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(54) Method and apparatus for three-dimensional image rendering of body organs

Verfahren und Vorrichtung zur Darstellung dreidimensionaler Bilder eines Körperorgans

Procédé et appareil pour le rendu d'image tridimensionnelle d'un organe du corps

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Description

FIELD OF THE INVENTION

[0001] The present invention relates generally to systems and methods for three-dimensional mapping and reconstruction, and specifically to mapping and reconstruction of the interior of body organs, such as the heart.

BACKGROUND OF THE INVENTION

[0002] Various methods of diagnostic imaging are known in the art. Methods used for imaging the heart, for example, include fluoroscopy, angiography, echocardiography, computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET) and single photon emission tomography (SPECT). Many of these methods produce three-dimensional (3D) image information, which can then be rendered for viewing in the form of parallel slices through the heart, or as a pseudo-3D display on a video monitor. In order to administer treatment, the treating physician must build a 3D picture in his or her mind based on the two-dimensional pictures that are displayed. The transposition is particularly tricky when therapy is to be administered inside the heart, such as local electrical ablation of aberrant electrical pathways, or laser myocardial revascularization.

[0003] It is also known in the art to map the heart using a mapping probe, typically a catheter, inside the heart chambers. Exemplary methods and devices for this purpose are described in U.S. Patents 5,471,982 and 5,391,199 and in PCT patent publications WO94/06349, WO96/05768 and WO97/24981. U.S. Patent 5,391,199, for example, describes a catheter that includes both electrodes for sensing cardiac electrical activity and miniature coils for determining the position of the catheter relative to an externally-applied magnetic field. Using this catheter a cardiologist can collect data from a set of sampled points in the heart within a short period of time, by measuring the electrical activity at a plurality of locations and determining the spatial coordinates of the locations. Locations of the mapping catheter within the heart can be superimposed on a 3D reconstruction of an image of the heart, such as an ultrasound image, acquired prior to or during the catheter study. Color codes are used to represent electrical activity sensed by the catheter.

[0004] U.S. Patent 5,738,096 describes methods for geometrical mapping of the endocardium based on bringing a probe into contact with multiple locations on a wall of the heart, and determining position coordinates of the probe at each of the locations. The position coordinates are combined to form a map of at least a portion of the heart. Once the position of the catheter is known, external sensors can be used to provide local physiological values of heart tissue adjacent to the tip of the catheter. For example, if the catheter incorporates a radioactive marker suitable for SPECT, local functional information can be gleaned from a SPECT image. Yet another example is determining local perfusion from Doppler-ultrasound images of the coronaries, from nuclear medicine images or from X-ray or CT angiography, and overlaying the perfusion map on the geometrical map. The image of the catheter in the perfusion map can be used to align the perfusion map and the geometrical map. Alternatively, the alignment may be carried out using fiducial marks or anatomical reference locations, either automatically or manually.

[0005] Further methods for creating a three-dimensional map of the heart based on these data are disclosed, for example, in European patent application EP 0 974 936. As indicated in that application, position coordinates (and optionally electrical activity, as well) are initially measured at about 10 to 20 points on the interior surface of the heart. These data points are generally sufficient to generate a preliminary reconstruction or map of the cardiac surface to a satisfactory quality. The preliminary map is preferably combined with data taken at additional points in order to generate a more comprehensive map.

[0006] In Schilling et al.'s "Mapping and Ablation of Ventricular Tachycardia with the Aid of a Non-contact Mapping System", published in Heart vol. 81, no. 6, June 1999 (1999-06), pages 570-575, XP002284986, there is disclosed a system and associated method of mapping heart chambers by using a conventional probe to construct a three-dimensional computer model of the endocardium, followed by detection of electrical activity with a multi electrode array and superimposing colour maps corresponding to the electrical activity on to the 3-D model. A final step is to navigate another catheter to critical sites to perform a procedure, such as ablation of those target sites.

[0007] In Faber et al.'s "Three-dimensional Displays of Left Ventricular Epicardial Surface from Standard Cardiac SPECT Perfusion Quantification Techniques", published in Journal of Nuclear Medicine, vol. 36, no. 4, April 1995 (1995-04), pages 697-703, XP008031998, there is disclosed a method for generating a left ventricular epicardial surface from SPECT perfusion tomograms. The method involves fitting averaged contours, such as circles perpendicular to a long-axis, to points obtained from perfusion quantification. The averaged radii are then converted to Cartesian coordinates and a 3-D map is generated to display the perfusion by colour coding.

SUMMARY OF THE INVENTION

[0008] It is an object of some aspects of the present invention to provide improved methods and apparatus for mapping and visualization of internal body structures, and particularly of the heart.

[0009] It is a further object of some aspects of the present invention to provide improved methods and apparatus for administering local treatment of pathological conditions within the heart.

[0010] In preferred embodiments of the present invention, a position-sensing catheter is used to generate a 3D geometrical map of the internal surface of a heart chamber of a subject. A 3D diagnostic image of the heart is captured in conjunction with generating the 3D map, typically either before or concurrently with the mapping. The image and map are brought into mutual registration, and diagnostic information from the image, such as perfusion information, is then marked on the 3D map, preferably in the form of color coding. Based on the combined diagnostic and geometrical information, a physician operating the catheter is able to identify and visualize areas of the heart that are in need of treatment, due to low perfusion, for example. The physician preferably uses the catheter to apply a local invasive therapy, such as laser revascularization, to specific points that are located using the color-coded 3D map. Alternatively, a local diagnostic technique, such as a biopsy, may be performed at such specific points.

[0011] There is provided, in accordance with a preferred embodiment of the present invention, apparatus for mapping a structure in a body of a subject, as defined in the accompanying claim 1.

[0012] Further embodiments are set out in the accompanying dependent claims.

[0013] The present invention will be more fully understood from the following detailed description of the preferred embodiments thereof, taken together with the drawings in which:

BRIEF DESCRIPTION OF THE DRAWINGS

[0014]

Fig. 1 is a schematic, pictorial illustration of a system for imaging, mapping and treatment of the heart, in accordance with a preferred embodiment of the present invention;

Fig. 2 is a flow chart that schematically illustrates a method for imaging, mapping and treating the heart, in accordance with a preferred embodiment of the present invention;

Fig. 3 is a schematic representation of a map of a chamber of the heart, in accordance with a preferred embodiment of the present invention;

Fig. 4 is a simplified geometrical representation of the map of Fig. 3, showing coordinates used in registering the map with an image of the heart, in accordance with a preferred embodiment of the present invention;

Fig. 5 is a schematic, exploded view of a 3D image of the heart, represented as a stack of parallel slices through the heart, in accordance with a preferred embodiment of the present invention;

Fig. 6 shows the slices of Fig. 5 arrayed side-by-side, illustrating registration of the slices with the 3D map of Fig. 3, in accordance with a preferred embodiment of the present invention; and

Fig. 7 is a schematic representation of the map of Fig. 3, after coloring of the map with diagnostic information from the image of Figs. 5 and 6, in accordance with a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0015] Fig. 1 is a schematic, pictorial illustration of a system 20 for three-dimensional geometrical mapping, imaging and treatment of a heart 24 of a subject 26, in accordance with a preferred embodiment of the present invention. System 20 comprises an elongate probe, preferably a catheter 30, which is inserted by a user 22 through a vein or artery of the subject into a chamber of the heart.

