim 1.

[0008] It is disclosed that acquiring the plurality of the 2D images includes inserting a probe including an ultrasound imaging device into the body, and capturing the 2D images using the probe inside the body. Inserting the probe includes inserting a catheter into a heart of the subject, and wherein the volume corresponds to the interior of a chamber of the heart. Inserting the catheter typically includes positioning the catheter so that the ultrasound imaging device is in a first chamber of the heart, wherein the volume may correspond to the interior of a second chamber of the heart, other than the first chamber, such that reconstructing the outer surface includes generating a 3D map of the interior surface of the second chamber.

[0009] Typically, acquiring the plurality of the 2D images includes capturing the 2D images using an ultrasound probe including a position transducer, and registering the identified pixels includes receiving and processing signals associated with the position transducer so as to find coordinates of the probe in the 3D reference frame, and registering the identified pixels in the 3D reference frame using the coordinates.

[0010] In some embodiments, identifying the pixels in the 2D ultrasonic images includes classifying pixels corresponding to locations in the body having a low reflectance as belonging to the interior of the cavity. Typically, classifying the pixels includes setting a threshold value, and classifying the pixels having respective gray-scale values below a specified threshold as belonging to the interior of the cavity. In alternative embodiments, acquiring the two-dimensional (2D) ultrasonic images includes capturing Doppler images in which color represents flow, and wherein identifying the pixels includes classifying pixels as belonging to the interior of the cavity responsively to respective color values of the pixels.

[0011] In a disclosed embodiment, reconstructing the outer surface includes applying a ball-pivoting algorithm to the pixels in the volume. Applying the ball-pivoting algorithm may include processing the pixels with a resolution of reconstruction that varies over the volume.

[0012] There is also provided, in accordance with an embodiment of the present invention, an apparatus according to claim 8.

[0013] There is additionally provided, in accordance

with an embodiment of the present invention, a computer software product according to claim 18.

[0014] The present invention will be more fully understood from the following detailed description of the embodiments thereof, taken together with the drawings in which:

BRIEF DESCRIPTION OF THE DRAWINGS

[0015]

Fig. 1 is a schematic, pictorial illustration of a catheter-based system for ultrasonic imaging, in accordance with an embodiment of the present invention; Fig. 2 is a schematic side view of the distal end of a catheter used in the system of Fig. 1;

Fig. 3 is a schematic representation of an ultrasound image captured by a catheter, in accordance with an embodiment of the present invention;

Fig. 4 is a flow chart that schematically illustrates a method for fast anatomical mapping using ultrasound images, in accordance with an embodiment of the present invention; and

Fig. 5 is a schematic representation of a 3D map of a heart chamber produced in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

[0016] Reference is now made to Figs. 1 and 2, which schematically illustrate a catheter-based ultrasound imaging system 20, in accordance with an embodiment of the present invention. Fig. 1 is a pictorial illustration of the overall system, while Fig. 2 is a side view of the distal end of a probe, such as a catheter 28, that is used in the system. This system and catheter are shown here by way of illustration, to assist in understanding the methods of ultrasound-based 3D mapping that are described further below. These methods, however, are not limited to catheter-based ultrasonic sensing and may similarly be applied, *mutatis mutandis*, using 2D or 3D ultrasound images acquired by other types of probes, both intra- and extra-corporeal. Furthermore, these methods may be used in mapping of other anatomical cavities, not only in the heart.

[0017] As shown in Fig. 1, an operator 22, such as a physician, inserts catheter 28 into the body of a patient 26, so that the distal end of the catheter passes through the vascular system into the patient's heart 24. The catheter is connected at its proximal end to a console 34, which typically comprises a processor 38 with suitable signal processing and user interface circuits. This processor receives and processes signals from catheter 28, as described hereinbelow. Processor 38 may comprise a general-purpose computer processor, which is programmed in software to carry out the functions that are described herein. This software may be downloaded to the processor in electronic form, over a network, for ex-

ample. Alternatively or additionally, the software may be stored on tangible computer-readable storage media, such as optical, magnetic, or electronic memory media. Further additionally or alternatively, at least some of the functions of the processor may be carried out by a digital signal processor (DSP) or by dedicated or programmable hardware logic circuits.

[0018] Typically, console 34 also enables a user to observe and regulate the functions of catheter 28 and to view and edit images that are formed using the catheter. For these purposes, the console comprises a display 40 and a user interface 42.

[0019] As shown in Fig. 2, the distal end of catheter 28 comprises an ultrasound imaging device 50, which is used to produce ultrasound images of the inside of the body. Device 50 typically comprises a phased array of transducers 52, which is operated, as is known in the art, so as to capture a two-dimensional (2D) "fan" image in the plane of the scanning ultrasonic beam (referred to herein as the "beam plane" or "image plane"), which contains the longitudinal axis of the catheter. The transducers receive ultrasonic waves that are reflected from objects in the beam plane and output signals in response to the reflected waves. Typically, these signals are conveyed by wires 56 running through catheter 28 to console 34, which processes the signals in order to form and display ultrasound images and 3D maps, as described hereinbelow.

[0020] The distal end of catheter 28 further comprises a position sensor 54, which generates signals that indicate the position (location and orientation) of the catheter within the body. Based on these position signals, console 34 determines the location and orientation of each fan image captured by imaging device 50. Processor 38 is thus able to determine the coordinates of objects appearing in the fan image, as well as to register and combine multiple 2D images captured at different catheter positions.

[0021] In the pictured embodiment, system 20 uses magnetic position sensing to determine position coordinates of the distal end of catheter 28 inside heart 24. To determine the position coordinates, a driver circuit 36 in console 34 drives field generators 30 to generate magnetic fields within the body of patient 26. Typically, field generators 30 comprise coils, which are placed below the patient's torso at known positions external to the body. These coils generate magnetic fields in a predefined working volume that contains heart 24. Sensor 54, which may comprise, for example, one or more coils within the distal end of catheter 28, generates electrical signals in response to these magnetic fields. Processor 38 processes these signals in order to determine the position (location and orientation) coordinates of the distal end of catheter 28. Console 34 may use the coordinates in driving display 40 to show the location and status of the catheter.

[0022] This method of position sensing and processing is implemented in the CARTO™ system produced by Bi-

osense Webster Inc. This sort of magnetic position sensing is described in detail, for example, in U.S. Patent 6,266,551.

[0023] Other systems that combine ultrasonic imaging with magnetic position sensing are described in U.S. Patents 6,690,963, 6,716,166 and 6,773,402.

[0024] Alternatively or additionally, system 20 may comprise an automated mechanism (not shown) for maneuvering and operating catheter 28 within the body of patient 26. In such embodiments, processor 38 generates a control input for controlling the motion of the catheter based on the signals provided by the position sensing system.

