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(54) ULTRASONIC METHOD AND APPARATUS FOR DETECTING MOVEMENTS OF OBJECTS

ULTRASCHALLVERFAHREN UND -GERÄT ZUR DETEKTION VON OBJEKTBEWEGUNGEN

METHODE ET DISPOSITIF A ULTRASONS POUR LA DETECTION DE MOUVEMENTS D'OBJETS

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EP-A- 0 961 135 **EP-A- 1 430 837**
US-A- 5 568 811

EP 1 680 690 B1

Description

Field of the invention

[0001] The present invention relates to a method and apparatus for displaying and detecting movements of objects, preferably the movements of muscle tissue during the cardiac cycle, more preferably to an ultrasonic method and apparatus for displaying and detecting the movements of parts of muscle tissue, such as the contraction pattern of ventricles and atria, in accordance with the preamble of independent claim 1 and independent claim 11. More specifically, the invention relates to a method and an apparatus for visualizing the contraction pattern of the heart of a human or animal body and to present a graphical representation of the surface of e.g. a heart chamber in order to detect whether it has a synchronous or asynchronous contraction.

State of the art

[0002] Presently, methods and apparatus are known for ultrasonic three-dimensional imaging wherein an object is scanned by two-or three-dimensional ultrasonic image scanning means in order to acquire cross-sectional images of the object wherein the discrete acquisition time of each cross-sectional image is recorded together with the image information. Thereafter, each of said cross-sectional images is digitalized and recorded together with its corresponding position and acquisition time. It is also well-known in the art to transform said cross-sectional images into a two- or three-dimensional data set by using surface reconstruction and/or volume rendering techniques and to display the three-dimensional data set over time, thereby showing a graphical representation of the scanned object in a three-dimensional manner which can be animated by displaying the three-dimensional representation at these discrete acquisition times. It is also well known in the art to acquire volume data with its corresponding resolution in space and time.

[0003] EP 0961 135 A1 which forms the closest prior art document discloses a method and an apparatus for rapidly generating a wire-frame volume model of the scanned object and how to display the surface of the object by interpolating over the wire-frame volume model. Thereby, it is possible to visualize e.g. the heart of a patient three-dimensionally as well as its movement over time in a virtual reality surface shell.

[0004] Nevertheless, ultrasonic scanning of the heart (echocardiography) has presented special challenges and problems because of the relatively complex movement of the heart and dynamic changes in the heart's configuration that occur during the cardiac cycle. Because of these problems and others, cardiac ultrasonic scanning historically has been limited to two- or three dimensional imaging wherein it has not been possible in an acceptable manner to view or visualize myocardial contraction throughout the cardiac cycle. For cardiologists and electro physiologists it is extremely important to understand the contraction pattern of heart muscle, in particular ventricles and atria. A regular synchronous contraction leads to optimal results in cardiac function. Inter- or intraventricular conduction disturbances can lead to asynchronous contraction of the heart chambers and thus reduce the function and efficiency of the heart. The current methods to assess asynchronous contraction are limited and labor intensive. Up to now the propagation of the contraction of the inner surface of heart chambers was examined throughout other imaging modalities like CT or MRI (Magnetic Resonance Imaging). Nevertheless, these techniques are not widespread as both acquisition and analysis of the movement of the chamber walls of the heart are time-consuming and complex.

[0005] Currently, MRI and CT techniques are able to provide static parameter distribution, thereby visualizing the contraction pattern of the ventricles two-dimensionally by using color coding (functional imaging). A drawback is the limited number of colors that can be differentiated by a human eye. Furthermore, the interpretation of color maps is usually non- intuitive with respect to local differences. For example, there is no natural interpretation for "yellow" being larger or smaller than "green". A workaround is the usage of a color map with a limited number of colors (e.g. blue and red) and smooth transitions. However, although the interpretation gets more intuitive, the differentiation between neighboring color levels becomes more difficult. Thus, usually only a limited interval of values is mapped at a time without a global overview of the propagation of the contraction of the heart surface.

[0006] Furthermore, EP-A-1 430 837 describes an ultrasonic apparatus suitable for visualizing contraction patterns by using a displacement information creator and by calculating an amount of displacement for respective sites on the surface of a target tissue at the telediastolic.

[0007] Finally, US-A-5 568 811 describes the measuring of the movements of tissue structures by correlating selected regions between at least two instants of time, and the visualizing of said tissue structure and its motion characteristic estimate.

Object of the invention

[0008] It is therefore an object of the invention to disclose an ultrasonic method and apparatus for detecting movements of objects in a quick and reliable manner, especially to describe a method and apparatus which allows quick and reproducible assessment of the contraction of a blood vessel, such as a heart muscle, especially to visualize the propagation of the contraction wave over the surface of a human's heart over time, especially the inner surface of heart chambers.

[0009] At the same time it is an object of the invention to disclose a method and an apparatus which obtains the above described information non-invasive and quick to reduce examination time thereby being as accurate as possible.