[0016] Catheter 30 preferably comprises at least one position sensor (not shown in the figures), most preferably located near the catheter's distal tip. The position sensor preferably comprises an electromagnetic sensor, which is mounted within the catheter by any suitable method, for example, using polyurethane glue or the like. The sensor is electrically connected to an electromagnetic sensor cable, which extends through the catheter body and into a control handle of the catheter. In the control handle, the wires of the sensor cable are connected to a circuit board (not shown), which amplifies the signals received from the electromagnetic sensor and transmits them to a computer housed in a console 34, in a form understandable to the computer. Because the catheter is designed for single use only, the circuit board preferably contains an EPROM chip, which shuts down the circuit board after the catheter has been used. This prevents the catheter, or at least the electromagnetic sensor, from being used twice. ;

[0017] To use the electromagnetic sensor, subject 26 is placed in a magnetic field generated, for example, by situating under the patient a pad containing field generator coils 28 for generating a magnetic field, driven by driver circuits 32. A reference electromagnetic sensor (not shown) is preferably fixed relative to the patient, e.g., taped to the patient's back, and catheter 30 containing its sensor is advanced into heart 24. The sensor preferably comprises three small coils, which in the magnetic field generate weak electrical signals indicative of their position in the magnetic field. Signals generated by both the fixed reference sensor and by the sensor in the heart are amplified and transmitted to console 34, which analyzes the signals and then displays the results on a monitor 36. By this method, the precise location of the sensor in the catheter relative to the reference sensor can be ascertained and visually displayed. The sensors can also detect displacement of the catheter that is caused by contraction of the heart muscle.

[0018] Suitable electromagnetic sensors for the purposes of the present invention are described, for example, in the above-mentioned U.S. Patent 5,391,199 and PCT patent publication WO 96/05768. A preferred electromagnetic mapping sensor is manufactured by Biosense Ltd. (Tirat Hacarmel, Israel) and marketed under the trade designation NOGA. Some of the mapping features of catheter 30 and system 20 are implemented in the NOGA-STAR catheter marketed by Biosense Webster, Inc., and in the Biosense-NOGA system, also marketed by Biosense Webster, Inc. Further aspects of the design of catheter 30 and of system 20 generally are described in EP-A-1 125 549.

[0019] Using such sensors, system 20 achieves continuous generation of six dimensions of position and orientation information with respect to catheter 30. Alternatively, the sensors used in catheter 20 may comprise other types of position and/or coordinate sensors, as described, for example, in U.S. Patent 5,391,199, 5,443,489 or 5,515,853, or in PCT publication WO 94/04938 or WO 99/05971, or substantially any other suitable type of position/coordinate sensing device known in the art.

[0020] As noted above, catheter 30 is coupled to console 34, which enables the user to observe and regulate the functions of the catheter. Console 34 includes a processor, preferably a computer with appropriate signal processing circuits (which are typically contained inside a housing of the computer). The processor is coupled to drive display 36. User 22 brings the distal tip of catheter 30 into contact with multiple points on the endocardial surface of heart 24, and the position coordinates are recorded at each point. The information derived from this analysis is used to reconstruct a three-dimensional geometrical map 38 of the endocardial surface of heart 24.

[0021] System 20 also comprises a diagnostic imaging unit 48, such as an echo Doppler unit, SPECT, PET, MRI, CT or other imaging unit known in the art. Unit 48 is used to capture a 3D diagnostic image of heart 24, preferably while user 22 is mapping the heart using catheter 30. Alternatively, the diagnostic image is captured before beginning the mapping, and unit 48 may, in this case, be separate from the other elements of system 20. Diagnostic data from the image captured by unit 48 are superimposed on map 38, using methods described hereinbelow. Depending on the type and configuration of unit 48, a wide range of different diagnostic data may be represented in the image, such as perfusion, metabolic factors, uptake of markers, heart wall motion or thickness, and/or other anatomical or electrical properties, as are known in the art. The image can also be timed to represent different phases in the heart cycle.

[0022] Typically, system 20 includes other elements, some of which are not shown in the figures for the sake of simplicity. In the present embodiment, the system preferably includes a laser console 49, which is used in performing direct myocardial revascularization, as described, for example, in PCT patent application PCT/IL97/00011 and in U.S. patent application 09/109,820, which published as US 6,171,303. Console 49 injects laser energy into a suitable waveguide (not shown) within catheter 30. The waveguide conveys the energy to the distal tip of the catheter, where it is applied to revascularize areas of the myocardium suffering from low perfusion. Alternatively, the system may include other therapeutic elements, as are known in the art, particularly elements for delivering local treatment in the heart, such as a radio-frequency driver coupled to an ablation electrode on catheter 30; an ultrasound generator coupled to high-power transducer in the catheter, for ultrasonic ablation of the endocardium; or a supply of a therapeutic agent, such as growth factors for angiogenesis, coupled to an injection needle in the catheter. Still further alternatively, the system may include invasive diagnostic elements, such as biopsy forceps that are operated through catheter 30.

[0023] Other elements that may be comprised in system 20 are described, for example, in EP-A-0 974 936.

[0024] Typically, system 20 includes an ECG monitor (not shown), coupled to receive signals from one or more body surface electrodes, so as to provide an ECG synchronization signal to console 34. As mentioned above, the system preferably also includes a reference position sensor, either on an externally-applied reference patch attached to the exterior of the patient's body, or on an internally-placed catheter, which is inserted into heart 24 and maintained in a fixed position relative to the heart. By comparing the position of catheter 30 to that of the reference catheter, the coordinates of catheter 30 are accurately determined relative to the heart, irrespective of heart motion. Alternatively, any other suitable method may be used to compensate for heart motion.

[0025] Fig. 2 is a flow chart that schematically illustrates a method for imaging, mapping and treatment of heart 24 using system 20, in accordance with a preferred embodiment of the present invention. At an imaging step 50, a diagnostic image of heart 24, such as a SPECT image, is captured. Preferably, although not necessarily, the image is captured while catheter 30 is already located inside the heart. The catheter is used to generate geometrical map 38, at a mapping step 52. Suitable mapping techniques for this purpose are described in the above-mentioned U.S. Patent 5,738,096.

The above-mentioned European patent application EP 0 974 936 describes accurate methods for creating the map itself based on the data gathered using catheter 30. The image captured at step 50 and the map created at step 52 are then registered one with the other, at a registration step 54.

[0026] Figs. 3 and 4 are schematic representations of map 38 generated by system 20 at step 52, illustrating a method used at registration step 54, in accordance with a preferred embodiment of the present invention. Fig. 3 is a wire frame rendition of the map, representing the left ventricle of heart 24. For the purposes of step 54, a longitudinal axis 72 is drawn through the map, passing through an apex 74 of the ventricle. Preferably, the axis and apex are found automatically by console 34. Alternatively or additionally, these or other features of the map are identified manually by user 22.

[0027] Fig. 4 is a simplified geometrical representation of a surface 80 of map 38, generated for the purpose of registration with a diagnostic image of heart 24. Surface 80 corresponds to an approximate locus of the endocardium of the heart, as determined from map 38. A coordinate system is defined in which each point 82 on surface 80 is represented by a distance R from apex 74 and an angle α relative to a downward direction 84 (i.e., the direction pointing toward the feet of subject 26).

[0028] In order to register the diagnostic image with map 38, axis 72 and apex 74 are identified in the image, as well, and are aligned with the axis and apex of the map. The identification is preferably automatic but may, alternatively or additionally, be carried out or assisted by user 22. Other landmarks and/or fiducial marks in the heart can also be used in performing the alignment. The scale of the image is adjusted so that its dimensions match those of the map as closely as possible. For many types of diagnostic images, such as perfusion maps, the resolution of the diagnostic information is low, so that imprecision of as much as 10 mm in mutual registration can be tolerated. When higher resolution is required, the registration of the diagnostic image with the geometrical map may be improved using methods of automatic registration such as those described in Appendix A. These methods are optional and are not essential to the present invention.

[0029] Fig. 5 is a schematic, exploded view of a 3D diagnostic image 90 of heart 24, following registration of the 3D image with geometrical map 38, in accordance with a preferred embodiment of the present invention. This view is generated at a bullseye rendition step 56 in the method of Fig. 2. The bullseye rendition of image 90 comprises a stack of parallel slices 92, which are perpendicular to axis 72. The slices are preferably taken at a fixed slice increment one from another along the axis. Each slice shows a section 94 of image 90, at a distance R from apex 74 that is determined by the slice number.