[0025] Although Fig. 1 shows a particular system configuration, other system configurations may be used in alternative embodiments of the present invention. For example, the methods described hereinbelow may be applied using position transducers of other types, such as impedance-based or ultrasonic position sensors. The term "position transducer" as used herein refers to an element mounted on or in catheter 28 that causes console 34 to receive signals indicative of the coordinates of the element. The position transducer may thus comprise a receiver in the catheter, such as sensor 54, which generates a position signal to the control unit based on energy received by the transducer; or it may comprise a transmitter, emitting energy that is sensed by a receiver external to the probe. Furthermore, the methods described hereinbelow may similarly be applied in mapping and imaging applications using not only catheters, but also probes of other types, both in the heart and in other body organs and regions, as well as ultrasound probes external to the body.

[0026] Fig. 3 is a schematic representation of an ultrasound image 60 captured by catheter 28, in accordance with an embodiment of the present invention.

[0027] The image has the form of a 2D fan, with its vertex at imaging device 50. As noted above, console 34 can determine the location of the vertex and the orientation of the fan in 3D space based on the signals received from position sensor 54. Dark areas 62, 64 in the image correspond to areas, such as the heart chambers, that are filled with blood and therefore have low reflectance. Brighter areas generally represent tissue, such as the internal and external heart walls.

[0028] As noted earlier, operator 22 may manipulate catheter 28 inside heart 24 to capture images from different locations and at different orientations. The reflections that make up the images may originate not only from the heart chamber in which the distal end of the catheter is located, but also from other heart chambers and anatomical structures. Thus, for example, catheter 28 may be inserted into the right atrium (which is relatively easy to access via the vena cava) and may capture images from the right atrium of the left atrium and possibly the ventricles.

[0029] Fig. 4 is a flow chart that schematically illustrates a method for fast anatomical mapping using ultra-

sound images, in accordance with an embodiment of the present invention. At each iteration of the method, sensor 50 acquires a 2D ultrasound fan image, having the general form of image 60 (Fig. 3), at an image acquisition step 70. Image acquisition may be gated to a certain annotation point in the heart cycle (such as systole or diastole), using an electrocardiogram (ECG) monitor for synchronization, for example, or the images may alternatively be acquired continuously, without gating. Processor 38 identifies the inside of the heart chamber of interest (the blood pool area) in each 2D image acquired by the ultrasound catheter, at a cavity identification step 72. These "dark," low-reflectance areas may be identified, for example, by applying a threshold to the gray scale levels of the ultrasound image. The threshold may be set automatically or manually. Any suitable method known in the art may be used to choose the threshold automatically, such as the Otsu method, in which the threshold is chosen based on clustering of the pixel gray-scale values.

[0030] Alternatively, other ultrasound imaging modes may be used in image capture at step 70, and the method used to identify the cavity at step 72 may be adapted accordingly. For example, the 2D images may be acquired using Doppler imaging techniques, such as Color Doppler, Power Doppler or Tissue Imaging Doppler, as are known in the art. Such techniques use image color (commonly referred to as pseudo-color) to represent flow. In Color Doppler, areas of blood flow are colored in the image, while areas of tissue are not. In this case, pixels having a color value above a certain threshold may be identified as belonging to the blood pool area at step 72. On the other hand, in Tissue Imaging Doppler, areas of tissue are colored while blood is not, so that pixels having a color value below a certain threshold will be identified as belonging to the blood pool area.

[0031] Whichever imaging modality is used, processor 38 applied the threshold to transform the 2D gray-scale or color image into a binary image, at a binarization step 74. In the binary image, pixels with the value '0' are classified as belonging to areas of blood, while pixels with the value '1' belong to tissue. Other image processing operations may be applied in order to improve the precision of separation between blood and tissue separation. For example, morphological erosion and dilation may be applied in succession to remove small dark areas, which may have been misidentified as blood pool areas, within tissue regions.

[0032] Processor 38 finds the vertex location and the orientation of the captured 2D image, at an image registration step 76. As noted above, the processor computes the location and orientation coordinates on the basis of the signals output by position sensor 54. Given the vertex position and image orientation, the processor can calculate the 3D coordinates of every pixel in the binarized image in the fixed 3D reference frame of field generators 30, and thus registers the 2D image pixels in the 3D volume.

[0033] After capturing each 2D image, the operator moves the catheter tip in the heart, and the above 2D image capture and processing steps are repeated until the processor has collected a sufficient number of binary pixel values within the volume of interest, at a capture completion step 78.

[0034] Processor 38 collects the pixels with value '0' (blood) and finds the outer surface bounding these pixels, at a surface reconstruction step 80. The outer surface bounding the blood pool in a heart chamber is the inner surface of the heart wall surrounding that chamber. Thus, by finding the bounding outer surface of the blood pool the processor has, in effect, constructed a 3D map of the chamber in question. Optionally, the processor may continue acquiring 2D images while reconstructing the 3D surface and may thus refine the map progressively.

[0035] Using the blood pool in the 3D domain as the basis for surface reconstruction has the advantage of offering a fast, efficient way to overcome the problem of image segmentation. Various algorithms may be used to reconstruct the outer surface of a volume based on a collection of interior points of this sort. For example, processor 38 may apply the ball-pivoting algorithm that is described in U.S. Patent 6,968,299. This algorithm computes a triangle mesh interpolating a given point cloud by "rolling" a ball of a certain radius over the point cloud. The vertices of the triangles that are found in this way define the outer surface of the cloud.

[0036] To reduce the computational load, not all the '0' pixels are necessarily used in building the model, and processor 38 may apply different resolution levels in different areas. The above-mentioned ball-pivoting algorithm may be adapted for this sort of variable-resolution mapping by using different ball radii in different regions of the map. High resolution is typically needed only in the blood-tissue interface area (along the edge of the blood pool). This area can be identified automatically or manually in the binary images. The processor then performs high-resolution reconstruction only near the tissue boundary, and uses low resolution elsewhere. In other words, the processor uses fewer pixels from the 2D images in areas far from the tissue, and more pixels in the area of the tissue interface (typically within a thickness on the order of 1 mm).

[0037] After processor 38 has reconstructed and displayed the 3D map in the manner described above, a user may apply image editing tools, via user interface 42, for example, to cut and/or morph the model in order to correct artifacts and remove features that are not of interest.