Summary of the invention

[0010] The objects of the invention are solved throughout the characterizing features of claims 1 and 11. Preferable embodiments are claimed within the subclaims and are further specified as follows:

[0011] The claimed ultrasonic method for displaying and detecting movements of objects comprises the steps of digitizing at least two-dimensional cross-sectional images of that object acquired at discrete acquisition times, recording each of these cross-sectional images and its corresponding position and acquisition time, transforming these cross-sectional images into a three-dimensional data set by using surface reconstruction and/or volume rendering techniques and displaying said three-dimensional data set over time wherein the three-dimensional data set is partitioned into a plurality of volume units, each volume unit has a unit surface and wherein the change of the volume of each volume unit is calculated over said acquisition times in order to obtain level information of each corresponding unit surface over time and wherein said level information is then displayed. This procedure also applies to acquisition methods where three-dimensional datasets are generated directly.

[0012] Preferably, two-dimensional ultrasonic image scanning means are used to acquire two-dimensional cross-sectional images of that object. However, it is also possible to use a three-dimensional ultrasonic image scanning means to acquire three-dimensional cross-sectional images which are volumes of said object. The term "cross-sectional image" therefore encompasses both possibilities.

[0013] While the invention uses known techniques to obtain a three-dimensional data set in order to display the contours of the object under examination, e.g. the heart during a cardiac cycle, it is now surprisingly possible with using an ultrasound apparatus to display the movement of the inner surface of the heart chambers during the cardiac cycle. In order to obtain singular information on the synchronicity of the contraction of the heart for each sub-set or segment of the heart surface, the present invention partitions said three-dimensional data set into a plurality of volume units and calculates the change of volume in order to obtain level information of a discrete and small surface unit of the object. Throughout such method it is possible to visualize the contraction front of a human's heart chambers in a three- or four-dimensional way.

Description of preferred embodiments

[0014] Preferably, the level information of each of the unit surfaces is a range of colors or a range of grey values in order to easily visualize at which "level or location" the surface of each volume unit is. The three-dimensional data set is preferably partitioned into a plurality of volume units by using a center of gravity within the object under examination and by linking all corners of said unit surface with the center of gravity. Thereby, the whole object is partitioned into said plurality of volume units, each being a three-dimensional segment of the object under examination.

[0015] At the same time it is advantageous to also partition the level information thereby using discrete level borders and allocating a limited number of colors, preferably two or three, to said discrete level information. Thereby, it is possible to visualize two or three positions of the surface of each volume unit in a simple manner, thereby indicating whether the surface is in a "contracted" state or an "expanded" state. By displaying the level information three-dimensionally or two-dimensionally over time it is possible to visualize the movement of the surface of the object like the propagation of a contraction wave over the surface of a heart during the cardiac cycle.

[0016] Even more preferably, the unit surfaces alone with their corresponding level information are displayed two-dimensionally on a two-dimensional map by using two-dimensional transformation methods which are per se known.

[0017] By visualizing the three-dimensional object two-dimensionally (like the two-dimensional world map of the earth) it is possible to visualize the movement of each segment of the surface of the object throughout a color representation of the two-dimensional surface of segment. Since the borders between the colors will move across the two-dimensional image it is possible to follow the e.g. propagation wave of the contraction of a heart chamber.

[0018] In accordance with a preferred embodiment of the present invention the propagation of said level information is displayed over time on said two-dimensional map wherein additionally two-dimensional propagation vectors may also be displayed. By using the length and direction of said two-dimensional propagation vectors it is possible to visualize the direction, amount and speed of volume change of respective volume units as well as their respective main positions and their numbers on said map. If a plurality of neighbouring volume units move at the same time into the same direction but earlier or later then volume units at other places of the object, the propagation vector will have a direction from the first group of volume units to the second group of volume units wherein the length of the propagation vector is a measure for the speed of the wave propagation and/or the difference in volume change. Here, the change of volume of each volume unit is preferably calculated by the application of noise reduction algorithms, edge enhancement algorithms and/or spatial artifacts reduction algorithms.

[0019] The discrete acquisition times for a cardiac object are preferably selected in accordance with an algorithm considering hearth cycle variations by electrocardiographic gating and/or respiratory cycle variations by impedance measurements. These are generally known in the state of the art.

[0020] The apparatus in accordance with the present invention comprises two- or three-dimensional ultrasonic scanning means for scanning an object in order to acquire cross-sectional images of said object at discrete acquisition times as well as digitizing means for digitizing each of said cross-sectional images, recording means for recording each of said cross-sectional images and its corresponding position and acquisition time, transforming means for transforming said cross-sectional images into a three-dimensional data set by using surface reconstruction and/or volume rendering techniques and displaying means for displaying said three-dimensional data set over time as well as partitioning means adapted to partition the three-dimensional data set into a plurality of volume units, each volume unit having a unit surface, calculating means which calculate the change of volume of each volume unit over said acquisition times in order to obtain level information of each corresponding unit surface overtime wherein displaying means display said level information.

[0021] The calculating means are preferably able to define a center of gravity which is one corner of all volume units which other corners are all included in the surface of the object. Thereby, it is guaranteed that a change in volume of each volume unit results in a level change of the respective unit surface. Said partitioning means partition said level information preferably by using discrete level borders and by allocating a limited number of colors, preferably two or three, to said discrete level information. At the same time transformation means transform said unit surfaces with their respective level information into a two-dimensional map over time by using known two-dimensional transformation methods and said displaying means preferably display the level information two-dimensionally.