[0030] Fig. 6 shows slices 92 of image 90 arrayed side-by-side, illustrating extraction of diagnostic data from the slices for application to map 38, in accordance with a preferred embodiment of the present invention. Referring, for example, to slice number 5, sectional image 94 comprises three essential parts: an inner region 100, showing the inside of the ventricle; a wall region 102, showing the myocardium; and an outer region 104, external to the heart. The diagnostic information of interest is in region 102. Assuming image 90 to be a SPECT image, showing perfusion in the heart wall, for example, region 102 will typically have the highest value of perfusion.

[0031] At a coloration transfer step 58, the diagnostic information from each slice 92 is transferred to map 38. Each slice has a known value of distance R from apex 74. For each angle α within the slice, point 82 on surface 80 of the map (Fig. 4) is assumed to be the point at that angle that is located radially in the middle of region 102. In the case that image 90 is a perfusion image, point 82 is simply taken to be the point of highest perfusion at the given angle. In other imaging modalities, finding region 102 is, for the most part, similarly straightforward. The value of the diagnostic data at each point 82 is preferably represented as a color applied to the corresponding region of map 38.

[0032] Fig. 7 is a schematic representation of a colored geometrical map 110, as produced at step 58, in accordance with a preferred embodiment of the present invention. Because of the limited ability of a line drawing to convey qualities of a color image, only two different color regions appear on map 110: a well-perfused region 112, and an ischemic region 114. Preferably, the ischemic region has a darker or "cooler" color than the well-perfused region. In actual applications, in which display 36 comprises a color monitor, a broad range of different colors is used in map 110 to describe different levels of perfusion or of other diagnostic qualities.

[0033] Preferably, system 20 is operated by user 22 to carry out an invasive therapeutic procedure, guided by map 110, at a therapeutic step 60. In the present example, laser console 49 is operated to irradiate ischemic region 114 via catheter 30 with high-intensity laser radiation, as described in the above-mentioned PCT patent application PCT/IL97/00011. The laser creates revascularization channels in the myocardium, which are marked by system 20 with spots 116 on map 110. The combination of the imaging, mapping and therapeutic modalities enables the user to concentrate the treatment in the region of heart 24 that is known to need it, and to ensure that the region is fully covered. Other local therapeutic and diagnostic procedures can similarly benefit from the guidance provided by map 110.

[0034] Although preferred embodiments are described hereinabove with reference to heart 24, the principles of the present invention may similarly be applied to imaging, mapping and treatment of other organs and body structures. It will thus be appreciated that the preferred 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. Rather, the scope of the present invention includes both combinations and subcombinations of the various features described hereinabove, as well as variations and modifications thereof which would occur to persons skilled in the art upon reading the foregoing description and which are not disclosed in the prior art.

APPENDIX A

[0035] This appendix provides details of step 54 in the method of Fig. 2, in which two 3D representations, *P* and *Q*, of a chamber of heart 24 are brought into mutual registration. To begin, a rough estimate is found for the transformation between *P* and *Q*, either manually, or using the principle axis of a bounding ellipsoid or by principle component decomposition. The bounding ellipsoid technique is further described in the above-mentioned European patent application EP 0 974 936

[0036] Fine registration between *P* and *Q* is then preferably found using a variation of the Iterative Closest Point (ICP) algorithm. This algorithm is described by Besl and McKay in "A Method for Registration of 3D Shapes," published in IEEE Transactions on Pattern Analysis and Machine Intelligence 14(2):239-256 (1992). The following steps are repeated until convergence:

1. Nearest point search: For each point p in P find the closest point q on Q. One can take a subset of points of P to improve computation speed. Similarly, all points of Q can be covered, too, to ensure robustness.
2. Compute registration: Evaluate a transformation T that minimizes the sum of squared distances between pairs of closest points (p,q). The transformation is preferably either rigid, similarity, affine or projective as described below.
3. Transform: Apply the transformation T to all points in P.

[0037] Given two surfaces, *P* and *Q,* and two sets of points, $\{p_i \in P\}_{i=1}^{n}$, $\{q_i \in Q\}_{i=1}^{n}$, step 2 of this algorithm seeks a transformation, *T,* from a family of transformations (according to the possible families described below) that minimizes the mean square error, ε, between the corresponding sets:

$$\varepsilon^2 = \frac{1}{n}\sum_{i=1}^{n}\left\|q_i - T(p_i)\right\|^2$$

Affine and Projective Transformations

[0038] For affine transformations, defined as *T*(*p*) = *Ap* + *t,* $A = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{21} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix}$ is a 3 x 3 matrix, and $t = \begin{pmatrix} t_1 \\ t_2 \\ t_3 \end{pmatrix}$ = is a translation vector. We must minimize $\varepsilon^2 = \frac{1}{n}\sum_{i=1}^{n}\left\|q_i - (Ap_i + t)\right\|^2$. Denoting $p_i = \begin{pmatrix} x_{i1} \\ x_{i2} \\ x_{i3} \end{pmatrix}$, and $q_i = \begin{pmatrix} y_{i1} \\ y_{i2} \\ y_{i3} \end{pmatrix}$, we have three systems of equations:

$$\underbrace{\begin{pmatrix} x_{11} & x_{12} & x_{13} & 1 \\ x_{21} & x_{22} & x_{23} & 1 \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & x_{n3} & 1 \end{pmatrix}}_{X} \underbrace{\begin{pmatrix} a_{j1} \\ a_{j2} \\ a_{j3} \\ t_j \end{pmatrix}}_{a_j} = \underbrace{\begin{pmatrix} y_{1j} \\ y_{2j} \\ \vdots \\ y_{nj} \end{pmatrix}}_{y_j} \qquad j = 1,2,3$$

[0039] Let a singular value decomposition of X be $X = UDV^T$. It then follows that $a_j = VDU^T y_j$

[0040] Projective transformations are evaluated in a similar way to the affine case.

Similarity and Rigid Transformation

[0041] Whereas in affine transforms triangles are transformed to triangles, similarity transformations preserve proportions. We seek a scaling factor, c, a 3×3 rotation matrix, R, and a 3-dimensional translation vector, t, such that $T(p) = cRp + t$, wherein the error $\varepsilon^2(R, T, c) = \frac{1}{n}\sum_{i=1}^{n} \left\| q_i - (cRp_i + t) \right\|^2$ is minimized.

[0042] A suitable method for finding the desired similarity transform is described by Umeyama, in "Least-Squares Estimation of Transformation Parameters Between Two Point Patterns," published in IEEE Transactions on Pattern Analysis and Machine Intelligence, 13(4): 376-380 (1991), which is incorporated herein by reference. Define the center of mass of both P and Q:

$$\mu_p = \frac{1}{n}\sum_{i=1}^{n} p_i$$

$$\mu_q = \frac{1}{n}\sum_{i=1}^{n} q_i$$

[0043] Then define the variance of the points on both P and Q:

$$\sigma_p^2 = \frac{1}{n}\sum_{i=1}^{n} \left\| p_i - \mu_p \right\|^2$$

$$\sigma_q^2 = \frac{1}{n}\sum_{i=1}^{n} \left\| q_i - \mu_q \right\|^2$$

[0044] The covariance matrix between the two surfaces is

$$\Sigma_{pq} = \frac{1}{n}\sum_{i=1}^{n} (q_i - \mu_q)(p_i - \mu_p)^T.$$

[0045] Let a singular value decomposition of Σ_{pq} be $\Sigma_{pq} = UDV^T$, and

$$S = \begin{cases} I & if\ \det(U)\det(V) = 1 \\ diag(1,1,-1) & if\ \det(U)\det(V) = -1 \end{cases}$$

[0046] The rotation, translation and scaling of the transformation are then given by:

$$R = USV^{\mathrm{T}}$$

$$t = \mu_q - cR\mu_p$$

$$c = \frac{1}{\sigma_p^2} trace(DS)$$

wherein the trace of a matrix is the sum of its diagonal elements.

[0047] In the case of rigid transformation no scaling is applied, so that $c = 1$.