[0038] Fig. 5 is a schematic representation of a 3D map 90 of a heart chamber, of a type that may be produced by the above method in accordance with an embodiment of the present invention. The map in this case shows the left ventricle of the heart, including parts of the pulmonary veins. This sort of map may be used for various purposes, such as serving as a starting point for an electro-anatomical map (of the type produced by the above-mentioned

CARTO system) or for segmentation of a full 3D ultrasonic or tomographic image.

[0039] It will be appreciated that the embodiments described above are cited by way of example, and that the present invention is not limited to what has been particularly shown and described hereinabove.

Claims

1. A method for three-dimensional (3D) mapping, comprising:

acquiring a plurality of two-dimensional (2D) ultrasonic images (60) of a cavity in a body of a living subject (26) using an ultrasound probe external to the body, the 2D images having different, respective positions in a 3D reference frame;

characterised by identifying in each of the 2D ultrasonic images pixels corresponding to locations within an interior of the cavity; registering the identified pixels from the plurality of the 2D images in the 3D reference frame so as to define a volume of pixels corresponding to the interior of the cavity; and reconstructing, using a processor (38), an outer surface of the volume of pixels, which represents the interior surface of the cavity, by collecting the volume of pixels and finding an outer surface bounding these pixels.

2. The method according to claim 1, wherein acquiring the plurality of the 2D images comprises capturing the 2D images using an ultrasound probe comprising a position transducer, and wherein registering the identified pixels comprises receiving and processing signals associated with the position transducer so as to find coordinates of the probe in the 3D reference frame, and registering the identified pixels in the 3D reference frame using the coordinates.
3. The method according to claim 1, wherein identifying the pixels in the 2D ultrasonic images comprises classifying pixels corresponding to locations in the body having a reflectance below a specified threshold as belonging to the interior of the cavity.
4. The method according to claim 3, wherein classifying the pixels comprises setting a threshold value, and classifying the pixels having respective gray-scale values below a specified threshold as belonging to the interior of the cavity.
5. The method according to claim 1, wherein acquiring the two-dimensional (2D) ultrasonic images comprises capturing Doppler images in which color rep-

resents flow, and wherein identifying the pixels comprises classifying pixels as belonging to the interior of the cavity responsively to respective color values of the pixels.

6. The method according to claim 1, wherein reconstructing the outer surface comprises applying a ball-pivoting algorithm to the pixels in the volume.

7. The method according to claim 6, wherein applying the ball-pivoting algorithm comprises processing the pixels with a resolution of reconstruction that varies over the volume.

8. An apparatus for three-dimensional (3D) mapping, comprising:

an ultrasound probe (28), which is configured to capture a plurality of two-dimensional (2D) ultrasonic images (60) of a cavity in a body of a living subject (26), the 2D images having different, respective positions in a 3D reference frame; and **characterised by** a processor (38), which is configured to identify in each of the 2D ultrasonic images pixels corresponding to locations within an interior of the cavity, to register the identified pixels from the plurality of the 2D images in the 3D reference frame so as to define a volume of pixels corresponding to the interior of the cavity, and to reconstruct an outer surface of the volume of pixels, which represents the interior surface of the cavity, by collecting the volume of pixels and finding an outer surface bounding these pixels.

9. The apparatus according to claim 8, wherein the ultrasound probe is configured to be inserted into the body and to capture the 2D images inside the body.

10. The apparatus according to claim 9, wherein the probe comprises a catheter adapted for insertion into a heart of the subject, wherein the catheter comprises an ultrasound imaging device.

11. The apparatus according to claim 10, wherein the catheter is adapted for insertion into the heart and so that the ultrasound imaging device is in a first chamber of the heart once inserted, and adapted to reconstruct the outer surface by generating a 3D map of an interior surface of a second chamber.

12. The apparatus according to claim 8, wherein the ultrasound probe comprises a position transducer, and wherein the processor is configured to receive and process signals associated with the position transducer so as to find coordinates of the probe in the 3D reference frame, and to register the identified pixels in the 3D reference frame using the coordinates.

13. The apparatus according to claim 8, wherein the processor is configured to classify the pixels corresponding to locations in the body having a reflectance below a specified threshold as belonging to the interior of the cavity.

14. The apparatus according to claim 8, wherein the processor is configured to set a threshold value, and to classify the pixels having respective gray-scale values below a specified threshold as belonging to the interior of the cavity.

15. The apparatus according to claim 8, wherein the two-dimensional (2D) ultrasonic images comprise Doppler images in which color represents flow, and wherein the processor is configured to classify pixels as belonging to the interior of the cavity responsively to respective color values of the pixels.

16. The apparatus according to claim 8, wherein the processor is configured to apply a ball-pivoting algorithm to the pixels in the volume in order to reconstruct the outer surface of the volume.

17. The apparatus according to claim 16, wherein the processor is configured to process the pixels with a resolution of reconstruction that varies over the volume.

18. A computer software product, comprising a computer-readable medium in which program instructions are stored, which instructions, when read by a processor, cause the processor to receive a plurality of two-dimensional (2D) ultrasonic images (60) of a cavity in a body of a living subject (26), the 2D images having different, respective positions in a 3D reference frame, to identify in each of the 2D ultrasonic images pixels corresponding to locations within an interior of the cavity, to register the identified pixels from the plurality of the 2D images in the 3D reference frame so as to define a volume of pixels corresponding to the interior of the cavity, and to reconstruct an outer surface of the volume of pixels, which represents the interior surface of the cavity, by collecting the volume of pixels and finding an outer surface bounding these pixels.

19. The product according to claim 18, adapted to capture the 2D ultrasonic images using an ultrasound imaging device in a first chamber of the heart, and to reconstruct the outer surface by generating a 3D map of an interior surface of a second chamber.

20. The product according to claim 18, wherein the 2D images are captured using an ultrasound probe comprising a position transducer, and wherein the instructions cause the processor to process signals associated with the position transducer so as to find

coordinates of the probe in the 3D reference frame, and to register the identified pixels in the 3D reference frame using the coordinates.

21. The product according to claim 18, wherein the instructions cause the processor to classify pixels corresponding to locations in the body having a reflectance below a specified threshold as belonging to the interior of the cavity.
22. The product according to claim 18, wherein the instructions cause the processor to apply a ball-pivoting algorithm to the pixels in the volume in order to reconstruct the outer surface.
23. The product according to claim 22, wherein the instructions cause the processor to process the pixels with a resolution of reconstruction that varies over the volume.