[0022] The apparatus furthermore preferably comprises electrocardiographic gating means and respiration trigger means for dynamically scanning cardiac objects. At the same time said apparatus has displaying means which are capable of displaying the two-dimensional map of the present invention and a two-dimensional map of an electrophysiological mapping system thereby being able to compare the propagation of the potential level and the propagation of the contraction level of each segment of the surface of a heart in order to provide reliable information for heart diagnosis for a doctor.

[0023] Some preferred embodiments of the present invention will be explained in conjunction with the drawings as follows:

Fig.1a shows an endoscope echocardiographical acquisition,

Fig.1b shows the principle of acquisition of sequentional cross-sectional images of a heart,

Fig.2 shows an example of a three-dimensional transducer probe,

Fig.3 shows schematically the segmented surface of a three-dimensional object,

Fig.3a shows one segment of Fig.3 partitioned in a plurality of volume units,

Fig.3b shows one volume unit of Fig.3a,

Fig.4 shows the change of volume of the volume unit of Fig.3b over time,

Fig.5 shows one partial segment of the object of Fig. 3 with lines of equal contraction levels at 6 different times,

Fig.6 shows a two-dimensional representation of the object of Fig. 3/ Fig. 5, and

Fig.7 shows 6 three-dimensional and two-dimensional representations of the object of Fig. 3 at 6 different acquisition times.

[0024] Fig.1a shows an object 1 like an internal organ or tissue (e.g. heart) which is scanned by an ultrasonic beam 8 from scanning means 4 like a transducer which is incorporated within a probe situated in a vene or arteries adjacent to the object 1 (such as in the esophagus adjacent to the heart chamber) wherein the scanning means 4 are linked with processing means (not shown) by an endoscope connection 3 within the endoscopical path 2. The transesophageal probe 4 houses a rotational-array transducer at a distal end of a standard endoscope. The scanning plane can be continuously rotated through 180° starting from a longitudinal imaging position via a control knob on the handle of the echoscope. The cardiac cross-sections encompass a cone shaped volume with its point originating in the transducer (compare also Fig 1b). Then a step motor is activated by the steering logic which controls the image acquisition in a given plane by an algorithm considering heart cycle variation by ECG-gating 5 and respiratory cycles variation by impedance measurement. For each position of the heart (e.g. systole or diastole) the heart is scanned by acquiring a series of cross-sections 6, thereby obtaining a set of cross-sectional images 7 which belong to a certain position of the heart (which is similar to a stroboscopical picture representing a certain position of the heart at each acquisition time t1, t2, ...t6).

[0025] Fig.1b shows an enlarged view of the principle of acquisition of sequential cross-sections 6. A transducer 4 being linked to the computer by an endoscope connection 3 scans the heart 1 consisting of the left ventricle 11 and right ventricle 10 by acquiring all acquisition planes 9 throughout the ultrasonic beam 8, thereby sweeping the ultrasonic beam in a direction S.

[0026] Fig.2 shows an example of a three-dimensional ultrasonic image scanning means, such as a transthoracic probe 24 which is able to acquire a matrix 23 of 3-D image elements. Herewith, three-dimensional cross-sectional images, namely volumes, can be acquired. Other image acquisition techniques are also possible, such as an ultrasonic catheter-probe.

[0027] Fig.3 shows schematically the three-dimensional representation of the surface of the object 1 which is divided into segments 11 having segment borders 12.

The three-dimensional volume 16 can be further divided into a plurality of volume units 21 each having a unit surface 20. Such partitioning is preferably done by linking each corner (in Fig.3a each volume unit has four corners on the surface) on the surface with a center of gravity 18 which is located inside the three-dimensional volume 16. As shown in Fig.3b, each volume unit 21 has a unit surface 20 which expands or contracts through various levels since the center of gravity 18 is at a fixed position. Whenever the volume of the three-dimensional volume 16 changes the volume change ΔV of each volume unit 21 results in a level change of the unit surface 20.

[0028] As shown in Fig. 3b three levels 13, 14 and 15 are divided by level borders 10 which are predeterminable. Whenever the time change ΔT is sufficient to raise the unit surface over a level border 10 the surface will receive - in accordance with a preferred embodiment of the present invention- another discrete level information such as another color. It is therefore possible to allocate e.g. the color blue to the first level 13, the color grey to the second level 15 and the color red to the third level 14.

[0029] Whenever the unit surface 20 is within one of the three above mentioned levels 13, 14 or 15 the surface will be allocated a certain level information e.g. the color blue for being in the first level 13. The respective unit surface 20 of the volume unit 21 as shown in Fig.3a will then be colored blue.