Claims

1. Apparatus for mapping a structure (24) in a body of a subject (26), comprising:

    an imaging device (48), adapted to capture a three-dimensional (3D) image (90) of the structure comprising diagnostic information;
    a probe (30), adapted to be inserted into the structure (24), so as to generate a 3D geometrical map (38) of the structure;
    a processor (34), coupled to the probe (30) and the imaging device (48), and adapted to register the image (90) with the map (38), such that each of a plurality of image points (82) in the image is identified with a corresponding map point in the map; and
    a display (36), coupled to be driven by the processor (34) to display the map (38), such that the diagnostic information associated with each of the image points (82) is displayed at the corresponding map point,
    wherein the processor (34) is adapted to:

        register (54) the image (90) with the map (38) by applying a transformation to at least one of the image and the map so that following the transformation, the image and the map have a common axis (72) and a common scale,
        divide the image into a plurality of parallel planar slices (92), perpendicular to the axis (72) and mutually spaced along the axis, wherein the plurality of image points (82) are located in the slices, and
        find an axial coordinate of each of the slices (92) and an angular coordinate of each of the image points (82) located in each of the slices, and to identify each of the image points with the map point having the same axial and angular coordinates.

2. Apparatus of claim 1, wherein, when the structure (24) comprises a wall (102) defining a cavity (100), the processor (34) is adapted to identify each of the image points (82) with the map point by finding, at the axial and the angular coordinate, the image point (82) that is within a section of the wall (102).

3. Apparatus of claim 1 or claim 2, which is adapted to provide a map (38) colored to reflect the diagnostic information.

4. Apparatus of any one of claims 1 to 3, wherein the diagnostic information:

    is related to blood flow in the structure (24);
    comprises local perfusion data;

comprises metabolic data;
is related to uptake of a substance in tissue of the structure (24); or
is related to motion of the structure (24).

5. Apparatus of any one of claims 1 to 4, wherein, to generate (52) the geometrical map (38), the probe (30) is adapted to be brought into contact with the structure (24) at a multiplicity of locations on the structure, and the processor (34) is adapted to record position coordinates of the probe at the locations.

6. Apparatus of claim 5, wherein the probe (30) comprises a position sensor for use in determining the position coordinates.

7. Apparatus of any one of claims 1 to 6, wherein the structure comprises a heart (24) of the subject (26), and wherein the geometrical map (38) comprises a map of an endocardial surface in a ventricle of the heart.

8. Apparatus of any one of claims 1 to 7, and comprising a medical instrument adapted to perform a medical procedure on the structure (24) guided by the diagnostic information displayed on the map (38).

9. Apparatus of claim 8, wherein the medical instrument is contained in the probe (30), which is adapted to be used to perform the procedure locally at locations selected on the geometrical map (38).

10. Apparatus of claim 9, wherein the processor (34) is adapted to mark on the geometrical map (38) the locations at which the procedure was performed.

11. Apparatus of any one of claims 8 to 10 for carrying out therapeutic procedure.

12. Apparatus of claim 11, wherein the diagnostic information relates to local blood flow in the structure, for carrying out a therapeutic procedure for improving the local blood flow.

13. Apparatus of any one of claims 8 to 10 for carrying out a diagnostic procedure.

Patentansprüche

1. Vorrichtung zum Abbilden einer Struktur (24) im Körper einer Person (26), die Folgendes umfasst:

eine Bildgebungseinrichtung (48), die dafür ausgelegt ist, ein dreidimensionales Bild (3D-Bild) (90) der Struktur, das diagnostische Informationen enthält, aufzunehmen;
eine Sonde (30), die dafür ausgelegt ist, in die Struktur (24) eingesetzt zu werden, um eine dreidimensionale geometrische Karte (38) der Struktur zu erzeugen;
einen Prozessor (34), der mit der Sonde (30) und mit der Bildgebungseinrichtung (48) gekoppelt ist und dafür ausgelegt ist, das Bild (90) auf die Karte (38) auszurichten, derart, dass jeder von mehreren Bildpunkten (82) in dem Bild mit einem entsprechenden Kartenpunkt in der Karte identifiziert wird; und
eine Anzeige (36), die so angeschlossen ist, dass sie durch den Prozessor (34) angesteuert wird, um die Karte (38) anzuzeigen, derart, dass die jedem der Bildpunkte (82) zugeordneten diagnostischen Informationen bei dem entsprechenden Kartenpunkt angezeigt werden,
wobei der Prozessor (34) dafür ausgelegt ist:

das Bild (90) auf die Karte (38) durch Anwenden einer Transformation auf das Bild und/oder auf die Karte auszurichten (54), so dass nach der Transformation das Bild und die Karte eine gemeinsame Achse (72) und einen gemeinsamen Maßstab haben,
das Bild in mehrere parallele, ebene Streifen (92), die zu der Achse (72) senkrecht sind und längs der Achse voneinander beabstandet sind, zu unterteilen, wobei sich die mehreren Bildpunkte (82) in den Streifen befinden, und
eine axiale Koordinate jedes der Streifen (92) und eine Winkelkoordinate jedes der Bildpunkte (82), die sich in jedem der Streifen befinden, zu ermitteln und jeden der Bildpunkte mit dem Kartenpunkt, der die gleiche axiale Koordinate und die gleiche Winkelkoordinate besitzt, zu identifizieren.

2. Vorrichtung nach Anspruch 1, wobei der Prozessor (34) dafür ausgelegt ist, dann, wenn die Struktur (24) eine einen

Hohlraum (100) definierende Wand (102) aufweist, jeden der Bildpunkte (82) mit dem Kartenpunkt dadurch zu identifizieren, dass bei der axialen Koordinate und bei der Winkelkoordinate der Bildpunkt (82) ermittelt wird, der sich in einem Abschnitt der Wand (102) befindet.

3. Vorrichtung nach Anspruch 1 oder Anspruch 2, die dafür ausgelegt ist, eine eingefärbte Karte (38) bereitzustellen, um die diagnostischen Informationen wiederzugeben.

4. Vorrichtung nach einem der Ansprüche 1 bis 3, wobei die diagnostischen Informationen:

auf den Blutfluss in der Struktur (24) bezogen sind;
lokale Perfusionsdaten enthalten;
Stoffwechseldaten enthalten;
auf die Aufnahme einer Substanz im Gewebe der Struktur (24) bezogen sind; oder
auf eine Bewegung der Struktur (24) bezogen sind.

5. Vorrichtung nach einem der Ansprüche 1 bis 4, wobei die Sonde (30), um die geometrische Karte (38) zu erzeugen (52), dafür ausgelegt ist, an mehreren Orten auf der Struktur mit der Struktur (24) in Kontakt gebracht zu werden, und der Prozessor (34) dafür ausgelegt ist, Positionskoordinaten der Sonde an den Orten aufzuzeichnen.

6. Vorrichtung nach Anspruch 5, wobei die Sonde (30) einen Positionssensor zur Verwendung bei der Bestimmung der Positionskoordinaten umfasst.

7. Vorrichtung nach einem der Ansprüche 1 bis 6, wobei die Struktur ein Herz (24) der Person (26) umfasst und wobei die geometrische Karte (38) eine Karte einer endokardialen Oberfläche in einem Ventrikel des Herzens umfasst.

8. Vorrichtung nach einem der Ansprüche 1 bis 7, die ein medizinisches Instrument umfasst, das dafür ausgelegt ist, an der Struktur (24) eine medizinische Prozedur auszuführen, die durch die auf der Karte (38) angezeigten diagnostischen Informationen angeleitet wird.

9. Vorrichtung nach Anspruch 8, wobei das medizinische Instrument in der Sonde (30) enthalten ist, die dafür ausgelegt ist, zur lokalen Ausführung der Prozedur an Orten, die auf der geometrischen Karte (38) ausgewählt werden, verwendet zu werden.

10. Vorrichtung nach Anspruch 9, wobei der Prozessor (34) dafür ausgelegt ist, auf der geometrischen Karte (38) die Orte zu markieren, an denen die Prozedur ausgeführt wurde.