Patentansprüche

1. Verfahren zum dreidimensionalen(3D)-Abbilden, das Folgendes umfasst:

Erfassen einer Vielzahl von zweidimensionalen(2D)-Ultraschallbildern (60) einer Körperhöhle in einer lebenden Person (26) unter Verwendung einer außerhalb des Körpers befindlichen Ultraschallsonde, wobei die jeweiligen 2D-Bilder unterschiedliche Positionen in einem 3D-Referenzsystem aufweisen; **gekennzeichnet durch** das Identifizieren von Pixeln in jedem der 2D-Ultraschallbilder, die Orten innerhalb eines Innenraums der Höhle entsprechen; Registrieren der identifizierten Pixel aus der Vielzahl von 2D-Bildern in dem 3D-Referenzsystem, um somit ein Volumen aus Pixeln, das dem Innenraum der Höhle entspricht, zu definieren; und Rekonstruieren, unter Verwendung eines Prozessors (38), einer äußeren Oberfläche des Volumens aus Pixeln, das die innere Oberfläche der Höhle repräsentiert, **durch** Sammeln des Volumens aus Pixeln und Finden einer äußeren Oberfläche, die diese Pixel umrandet.

2. Verfahren nach Anspruch 1, wobei das Erfassen der Vielzahl der 2D-Bilder das Aufnehmen der 2D-Bilder unter Verwendung einer Ultraschallsonde, die einen Positionswandler umfasst, umfasst, und wobei das Registrieren der identifizierten Pixel das Empfangen und Verarbeiten von Signalen, die mit dem Positionswandler assoziiert sind, um somit Koordinaten der Sonde in dem 3D-Referenzsystem zu finden, und das Registrieren der identifizierten Pixel in dem 3D-Referenzsystem unter Verwendung der Koordinaten umfasst.

3. Verfahren nach Anspruch 1, wobei das Identifizieren der Pixel in den 2D-Ultraschallbildern das Klassifizieren von Pixeln, die Orten im Körper mit einer Reflektivität unter einer spezifizierten Schwelle entsprechen, als dem Innenraum der Höhle zugehörig umfasst.

4. Verfahren nach Anspruch 3, wobei das Klassifizieren der Pixel das Einstellen eines Schwellenwertes und Klassifizieren der Pixel, die entsprechende Grauwerte unter einer spezifizierten Schwelle aufweisen, als dem Innenraum der Höhle zugehörig umfasst.

5. Verfahren nach Anspruch 1, wobei das Erfassen der zweidimensionalen(2D)-Ultraschallbilder das Aufnehmen von Doppler-Bildern, in denen Farbe Strömung repräsentiert, umfasst und wobei das Identifizieren der Pixel, als Reaktion auf jeweilige Farbwerte der Pixel, das Klassifizieren von Pixeln als dem Innenraum der Höhle zugehörig umfasst.

6. Verfahren nach Anspruch 1, wobei das Rekonstruieren der äußeren Oberfläche das Anwenden eines Ball-Pivoting-Algorithmus auf die Pixel in dem Volumen umfasst.

7. Verfahren nach Anspruch 6, wobei das Anwenden des Ball-Pivoting-Algorithmus das Verarbeiten der Pixel mit einer Auflösung der Rekonstruktion, die über das Volumen hinweg variiert, umfasst.

8. Einrichtung zum dreidimensionalen(3D)-Abbilden, die Folgendes umfasst:

eine Ultraschallsonde (28), die ausgelegt ist zum Erfassen einer Vielzahl von zweidimensionalen(2D)-Ultraschallbildern (60) einer Körperhöhle in einer lebenden Person (26), wobei die jeweiligen 2D-Bilder unterschiedliche Positionen in einem 3D-Referenzsystem aufweisen; und **gekennzeichnet durch** einen Prozessor (38), der ausgelegt ist zum Identifizieren von Pixeln in jedem der 2D-Ultraschallbilder, die Orten innerhalb eines Innenraums der Höhle entsprechen; zum Registrieren der identifizierten Pixel aus der Vielzahl von 2D-Bildern in dem 3D-Referenzsystem, um somit ein Volumen aus Pixeln, das dem Innenraum der Höhle entspricht, zu definieren; und zum Rekonstruieren einer äußeren Oberfläche des Volumens aus Pixeln, das die innere Oberfläche der Höhle repräsentiert, **durch** Sammeln des Volumens aus Pixeln und Finden einer äußeren Oberfläche, die diese Pixel umrandet.

9. Einrichtung nach Anspruch 8, wobei die Ultraschallsonde ausgelegt ist zum Einführen in den Körper

und zum Aufnehmen der 2D-Bilder innerhalb des Körpers.

10. Einrichtung nach Anspruch 9, wobei die Sonde einen Katheter umfasst, der ausgelegt ist zum Einführen in ein Herz der Person, wobei der Katheter eine Ultraschallabbildungsvorrichtung umfasst. 5
11. Einrichtung nach Anspruch 10, wobei der Katheter ausgelegt ist zum Einführen in das Herz, sodass sich die Ultraschallabbildungsvorrichtung nach dem Einführen in einer ersten Kammer des Herzens befindet, und ausgelegt ist zum Rekonstruieren der äußeren Oberfläche durch Erzeugen einer 3D-Abbildung einer inneren Oberfläche einer zweiten Kammer. 10 15
12. Einrichtung nach Anspruch 8, wobei die Ultraschallsonde einen Positionswandler umfasst, und wobei der Prozessor ausgelegt ist zum Empfangen und Verarbeiten von Signalen, die mit dem Positionswandler assoziiert sind, um somit Koordinaten der Sonde in dem 3D-Referenzsystem zu finden, und zum Registrieren der identifizierten Pixel in dem 3D-Referenzsystem unter Verwendung der Koordinaten. 20 25
13. Einrichtung nach Anspruch 8, wobei der Prozessor ausgelegt ist zum Klassifizieren der Pixel, die Orten im Körper mit einer Reflektivität unter einer spezifizierten Schwelle entsprechen, als dem Innenraum der Höhle zugehörig. 30
14. Einrichtung nach Anspruch 8, wobei der Prozessor ausgelegt ist zum Einstellen eines Schwellenwertes und zum Klassifizieren der Pixel, die entsprechende Grauwerte unter einer spezifizierten Schwelle aufweisen, als dem Innenraum der Höhle zugehörig. 35
15. Einrichtung nach Anspruch 8, wobei die zweidimensionalen(2D)-Ultraschallbilder Doppler-Bilder umfassen, in denen Farbe Strömung repräsentiert, und wobei der Prozessor ausgelegt ist, als Reaktion auf jeweilige Farbwerte der Pixel, zum Klassifizieren von Pixeln als dem Innenraum der Höhle zugehörig. 40
16. Einrichtung nach Anspruch 8, wobei der Prozessor ausgelegt ist zum Anwenden eines Ball-Pivoting-Algorithmus auf die Pixel in dem Volumen, um die äußere Oberfläche des Volumens zu rekonstruieren. 45
17. Vorrichtung nach Anspruch 16, wobei der Prozessor ausgelegt ist zum Verarbeiten der Pixel mit einer Auflösung der Rekonstruktion, die über das Volumen hinweg variiert. 50
18. Computersoftwareprodukt, das ein computerlesbares Medium umfasst, in dem Programmanweisungen gespeichert werden, wobei die Anweisungen, 55