[0030] Fig.4 shows the volume change ΔV of three volume units 20a, 20b and 20c (20b of Fig. 3b) over time. If the cardiac cycle of a heart is examined t1 is the time shortly after the end of the diastole, t_p is the time at the end of the systole and t6 is the time shortly before the enddiastole. At the time t_p the volume unit 20b has reached its lowest volume so that the unit surface 20b has reached its lowest level. The respective time t_p is not the time when all volume units 20a, 20b or 20c reach their smallest volume but only the time at which one singular volume unit 20b reaches its lowest volume. Other volume units 21 reach their lowest "position" at other times of lowest volume t_{p2}, t_{p3} between t1 and t6.

[0031] As can be seen from Fig. 4, all volume units 20a, 20b and 20c received different level infommation, namely the first volume units 20a the information 14, since the time of the lowest volume t_{p2} is in the area 14, the second volume units 20b (of Fig. 3b) the information 15, since the time of the lowest volume t_{p1} is in the area 15 and the third volume units 20c the information 13, since the time of the lowest volume t_{p3} is in the area 14. When "moving" the level information along time, each volume unit will receive different level information, such as colors, over time and hence, it is possible to visualize the contraction wave as a movie. Statically, each volume unit has a certain "time stamp" ΔT, namely the time necessary to reach the time of lowest volume $t_{p.}$

[0032] Fig.5 shows a dynamic display of a two-dimensional surface in a three-dimensional space. The volume 16 is partially shown in Fig.5 with the level borders 10 displaying the borders of various levels 13, 14 and 15. The first level 13 indicates wall segments that have already reached their peak contraction. From t1 to t2 the color limits are shifted so that the color for level 13 is addressed to level 14 and for t3 addressed to level 15 and so on. This way a certain color indicates the regions that are momentarily in their peak contraction phase and following the propagation of the color over time displays the mechanical muscle contraction front of the heart chamber. The contraction front of the heart chamber propagates over time since the various segments 20 of the inner surface of the heart chamber move at different times into different directions.

[0033] When transforming the three-dimensional representation of the volume 16 as shown in Fig.5 into a two-dimensional map as shown in Fig.6 a two-dimensional transformation method is used. Preferably, the center axis 22 of the three-dimensional volume is used as the center of the two-dimensional map which spreads the surface of the three-dimensional volume as schematically shown by segments 11 and segment borders 12.

[0034] Fig.6 thereby shows these segments 11 of the three-dimensional volume of Fig. 3 or Fig. 5 with a first subset of unit surfaces 20 (only partially displayed in Fig. 6) indicating a first level 13, second subset of unit surfaces 20 indicating a third level 14 and the rest of the unit surfaces 20 indicating a third subset, namely a second level 15, e.g. in grey colors. The representation of the volume in Fig.6 displays a discrete acquisition time t1, ... t6 with a certain area/region of the object being at a third level 14 and another area or region being at a first level 13 (e.g. blue colored) thereby indicating that the first area has a state in a first level 13 while the second area has another state in a third level 14 (e.g. red colored).

[0035] Figure 6 also shows the propagation vector 19 which originates from the center axis 22 and points into the direction of the propagation of the contraction. Since the first area is in its first level 13, the propagation vector 19 leads into the direction of the contraction source of that area.

[0036] Figure 7 shows six different acquisition times t1 ... t6 wherein the three-dimensional volume 16 in accordance with Fig. 3 is shown above the two-dimensional representation of the surface of the three-dimensional volume 16. The first levels 13, second levels 15 and third levels 14 are visualized throughout two-dimensional areas on the two-dimensional map as well as on the three-dimensional surface 16, accordingly.

[0037] Fig.7 shows the circular two-dimensional contraction front mapping of the left ventricle of a human's heart chamber thereby showing areas being at a first level 13 (contracted) and areas being at a third level 14 (expanded). By selecting times t1 ... t6 the dynamic range of colors is aliased at both upper and lower limits. As a result the two-dimensional display shows only two colors, namely blue and red distinguished by the second level grey or white. By progressively advancing the time window through the cardiac cycle one can observe the areas that achieve peak contraction t_p in a progressive fashion.

This can then be displayed as a digital movie showing the mechanical peak contraction as a continuous wave throughout the left ventricle of the heart. The color coding of each static position of the surface of the heart enables the color mapping of all unit surfaces 20 and a continuous mapping of the propagation of the contraction wave of the heart. The resolution within a single frame can thereby be tuned to be as fine as necessary to resolve local differences by increasing the number of acquisition times and thus the number of frames as well as by increasing the number of volume units.

[0038] The example of Fig. 7 shows such a sequence of 6 static frames. The invention, however, enables to display these frames as part of a dynamic clip thereby being viewed as a movie. The propagation of a certain color over time over the two-dimensional map shows the temporal evolution of the contraction pattern and thus allows for an easy assessment of synchrony- or asynchrony and its propagation of the heart cycle. Such display can easily be compared with the mapping of electrophysiological potentials over time thereby comparing the excitation and contraction of the heart muscle.

[0039] As shown in Fig.6 the propagation vector 19 can also be used in such movie representation. It is possible to create such propagation vector taking into account the spatial pattern of contraction in addition to temporal assessment. The two-dimensional vector represents both the quantity of myocardium in the left ventricle that has reached peak contraction and the mean direction of the contraction wave. This can be implemented as a moving arrow superimposed on the contraction front propagation. The origin of the vector is based preferably in the center 22 of the parametric image.