11. Vorrichtung nach einem der Ansprüche 8 bis 10 zum Ausführen einer therapeutischen Prozedur.

12. Vorrichtung nach Anspruch 11, wobei sich die diagnostischen Informationen auf einen lokalen Blutfluss in der Struktur beziehen, um eine therapeutische Prozedur zum Verbessern des lokalen Blutflusses auszuführen.

13. Vorrichtung nach einem der Ansprüche 8 bis 10 zum Ausführen einer diagnostischen Prozedur.

Revendications

1. Procédé de mappage d'une structure (24) dans le corps d'un sujet (26), comprenant :

un dispositif d'imagerie (48) conçu pour capturer une image tridimensionnelle (3D) (90) de la structure comprenant des informations de diagnostic ;
une sonde (30), conçue pour être insérée dans la structure (24) de manière à générer une cartographie géométrique 3D (38) de la structure ;
un processeur (34), couplé à la sonde (30) et au dispositif d'imagerie (48), et conçu pour enregistrer l'image (90) avec la carte (38), de telle sorte que chacun d'une pluralité de points d'image (82) dans l'image soit identifié avec un point de carte correspondant dans la carte ; et
un affichage (36), couplé pour être commandé par le processeur (34) pour afficher la carte (38), de sorte que les informations de diagnostic associées à chacun des points d'image (82) soient affichées au niveau du point de carte correspondant,

où le processeur (34) est conçu pour :

enregistrer (54) l'image (90) avec la carte (38) en appliquant une transformation à au moins un élément parmi l'image et la carte de sorte que, après la transformation, l'image et la carte aient un axe commun (72) et une échelle commune,
diviser l'image en une pluralité de tranches planes parallèles (92), perpendiculaires à l'axe (72) et mutuellement espacées le long de l'axe, où la pluralité de points d'image (82) sont situés dans les tranches, et
trouver une coordonnée axiale de chacune des tranches (92) et une coordonnée angulaire de chacun des points d'image (82) situés dans chacune des tranches, et identifier chacun des points d'image au point de carte ayant les mêmes coordonnées axiales et angulaires.

2. Appareil selon la revendication 1, dans lequel, lorsque la structure (24) comprend une paroi (102) définissant une cavité (100), le processeur (34) est conçu pour identifier chacun des points d'image (82) avec le point de carte en trouvant, au niveau des coordonnées axiales et angulaires, le point d'image (82) qui se situe dans une section de la paroi (102).

3. Appareil selon la revendication 1 ou la revendication 2, qui est conçu pour fournir une carte (38) colorée pour refléter les informations de diagnostic.

4. Appareil selon l'une quelconque des revendications 1 à 3, dans lequel les informations de diagnostic :

concernent le débit sanguin dans la structure (24) ;
comprennent des données de perfusion locales ;
comprennent des données métaboliques ;
concernent l'absorption d'une substance dans le tissu de la structure (24) ; ou
concernent le mouvement de la structure (24).

5. Appareil selon l'une quelconque des revendications 1 à 4, dans lequel, pour générer (52) la carte géométrique (38), la sonde (30) est conçue pour être placée en contact avec la structure (24) à une pluralité d'emplacements sur la structure, et le processeur (34) est conçu pour enregistrer les coordonnées des positions de la sonde aux emplacements.

6. Appareil selon la revendication 5, dans lequel la sonde (30) comprend un capteur de position à utiliser pour déterminer les coordonnées des positions.

7. Appareil selon l'une quelconque des revendications 1 à 6, dans lequel la structure comprend le coeur (24) du sujet (26), et où la carte géométrique (38) comprend une carte d'une surface endocardique dans un ventricule du coeur.

8. Appareil selon l'une quelconque des revendications 1 à 7, et comprenant un instrument médical conçu pour exécuter une procédure médicale sur la structure (24) guidée par les informations de diagnostic affichées sur la carte (38).

9. Appareil selon la revendication 8, dans lequel l'instrument médical est contenu dans la sonde (30), laquelle est conçue pour être utilisée pour exécuter la procédure localement à des emplacements sélectionnés sur la carte géométrique (38).

10. Appareil selon la revendication 9, dans lequel le processeur (34) est conçu pour marquer sur la carte géométrique (38) les emplacements au niveau desquels la procédure a été exécutée.

11. Appareil selon l'une quelconque des revendications 8 à 10 destiné à exécuter une procédure thérapeutique.

12. Appareil selon la revendication 11, dans lequel les informations de diagnostic concernent le débit sanguin dans la structure, pour exécuter une procédure thérapeutique pour améliorer le débit sanguin local.