wenn sie von dem Prozessor gelesen werden, den Prozessor veranlassen zum Empfangen einer Vielzahl von zweidimensionalen(2D)-Ultraschallbildern (60) einer Körperhöhle in einer lebenden Person (26), wobei die jeweiligen 2D-Bilder unterschiedliche Positionen in einem 3D-Referenzsystem aufweisen; zum Identifizieren von Pixeln in jedem der 2D-Ultraschallbilder, die Orten innerhalb eines Innenraums der Höhle entsprechen; zum Registrieren der identifizierten Pixel aus der Vielzahl von 2D-Bildern in dem 3D-Referenzsystem, um somit ein Volumen aus Pixeln, das dem Innenraum der Höhle entspricht, zu definieren; und zum Rekonstruieren einer äußeren Oberfläche des Volumens aus Pixeln, das die innere Oberfläche der Höhle repräsentiert, durch Sammeln des Volumens aus Pixeln und Finden einer äußeren Oberfläche, die diese Pixel umrandet.

19. Produkt nach Anspruch 18, ausgelegt zum Aufnehmen der 2D-Ultraschallbilder unter Verwendung einer Ultraschallabbildungsvorrichtung in einer ersten Kammer des Herzens und zum Rekonstruieren der äußeren Oberfläche durch Erzeugen einer 3D-Abbildung einer inneren Oberfläche einer zweiten Kammer. 20 25
20. Produkt nach Anspruch 18, wobei die 2D-Bilder unter Verwendung einer Ultraschallsonde aufgenommen werden, die einen Positionswandler umfasst, und wobei die Anweisungen den Prozessor veranlassen zum Verarbeiten von Signalen, die mit dem Positionswandler assoziiert sind, um somit Koordinaten der Sonde in dem 3D-Referenzsystem zu finden, und zum Registrieren der identifizierten Pixel in dem 3D-Referenzsystem unter Verwendung der Koordinaten. 30 35
21. Produkt nach Anspruch 18, wobei die Anweisungen den Prozessor veranlassen zum Klassifizieren von Pixeln, die Orten im Körper mit einer Reflektivität unter einer spezifizierten Schwelle entsprechen, als dem Innenraum der Höhle zugehörig. 40
22. Produkt nach Anspruch 18, wobei die Anweisungen den Prozessor veranlassen zum Anwenden eines Ball-Pivoting-Algorithmus auf die Pixel in dem Volumen, um die äußere Oberfläche zu rekonstruieren. 45
23. Produkt nach Anspruch 22, wobei die Anweisungen den Prozessor veranlassen zum Verarbeiten der Pixel mit einer Auflösung der Rekonstruktion, die über das Volumen hinweg variiert. 50

Revendications

1. Procédé de cartographie tridimensionnelle (3D), comprenant : l'acquisition d'une pluralité d'images

- ultrasonores bidimensionnelles (2D) (60) d'une cavité à l'intérieur du corps d'un sujet vivant (26) à l'aide d'une sonde à ultrasons externe au corps, les images 2D ayant des positions respectives différentes dans une trame de référence 3D ; **caractérisé par** l'identification dans chacune des images ultrasonores 2D de pixels correspondant à des emplacements dans un intérieur de la cavité ; le repérage des pixels identifiés parmi la pluralité des images 2D dans la trame de référence 3D de façon à définir un volume de pixels correspondant à l'intérieur de la cavité ; et la reconstruction, à l'aide d'un processeur (38), d'une surface extérieure du volume de pixels, qui représente la surface intérieure de la cavité, par collecte du volume de pixels et détermination d'une surface externe délimitant ces pixels.
2. Procédé selon la revendication 1, dans lequel l'acquisition de la pluralité des images 2D comprend la capture des images 2D à l'aide d'une sonde à ultrasons comprenant un transducteur de position, et dans lequel le repérage des pixels identifiés comprend la réception et le traitement de signaux associés au transducteur de position de façon à déterminer des coordonnées de la sonde dans la trame de référence 3D, et le repérage des pixels identifiés dans la trame de référence 3D à l'aide des coordonnées.
 3. Procédé selon la revendication 1, dans lequel l'identification des pixels dans les images ultrasonores 2D comprend la classification des pixels correspondant à des emplacements dans le corps ayant une réflectance inférieure à un seuil spécifié comme appartenant à l'intérieur de la cavité.
 4. Procédé selon la revendication 3, dans lequel la classification des pixels comprend le réglage d'une valeur seuil, et la classification des pixels ayant des valeurs d'échelle de gris respectives inférieures à un seuil spécifié comme appartenant à l'intérieur de la cavité.
 5. Procédé selon la revendication 1, dans lequel l'acquisition des images ultrasonores bidimensionnelles (2D) comprend la capture d'images Doppler dans lesquelles une couleur représente un écoulement, et dans lequel l'identification des pixels comprend la classification des pixels comme appartenant à l'intérieur de la cavité en fonction des valeurs de couleurs respectives des pixels.
 6. Procédé selon la revendication 1, dans lequel la reconstruction de la surface extérieure comprend l'application d'un algorithme de la boule pivotante aux pixels contenus dans le volume.
 7. Procédé selon la revendication 6, dans lequel l'ap-
 8. Appareil de cartographie tridimensionnelle (3D), comprenant : une sonde à ultrasons (28), qui est configurée pour capturer une pluralité d'images ultrasonores bidimensionnelles (2D) (60) d'une cavité à l'intérieur du corps d'un sujet vivant (26), les images 2D ayant des positions respectives différentes dans une trame de référence 3D ; et **caractérisé par** un processeur (38), qui est configuré pour identifier dans chacune des images ultrasonores 2D des pixels correspondant à des emplacements dans un intérieur de la cavité, repérer les pixels identifiés parmi la pluralité des images 2D dans la trame de référence 3D de façon à définir un volume de pixels correspondant à l'intérieur de la cavité, et reconstruire une surface extérieure du volume de pixels, qui représente la surface intérieure de la cavité, par collecte du volume de pixels et détermination d'une surface externe délimitant ces pixels.
 9. Appareil selon la revendication 8, dans lequel la sonde à ultrasons est configurée pour être insérée dans le corps et pour capturer les images 2D à l'intérieur du corps.
 10. Appareil selon la revendication 9, dans lequel la sonde comprend un cathéter adapté pour être inséré dans le coeur du sujet, le cathéter comprenant un dispositif d'imagerie par ultrasons.
 11. Appareil selon la revendication 10, dans lequel le cathéter est adapté pour être inséré dans le coeur, de telle sorte que le dispositif d'imagerie par ultrasons se trouve dans une première chambre du coeur une fois inséré, et adapté pour reconstruire la surface extérieure par génération d'une carte 3D d'une surface intérieure d'une deuxième chambre.
 12. Appareil selon la revendication 8, dans lequel la sonde à ultrasons comprend un transducteur de position, et dans lequel le processeur est configuré pour recevoir et traiter des signaux associés au transducteur de position de façon à déterminer des coordonnées de la sonde dans la trame de référence 3D, et pour repérer les pixels identifiés dans la trame de référence 3D à l'aide des coordonnées.
 13. Appareil selon la revendication 8, dans lequel le processeur est configuré pour classer les pixels correspondant à des emplacements dans le corps ayant une réflectance inférieure à un seuil spécifié comme appartenant à l'intérieur de la cavité.
 14. Appareil selon la revendication 8, dans lequel le pro-