[0040] Additional vectors can be added for secondary sources of contraction designed in the same manner. This is e.g. necessary as some patients may display two or more waves of contraction as is seen after heart failure with significant dyssynchrony secondary to areas of scarring (electrical signals will delay as they circumvent scar and may result in two separate areas starting contract almost simultaneously) or in biventricular pacing.

[0041] An alternative vector representation of the propagation vector 19 can also be implemented by defining a vector with its origin in the area of earliest peak contraction, that is the area which reaches the first level 13 first, and the length and direction of the vector following the wave of peak contraction throughout the left ventricle. In the case of multiple wave spreading in various directions from the area of origin multiple propagation vectors 19 can be displayed in the same manner (multiple contraction vector mapping-MCVM).

[0042] The above described method can also be used for images which are acquired with CT or MR technology as long as the data is able to be transformed into a three-dimensional data set by using surface reconstruction and/or volume rendering techniques, and being able to be displayed as a three-dimensional data set over time.

Claims

1. Method for displaying movements of objects, comprising the steps of

   - digitizing each of at least two-dimensional cross-sectional images (7) of an object (1) acquired at discrete acquisition times (t1-t6) by scanning the object by image scanning means (4),
   - recording each of said cross-sectional images (7) and its corresponding position and acquisition time (t1-t6), and
   - transforming said cross-sectional images (7) into a three-dimensional data set by using surface reconstruction and/or volume rendering techniques,

   characterized by,

   - partitioning the three-dimensional data set into a plurality of volume units (21), wherein each volume unit (21) has a unit surface (20), wherein such unit surface (20) is a small surface unit of said object (1),
   - calculating the change of volume of each volume unit (21) over said acquisition times (t1-t6) to obtain level information (13-15) of each corresponding unit surface (20) over time, wherein such level information (13-15) is an information for visualizing the location of the unit surface (20), and
   - displaying said level information (13-15).

2. Method as claimed in claim 1,
   characterized by,
   said level information (13-15) being a range of colors or a range of grey values and each of said volume units (21) is a three-dimensional segment of said object (1).

3. Method as claimed in claims 1 or 2,
   characterized by,
   partitioning said three-dimensional data set into a plurality of volume units (21) by using a centre of gravity (18) within said object (1) and linking all corners of said unit surfaces (20) with said centre of gravity (18).

4. Method as claimed one of the preceding claims,
   characterized by,
   partitioning said level information (13-15) using discrete level borders (10) and allocating a limited number of colors, preferably two or three, to said discrete level information.

5. Method as claimed one of the preceding claims,
   characterized by,
   displaying said level information (13-15) three-dimensionally over time.

6. Method as claimed in one of the preceding claims, **characterized by**, displaying said unit surfaces (20) and their corresponding level information (13-15) two-dimensionally on a map by using a two-dimensional transformation method.

7. Method as claimed in claim 6, **characterized by**, displaying the propagation of said level information (13-15) over time on said map, preferably by additionally displaying a two-dimensional propagation vector (19).

8. Method as claimed in claim 6 or 7, **characterized by**, displaying the length and direction of said two-dimensional propagation vector (19) in relation to the direction, amount and speed of volume change of respective volume units (21) as well their respective positions and their numbers on said map.

9. Method as claimed in one of the preceding claims, **characterized by**, calculating the change of volume of each volume unit (21) by application of noise reduction algorithms, edge enhancement algorithms and/or spatial artifacts reduction algorithms.

10. Method as claimed in one of the preceding claims, **characterized by**, selecting said discrete acquisition times (t1-t6) for a cardiac object (1) in motion in accordance with an algorithm considering heart cycle variations by electrocardiographic gating and respiratory cycle variations by impedance measurements.

11. Apparatus for detecting movements of objects, comprising ultrasonic scanning means (4) for scanning an object (1) to acquire at least two-dimensional cross-sectional images (7) of said object (1) at discrete acquisition times (t1-t6), digitizing means for digitizing each of said cross-sectional images (7), recording means for recording each of said cross-sectional images (7) and its corresponding position and acquisition time (t1-t6), and
transforming means for transforming said cross-sectional images (7) into a three-dimensional data set by using surface reconstruction and/or volume rendering techniques,
characterized in that the apparatus further comprises
partitioning means adapted to partition the three-dimensional data set into a plurality of volume units (21), wherein each volume unit (21) has a unit surface (20), wherein such unit surface (20) is a small surface unit of said object (1),
calculating means adapted to calculate the change of volume of each volume unit (21) over said acquisition times (t1-t6) to obtain level information (13-15) of each corresponding unit surface (20) over time, wherein such level information (13-15) is an information of the location of the unit surface (20), and displaying means adapted to display said level information (13-15).

12. Apparatus as claimed in claim 11, **characterized in that**, said partitioning means are adapted to partition said level information (13-15) using discrete level borders (10) and allocate a limited number of colors, preferably two or three, to said discrete level information, and **in that** the apparatus further comprises transformation means adapted to transform said unit surfaces (20) with their respective level information (13-15) two-dimensionally over time on a map by using a two-dimensional transformation method, and **in that**
said displaying means are adapted to display said level information (13-15) two-dimensionally.