13. Appareil selon l'une quelconque des revendications 8 à 10 destiné à exécuter une procédure de diagnostic.

FIG. 1

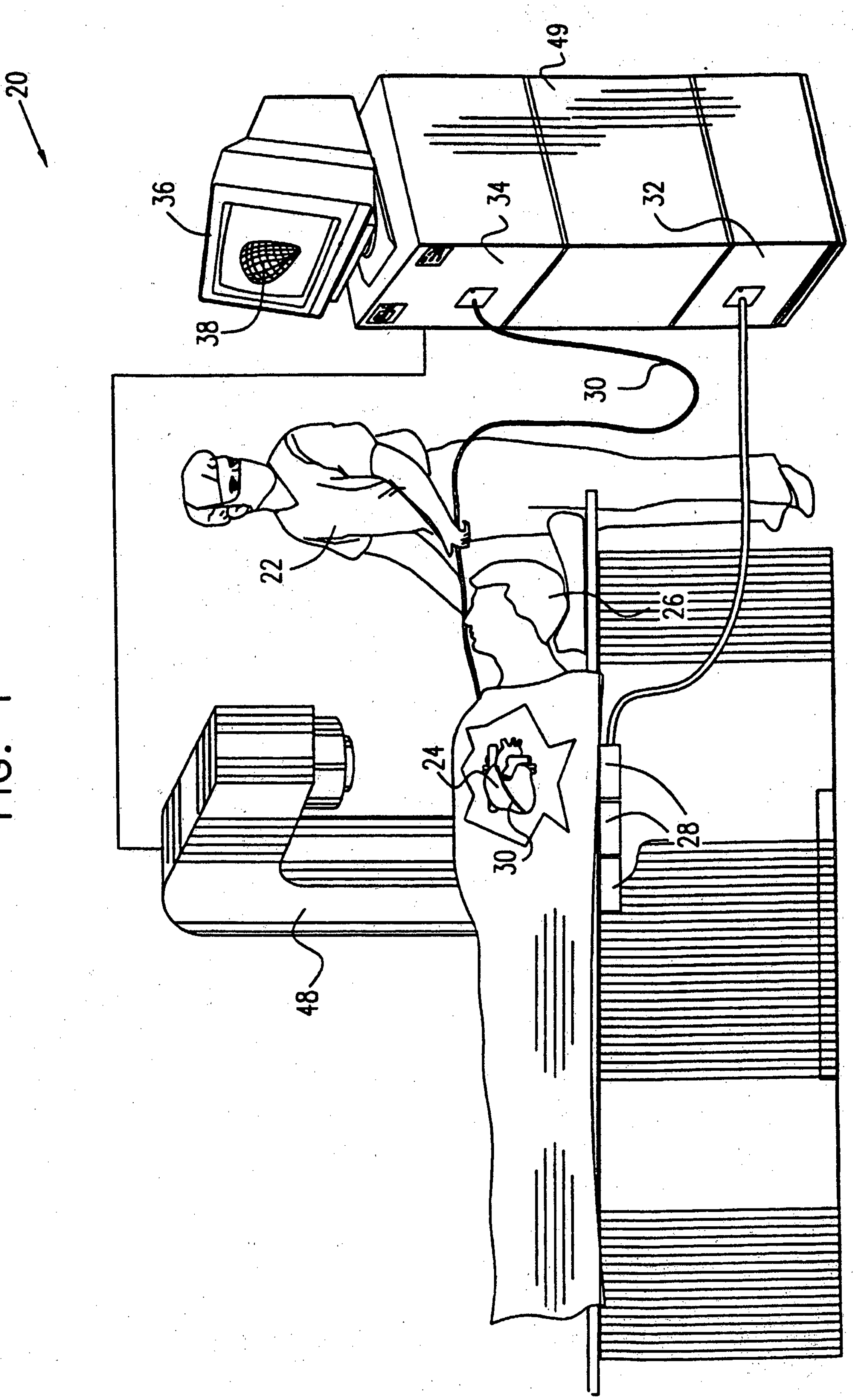


FIG. 2

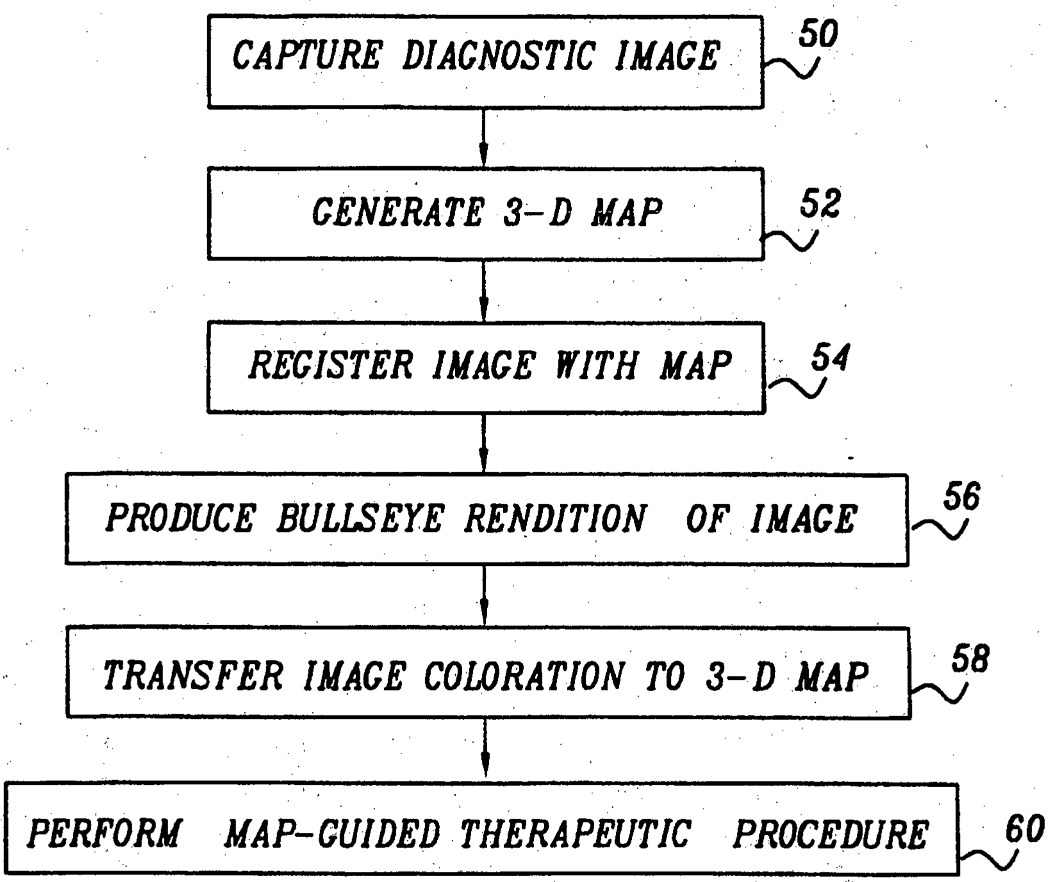

CAPTURE DIAGNOSTIC IMAGE
50
GENERATE 3-D MAP
52
REGISTER IMAGE WITH MAP
54
PRODUCE BULLSEYE RENDITION OF IMAGE
56
TRANSFER IMAGE COLORATION TO 3-D MAP
58
PERFORM MAP-GUIDED THERAPEUTIC PROCEDURE
60

FIG. 3

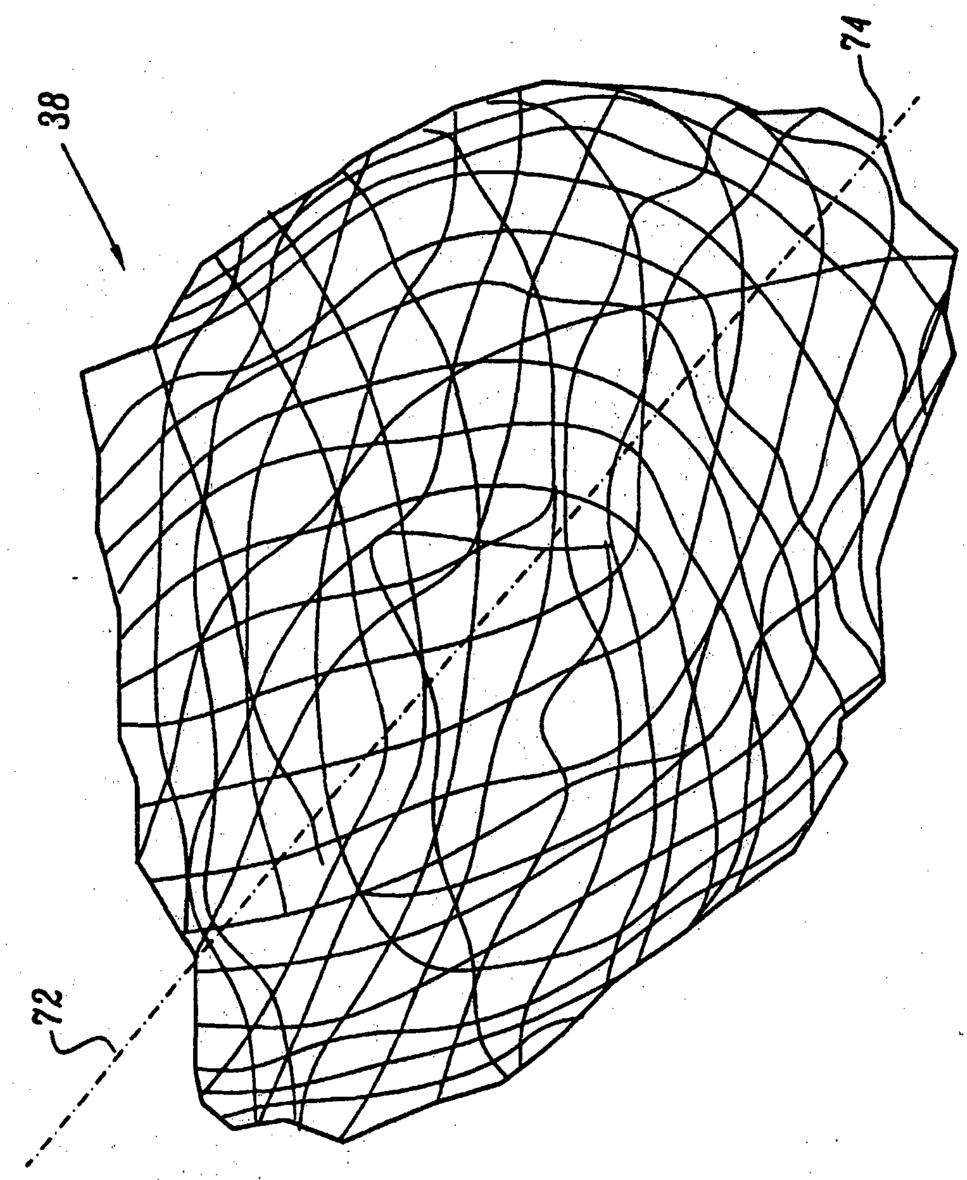
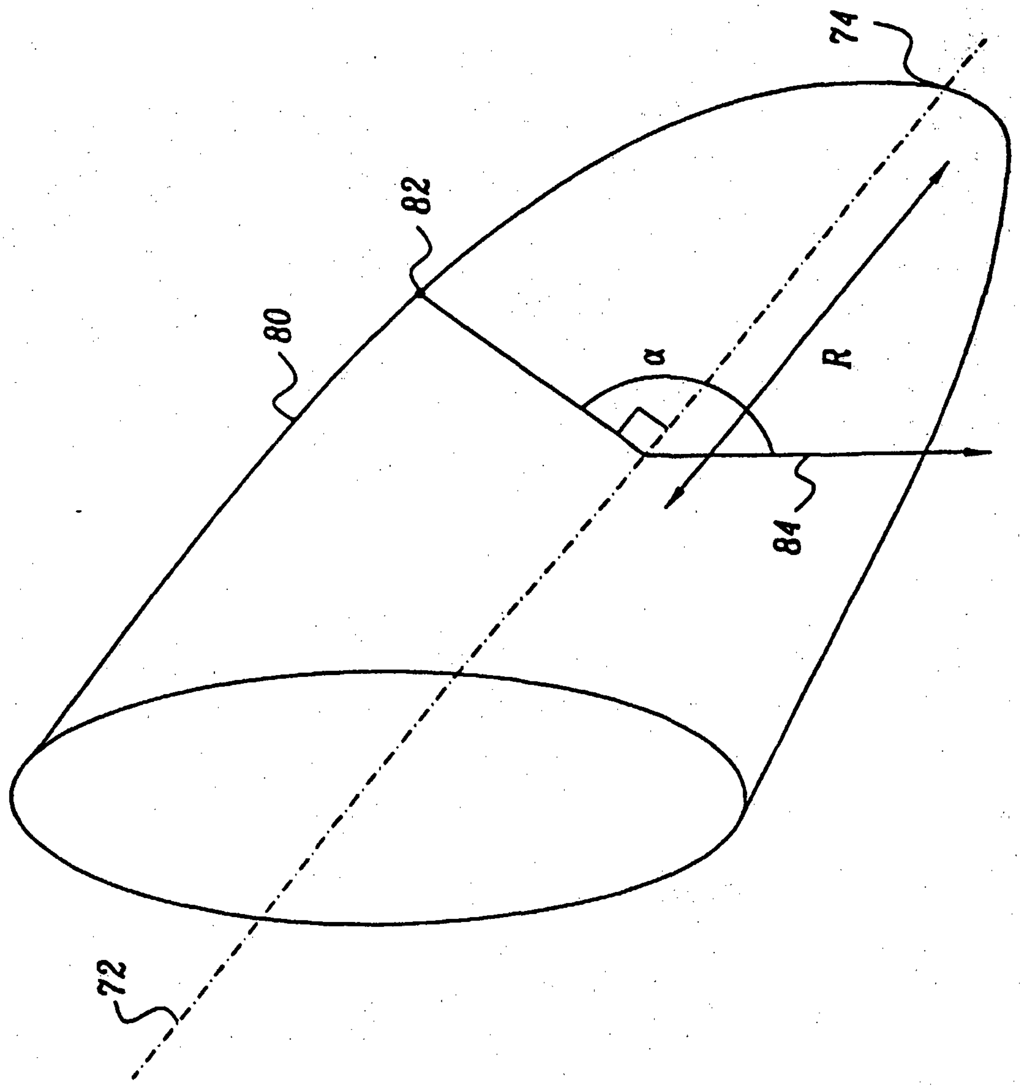