cesseur est configuré pour régler une valeur seuil, et pour classer les pixels ayant des valeurs d'échelle de gris respectives inférieures à un seuil spécifié comme appartenant à l'intérieur de la cavité.

15. Appareil selon la revendication 8, dans lequel les images ultrasonores bidimensionnelles (2D) comprennent des images Doppler dans lesquelles une couleur représente un écoulement, et dans lequel le processeur est configuré pour classer les pixels comme appartenant à l'intérieur de la cavité en fonction des valeurs de couleurs respectives des pixels.
16. Appareil selon la revendication 8, dans lequel le processeur est configuré pour appliquer un algorithme de la boule pivotante aux pixels contenus dans le volume afin de reconstruire la surface extérieure du volume.
17. Appareil selon la revendication 16, dans lequel le processeur est configuré pour traiter les pixels avec une résolution de reconstruction qui varie sur le volume.
18. Produit de logiciel informatique, comprenant un support lisible par ordinateur dans lequel sont stockées des instructions de programme, lesquelles instructions, lorsqu'elles sont lues par un processeur, font en sorte que le processeur reçoive une pluralité d'images ultrasonores bidimensionnelles (2D) d'une cavité à l'intérieur du corps d'un sujet vivant, les images 2D ayant des positions respectives différentes dans une trame de référence 3D, identifie dans chacune des images ultrasonores 2D des pixels correspondant à des emplacements dans un intérieur de la cavité, repère les pixels identifiés parmi la pluralité des images 2D dans la trame de référence 3D de façon à définir un volume de pixels correspondant à l'intérieur de la cavité, et reconstruit une surface extérieure du volume de pixels, qui représente la surface intérieure de la cavité, par collecte du volume de pixels et détermination d'une surface externe délimitant ces pixels.
19. Produit selon la revendication 18, adapté pour capturer les images ultrasonores 2D à l'aide d'un dispositif d'imagerie par ultrasons dans une première chambre du cœur et pour reconstruire la surface extérieure par génération d'une carte 3D d'une surface intérieure d'une deuxième chambre.
20. Produit selon la revendication 18, dans lequel les images 2D sont capturées à l'aide d'une sonde à ultrasons comprenant un transducteur de position, et dans lequel les instructions font en sorte que le processeur traite les signaux associés au transducteur de position de façon à déterminer des coordonnées de la sonde dans la trame de référence 3D, et

repère les pixels identifiés dans la trame de référence 3D à l'aide des coordonnées.

21. Produit selon la revendication 18, dans lequel les instructions font en sorte que le processeur classe les pixels correspondant à des emplacements dans le corps ayant une réflectance inférieure à un seuil spécifié comme appartenant à l'intérieur de la cavité.
22. Produit selon la revendication 18, dans lequel les instructions font en sorte que le processeur applique un algorithme de la boule pivotante aux pixels contenus dans le volume afin de reconstruire la surface extérieure.
23. Produit selon la revendication 22, dans lequel les instructions font en sorte que le processeur traite les pixels avec une résolution de reconstruction qui varie sur le volume.