13. Apparatus as claimed in claims 11 or 12, **characterized in that**, said display means are adapted to display a two-dimensional propagation vector (19), thereby displaying the length and direction of said two-dimensional propagation vector (19) in relation to the direction, amount and speed of volume change of respective volume units (21) as well their respective position and their numbers on said map.

14. Apparatus as claimed in one of the claims 11 - 13, **characterized in that**, said apparatus further comprises electrocardiographic gating means and respiration trigger means for dynamically scanning cardiac objects (1).

Patentansprüche

1. Verfahren zum Darstellen von Bewegungen von Objekten, umfassend die Schritte:

   - Digitalisieren von jedem der wenigstens zweidimensionalen Querschnittsbilder (7) eines Objekts (1), die bei diskreten Erfassungszeiten (t1-t6) durch Scannen bzw. Abtasten des Objekts mittels Bildscannmitteln (4) aufgenommen wurden,
   - Speichern von jedem der Querschnittsbilder (7) und ihrer entsprechenden Position und Erfassungszeit (t1-t6),
   - Umwandeln der Querschnittsbilder (7) in einen dreidimensionalen Datensatz durch Verwenden von Oberflächenrekonstruktions- und/oder Volumenwiedergabemethoden,

gekennzeichnet durch

- Unterteilen bzw. Partitionieren des dreidimensionalen Datensatzes in eine Vielzahl an Volumeneinheiten (21), wobei jede Volumeneinheit (21) eine Einheitsoberfläche (20) aufweist, wobei eine derartige Einheitsoberfläche (20) eine kleine Flächeneinheit des Objekts (1) ist,
- Berechnen der Volumenänderung von jeder Volumeneinheit (21) in Abhängigkeit von den Erfassungszeiten (t1-t6), um eine Niveauinformation (13-15) von jeder entsprechenden Einheitsoberfläche (20) in Abhängigkeit von der Zeit zu erhalten, wobei eine derartige Niveauinformation (13-15) eine Information zum Visualisieren der Lage der Einheitsoberfläche (20) ist, und
- Darstellen der Niveauinformation (13-15).

2. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** die Niveauinformation (13-15) ein Bereich an Farben oder ein Bereich an Grauwerten ist, und dass jede der Volumeneinheiten (21) ein dreidimensionales Teilstück des Objekts (1) ist.

3. Verfahren nach Anspruch 1 oder 2, **gekennzeichnet durch** das Unterteilen des dreidimensionalen Datensatzes in eine Vielzahl an Volumeneinheiten (21) **durch** Verwenden eines Schwerpunkts (18) im Innern des Objekts (1) und **durch** Verbinden aller Ecken der Einheitsoberflächen (20) mit dem Schwerpunkt (18).

4. Verfahren nach einem der vorhergehenden Ansprüche, **gekennzeichnet durch** das Unterteilen der der Niveauinformation (13-15) **durch** Verwenden von diskreten Niveaugrenzen (10) und **durch** Zuweisen der diskreten Niveauinformation eine begrenzte Anzahl an Farben, bevorzugt zwei oder drei.

5. Verfahren nach einem der vorhergehenden Ansprüche, **gekennzeichnet durch** das dreidimensionale Darstellen der Niveauinformation (13-15) in Abhängigkeit von der Zeit.

6. Verfahren nach einem der vorhergehenden Ansprüche, **gekennzeichnet durch** das zweidimensionale Darstellen der Einheitsoberflächen (20) und ihrer entsprechenden Niveauinformation (13-15) auf einer Karte **durch** Verwenden eines zweidimensionalen Umwandlungsverfahrens.

7. Verfahren nach Anspruch 6, **gekennzeichnet durch** das Darstellen der Übertragung der Niveauinformation (13-15) in Abhängigkeit von der Zeit auf der Karte, bevorzugt **durch** zusätzliches Darstellen eines zweidimensionalen Übertragungsvektors (19).

8. Verfahren nach Anspruch 6 oder 7, **gekennzeichnet durch** das Darstellen der Länge und der Richtung des zweidimensionalen AÜbertragungsvektors (19) in Anhängigkeit von der Richtung, dem Umfang und der Geschwindigkeit der Volumenänderung der jeweiligen Volumeneinheiten (21) sowie ihrer jeweiligen Positionen und ihrer Nummern auf der Karte.

9. Verfahren nach einem der vorhergehenden Ansprüche, **gekennzeichnet durch** das Berechnen der Volumenänderung von jeder Volumeneinheit (21) durch Anwendung von Rauschverminderungsalgorithmen, Kantenglättungsalgorithmen und/oder Algorithmen zur Verminderung von räumlichen Artefakten.

10. Verfahren nach einem der vorhergehenden Ansprüche, **gekennzeichnet durch** das Auswählen der diskreten Erfassungszeiten (t1-t6) für ein in Bewegung befindliches kardiales Objekt (1) in Übereinstimmung mit einem Algorithmus, der Herzzyklusänderungen **durch** Elektrokardiographie-Gating und Atemzyklusänderungen **durch** Impedanzmessungen berücksichtigt.