FIG. 4



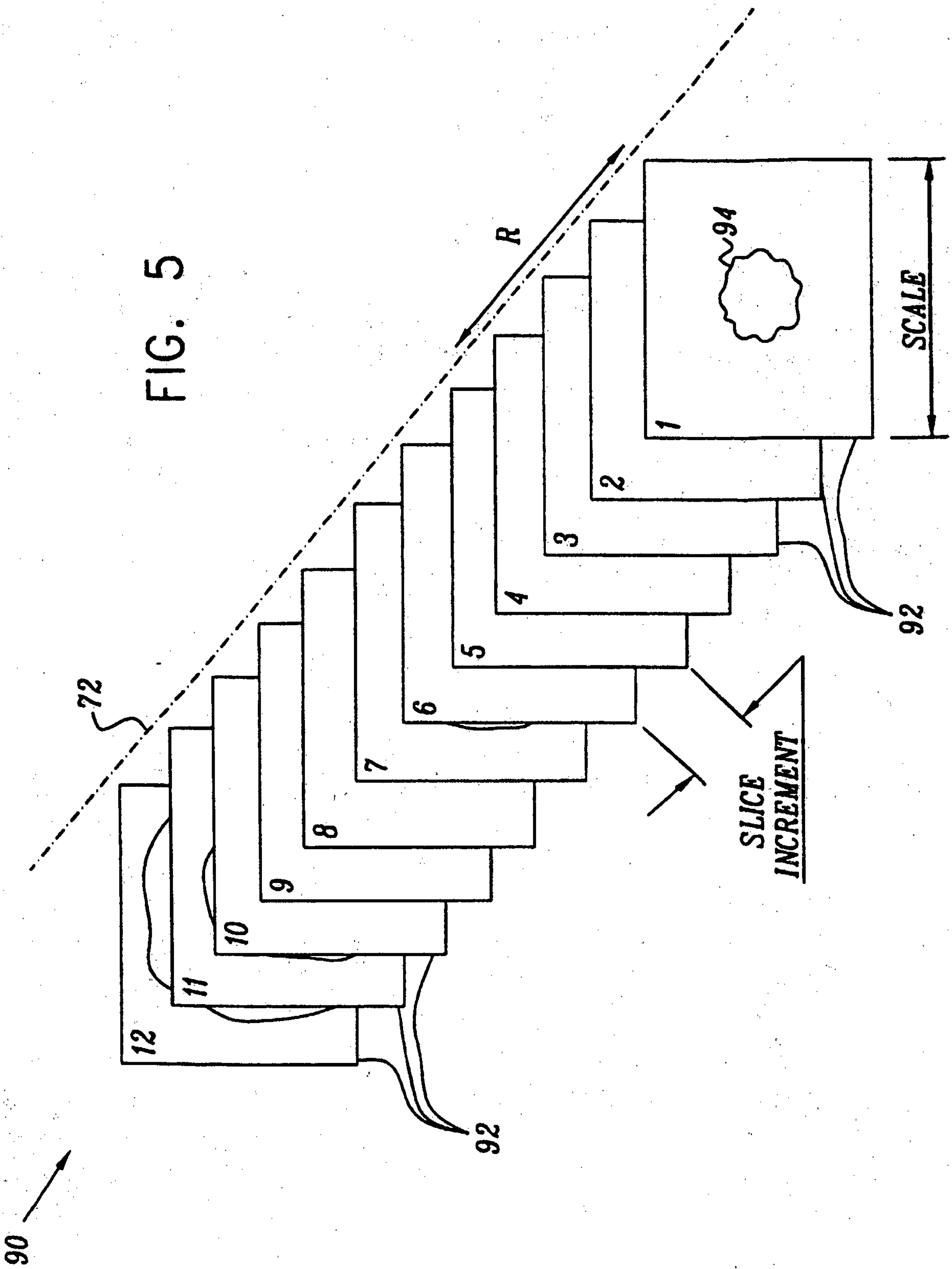
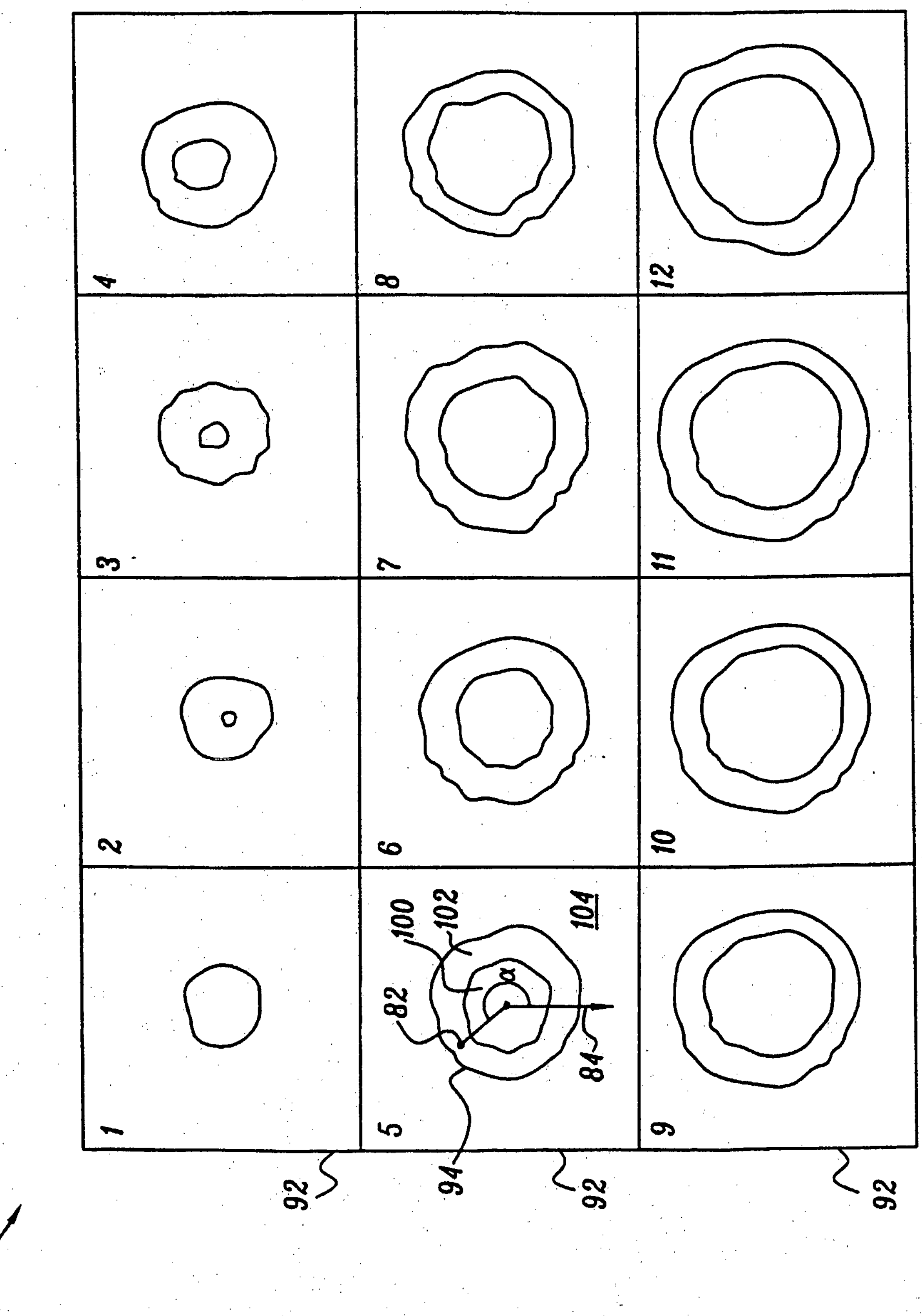