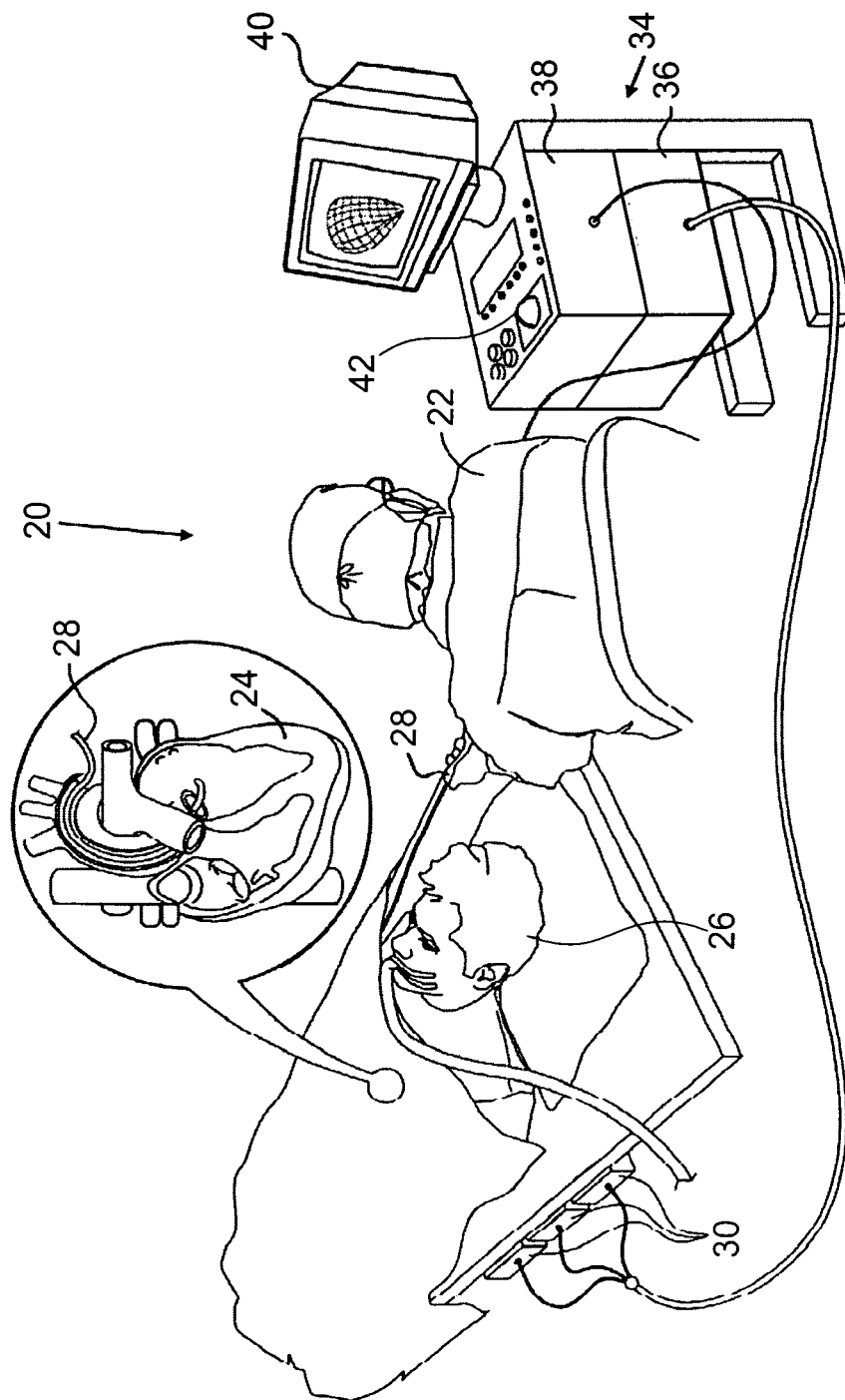


FIG. 1

FIG. 2

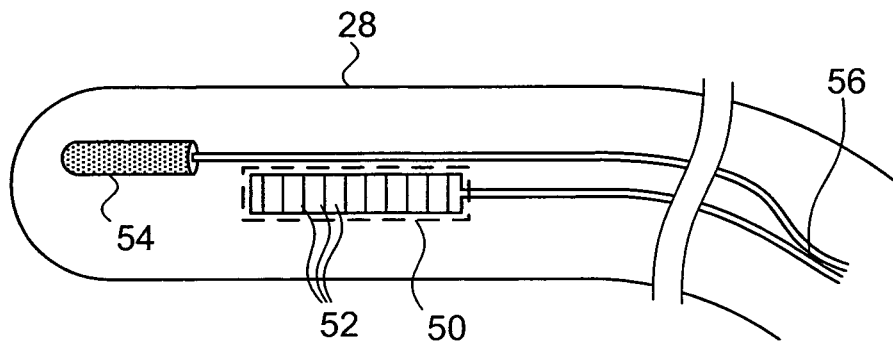


FIG. 3

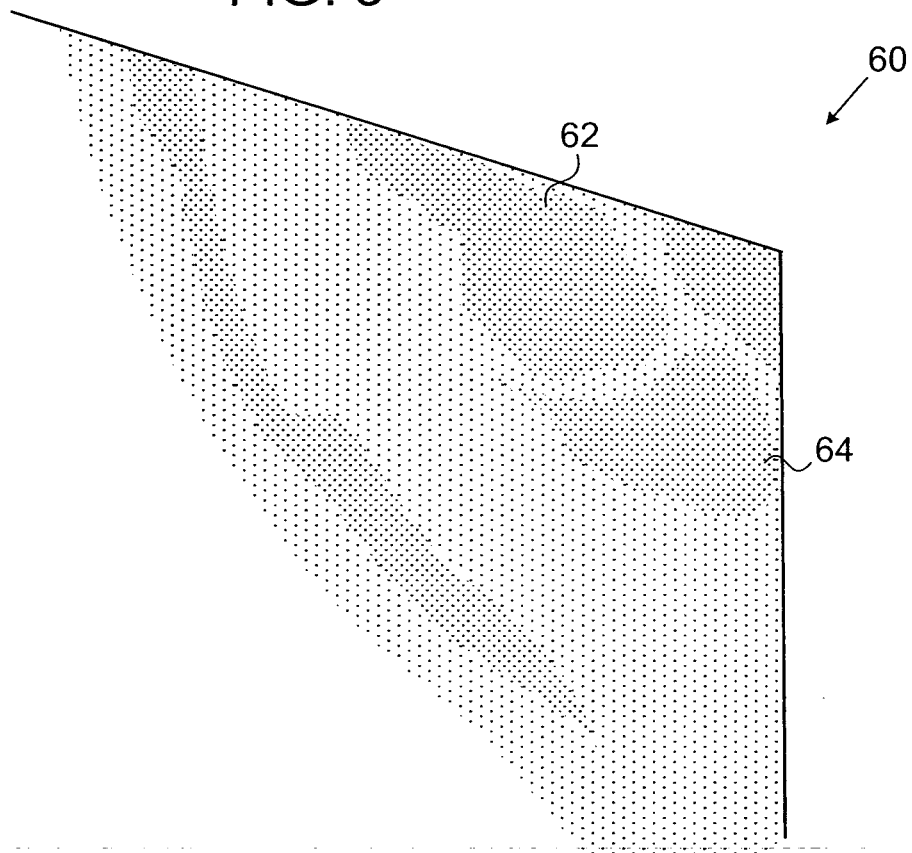


FIG. 4

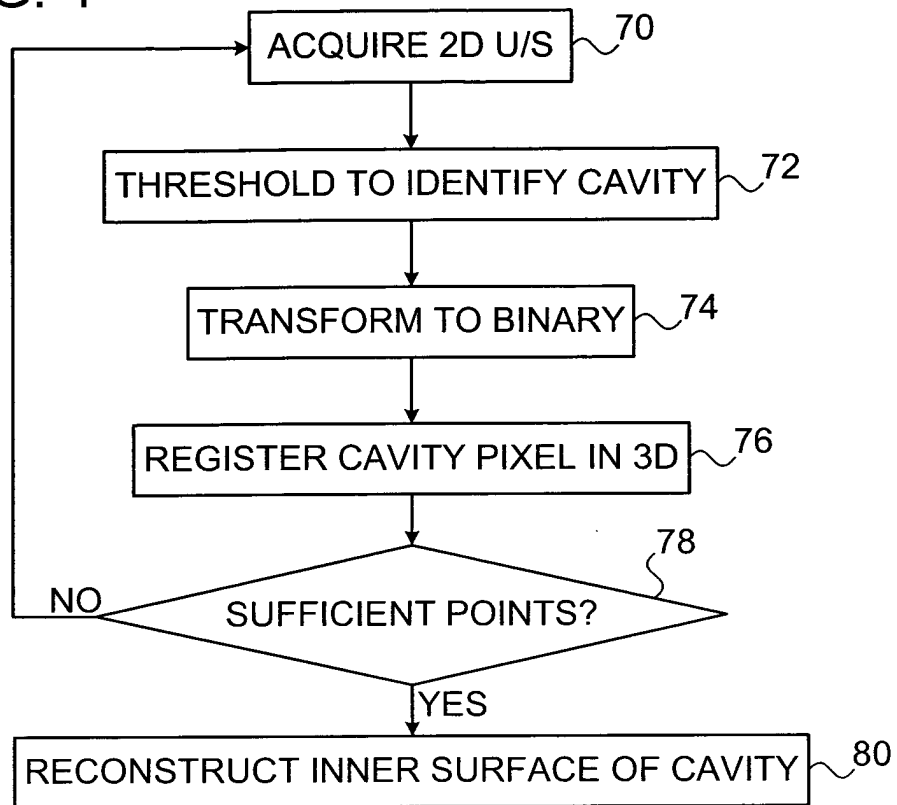
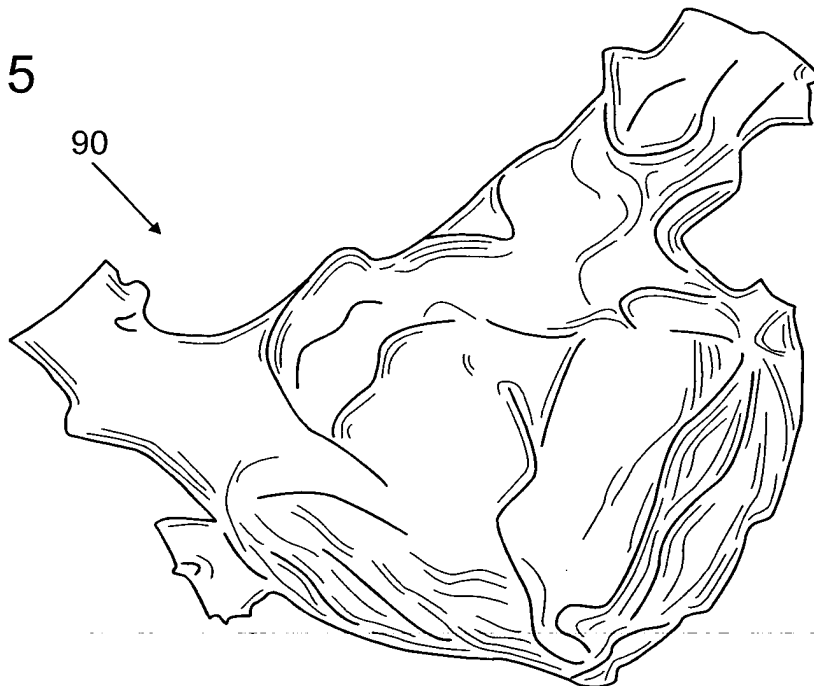


FIG. 5



REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- WO 0019908 A [0003]
- US 6004269 A [0003]
- WO 9955233 A [0004]
- US 20060241445 A [0005]
- WO 2005112773 A2 [0005]
- US 6266551 B [0022]
- US 6690963 B [0023]
- US 6716166 B [0023]
- US 6773402 B [0023]
- US 6968299 B [0035]

专利名称(译)	使用超声图像的快速解剖映射		
公开(公告)号	EP2338419B1	公开(公告)日	2017-02-01
申请号	EP2010252188	申请日	2010-12-22
[标]申请(专利权)人(译)	韦伯斯特生物官能(以色列)有限公司		
申请(专利权)人(译)	生物传感韦伯斯特 (以色列) 有限公司		
当前申请(专利权)人(译)	生物传感韦伯斯特 (以色列) 有限公司.		
[标]发明人	ALTMANN ANDRES CLAUDIO KILIM NAHUM GOLDBERG AVIVA		
发明人	ALTMANN, ANDRES CLAUDIO KILIM, NAHUM GOLDBERG, AVIVA		
IPC分类号	A61B8/12 G06T7/00		
CPC分类号	A61B8/12 A61B8/4254 A61B8/4488 A61B8/5238 A61B8/543 G06T7/593 G06T17/00 G06T2200/08 G06T2207/10132 G06T2207/30048		
优先权	12/646225 2009-12-23 US		
其他公开文献	EP2338419A1		
外部链接	Espacenet		

摘要(译)

用于三维 (3D) 映射的方法包括获取活体的体内的腔的多个二维 (2D) 超声图像, 2D图像在3D参考帧中具有不同的相应位置。在每个2D超声图像中, 识别与腔内部内的位置对应的像素。来自多个2D图像的识别的像素被配准在3D参考系中, 以便限定与腔的内部对应的体积。重建体积的外表面, 表示腔的内表面。