11. Vorrichtung zum Erfassen von Bewegungen von Objekten, umfassend Ultraschallscannmittel (4) zum Scannen bzw. Abtasten eines Objekts (1), um wenigstens zweidimensionale Querschnittsbilder (7) des Objekts (1) bei diskreten Erfassungszeiten (t1-t6) zu erhalten, Digitalisierungsmittel zum Digitalisieren von jedem der Querschnittsbilder (7), Speichermittel zum Speichern von jedem der Querschnittsbilder (7) und ihrer entsprechenden Position und Erfassungszeit (t1-t6), und Umwandlungsmittel zum Umwandeln der Querschnittsbilder (7) in einen dreidimensionalen Datensatz durch Verwenden von Oberflächenrekonstruktions- und/oder Volumenwiedergabemethoden, **dadurch gekennzeichnet, dass** die Vorrichtung ferner umfasst: Partitionierungsmittel, die geeignet sind den dreidimensionalen Datensatz in eine Vielzahl an Volumeneinheiten (21) zu unterteilen, wobei jede Volumeneinheit (21) eine Einheitsoberfläche (20) aufweist, wobei eine derartige Einheitsoberfläche (20) eine kleine Flächeneinheit des Objekts (1) ist, Berechnungsmittel, die geeignet sind die Volumenänderung von jeder Volumeneinheit (21) in Abhängigkeit von den Erfassungszeiten (t1-t6) zu berechnen, um eine Niveauinformation (13-15) von jeder entsprechenden Einheitsoberfläche (20) in Abhängigkeit von der Zeit zu erhalten, wobei eine derartige Niveauinformation (13-15) eine Information der Lage der Einheitsoberfläche (20) ist, und Darstellungsmittel, die geeignet sind die Niveauinformation (13-15) darzustellen.

12. Vorrichtung nach Anspruch 11, **dadurch gekennzeichnet, dass** die Partitionierungsmittel geeignet

sind, die Niveauinformation (13-15) durch Verwenden von diskreten Niveaugrenzen (10) aufzuteilen und der diskreten Niveauinformation eine begrenzte Anzahl an Farben, bevorzugt zwei oder drei, zuzuweisen, und dass die Vorrichtung ferner Umwandlungsmittel umfasst, die geeignet sind die Einheitsoberflächen (20) mit ihrer jeweiligen Niveauinformation (13-15) zweidimensional, in Abhängigkeit von der Zeit auf eine Karte durch Verwenden eines zweidimensionalen Umwandlungsverfahrens umzuwandeln, und dass die Darstellungsmittel geeignet sind, die Niveauinformation (13-15) zweidimensional darzustellen.

13. Vorrichtung nach Anspruch 11 oder 12, **dadurch gekennzeichnet, dass** die Darstellungsmittel geeignet sind einen zweidimensionalen Übertragungsvektor (19) darzustellen, wodurch die Länge und die Richtung des zweidimensionalen Übertragungsvektors (19) in Anhängigkeit von der Richtung, dem Umfang und der Geschwindigkeit der Volumenänderung der jeweiligen Volumeneinheiten (21) sowie ihre jeweilige Lage und ihre Nummern auf der Karte dargestellt werden.

14. Vorrichtung nach einem der Ansprüche 11 bis 13, **dadurch gekennzeichnet, dass** die Vorrichtung ferner Elektrokardiographie-Gatingmittel und Atmungsauslösemittel für das dynamische Scannen bzw. Abtasten von kardialen Objekten (1) umfasst.

Revendications

1. Procédé pour afficher des mouvements d'objets, comprenant les étapes consistant à :

- numériser chacune des images (7) de section transversale au moins bidimensionnelles d'un objet (1) acquises à des temps d'acquisition discrets (t1-t6) en scannant l'objet par des moyens de scannage d'images (4),
- enregistrer chacune desdites images (7) de section transversale ainsi que sa position et son temps d'acquisition correspondant (t1-t6), et
- transformer lesdites images de section transversale (7) en un jeu de données tridimensionnelles en utilisant des techniques de reconstruction de surface et/ou de restitution en volume,

caractérisé par les étapes consistant à

- cloisonner le jeu de données tridimensionnelles en une pluralité d'unités volumétriques (21), telles que chaque unité volumétrique (21) possède une surface unitaire (20), et chacune de ces surfaces unitaire (20) est une petite unité de surface dudit objet (1),
- calculer le changement de volume de chaque unité volumétrique (21) au cours desdits temps d'acquisition (t1-t6) pour obtenir les informations de niveau (13-15) de chaque surface unité correspondante (20) au cours du temps, et les informations de niveau (13-15) sont des informations pour visualiser la localisation de la surface unitaire (20), et
- affichez lesdites informations de niveau (13-15).

2. Procédé selon la revendication 1,
caractérisé en ce que lesdites informations de niveau (13-15) sont constituées par une gamme de couleur ou par une gamme de valeur de gris, et chacune desdites unités volumétriques (21) est un segment tridimensionnel dudit objet (1).