FIG. 5

FIG. 6



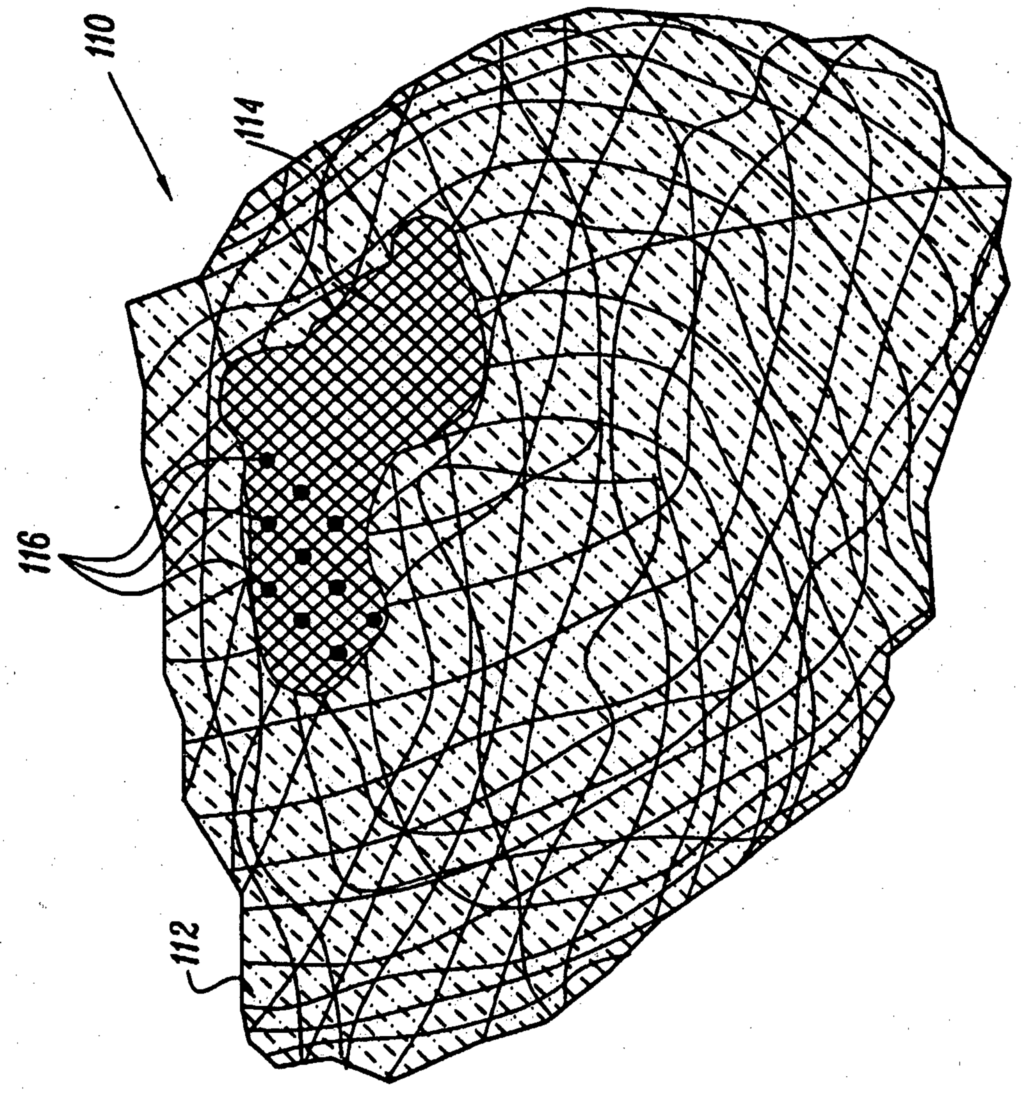


FIG. 7

REFERENCES CITED IN THE DESCRIPTION

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专利名称(译)	用于身体器官的三维图像渲染的方法和设备		
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[标]申请(专利权)人(译)	生物感覺有限公司		
申请(专利权)人(译)	生物传感，INC.		
当前申请(专利权)人(译)	生物传感韦伯斯特，INC.		
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发明人	KEIDAR, YARON		
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CPC分类号	A61B8/5276 A61B5/0456 A61B5/062 A61B5/1077 A61B5/721 A61B6/503 A61B8/0883 G06T7/30 G06T17/00 G06T2207/30048		
优先权	09/643666 2000-08-18 US		
其他公开文献	EP1182619A3 EP1182619A2		
外部链接	Espacenet		

摘要(译)

用于在对象的身体中映射结构的方法包括捕获包括诊断信息的结构的三维（3D）图像，以及使用插入到结构中的探针生成该结构的3D几何图。将图像与地图配准，使得利用地图中的对应地图点来识别图像中的多个图像点中的每一个。显示地图，使得与每个图像点相关联的诊断信息显示在相应的地图点处。

$$\{p_i \in P\}_{i=1}^{n},$$