(15)  EUROPEAN PATENT OFFICE (11) EP 2 338 419 B1 (12) EUROPEAN PATENT SPECIFICATION (45) Date of publication and mention of the grant of the patent: 01.02.2017 Bulletin 2017/05 (21) Application number: 10252188.7 (22) Date of filing: 22.12.2010 (54) Fast anatomical mapping using ultrasound images Schnelle anatomische Abbildung mit Ultraschallbildern Cartographie anatomique rapide utilisant des images à ultrasons (84) Designated Contracting States: AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IL IT LI LV MC ME NL NO PL PT RO RS SE SI SK SM TR (43) Date of publication of application: 29.06.2011 Bulletin 2011/26 (73) Proprietor: Biosense Webster (Israel), Ltd. Yotvatem 26062 (IL) (72) Inventors: • Altmann, Andres Claudio Haifa 34614 (IL) • Kilim, Nahum Haifa 35439 (IL) • Goldberg, Aviva Hadera 35505 (IL) (74) Representative: Small, Gary James Carpaneto & Ransford LLP One Southampton Row London WC1B 5HA (GB) (56) References cited: EP-A1: 1 750 216 EP-A2: 1 929 956 WO-A: 2006/080697 WO-A2: 2006/112721 US-A: 5 682 895 US-A1: 2002 102 823 US-A1: 2003 153 823 US-B1: 6 443 954 US-B1: 6 968 299 • SPECTER ET AL. "Surface segmentation using a modified fast-pivoting algorithm", IMAGE PROCESSING, 2004, ICP '04, 2004, INTERNATIONAL CONFERENCE ON SINGAPORE 24-27 OCT. 2004, PISCATAWAY, NJ, USA, IEEE, vol. 3, 24 October 2004 (2004-10-24), pages 1331-1334, XP010766145, DOI: 10.1109/ICP.2004.1421457 ISBN: 076-0-7805-9554-2		EP 2 338 419 B1 Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 9(1) European Patent Convention) Printed by: Aviva 75017 PAKIS (FR)
---	--	---