3. Procédé selon les revendications 1 ou 2,
caractérisé en ce que l'on cloisonne le jeu de données tridimensionnelles en une pluralité d'unités volumétriques (21) en utilisant un centre de gravité (18) dans ledit objet (1) et en effectuant une liaison de tous les coins desdites surfaces unitaires (20) avec ledit centre de gravité (18).

4. Procédé selon l'une des revendications précédentes,
caractérisé
en ce que l'on cloisonne lesdites informations de niveau (13-15) en utilisant des bordures de niveau discrètes (10) et en allouant un nombre limité de couleurs, de préférence deux ou trois, auxdites informations de niveau discrètes.

5. Procédé selon l'une des revendications précédentes,
caractérisé en ce que l'on affiche lesdites informations de niveau (13-15) de manière tridimensionnelle en fonction du temps.

6. Procédé selon l'une des revendications précédentes,
caractérisé en ce que l'on affiche lesdites surfaces unitaires (20) et leurs informations de niveau correspondantes (13-15) de manière bidimensionnelle sur une carte en utilisant un procédé de transformation bidimensionnelle.

7. Procédé selon la revendication 6,
caractérisé en ce que l'on affiche la propagation desdites informations de niveau (13-15) au cours du temps sur ladite carte, de préférence en affichant additionnellement un vecteur de propagation bidimensionnel (19).

8. Procédé selon la revendication 6 ou 7,
caractérisé en ce que l'on affiche la longueur et la direction du directeur de propagation bidimensionnel (19) en relation à la direction, la quantité et la vitesse

de changement de volume des unités volumétriques respectives (21) ainsi que leurs positions respectives et leurs numéros sur ladite carte.

9. Procédé selon l'une des revendications précédentes,
caractérisé en ce que l'on calcule le changement de volume de chaque unité volumétrique (21) par application d'algorithmes de réduction de bruit, d'algorithmes de renforcement de bordure et/ou d'algorithmes de réduction d'artefacts spatiaux.

10. Procédé selon l'une des revendications précédentes,
caractérisé en ce que l'on choisit lesdits temps d'acquisition discrets (t1-t6) pour un objet cardiaque (1) en mouvement en accord avec un algorithme en considérant les variations du cycle le cardiaque par portillonnage électrocardiographique et les variations du cycle respiratoire par des mesures d'impédance.

11. Appareil pour détecter des mouvements d'objets, comprenant des moyens de scannage à ultrasons (4) pour scanner un objet (1) et acquérir des images de section transversale au moins bidimensionnelle (7) dudit objet (1) à des temps discrets (t1-t6), des moyens de numérisation pour numériser chacune desdites images de section transversale (7), des moyens d'enregistrement pour enregistrer chacune desdites images de section transversale (7) et sa position correspondante ainsi que son temps d'acquisition correspondant (t1-t6), et
des moyens de transformation pour transformer lesdites images de section transversale (7) en un jeu de données tridimensionnelles en utilisant des techniques de reconstruction de surface et/ou des techniques de restitution en volume,
caractérisé en ce que ledit appareil comprend en outre des moyens de cloisonnement adaptés pour cloisonner le jeu de données tridimensionnel en une pluralité d'unités volumétriques (21), dans lesquelles chaque unité volumétrique (21) comprend une surface unitaire (20), ladite surface unitaire (20) étant une petite unité de surface dudit objet (1),
des moyens de calcul adaptés pour calculer le changement de volume de chaque unité volumétrique (21) au cours desdits temps d'acquisition (t1-t6) pour obtenir des informations de niveau (13-15) de chaque surface unitaire correspondante (20) au cours du temps, dans lequel lesdites informations de niveau (13-15) sont des informations sur l'emplacement de la surface unitaire (20), et des moyens d'affichage adaptés pour afficher lesdites informations de niveau (13-15).

12. Appareil selon la revendication 11,
caractérisé en ce que lesdits moyens de cloisonnement sont adaptés pour cloisonner lesdites informations de niveau (13-15) en utilisant des bordures de niveau discrètes (10) et allouer un nombre limité de couleurs, de préférence deux ou trois, auxdites informations de niveau discrètes, et **en ce que** l'appareil comprend en outre des moyens de transformation adaptés pour transformer lesdites surfaces unitaires (20) avec leurs informations de niveau respectives (13-15) de manière dimensionnelle au cours du temps sur une carte en utilisant un procédé de transformation bidimensionnel, et **en ce que** lesdits moyens d'affichage sont adaptés pour afficher lesdites informations de niveau (13-15) de manière bidimensionnelle.

13. Appareil selon les revendications 11 ou 12,
caractérisé en ce que lesdits moyens d'affichage sont adaptés pour afficher un vecteur de propagation bidimensionnel (19), pour afficher ainsi la longueur et la direction dudit vecteur de propagation bidimensionnel (19) en relation avec la direction, la quantité et la vitesse de changement volumétrique des unités volumétriques respectives (21), de même que leurs positions respectives et leurs numéros sur ladite carte.

14. Appareil selon l'une des revendications 11 à 13,
caractérisé en ce que ledit appareil comprend en outre des moyens de portillonnage électrocardiographique et des moyens de déclenchement de respiration pour scanner de manière dynamique des objets cardiaques (1).

Fig. 1a

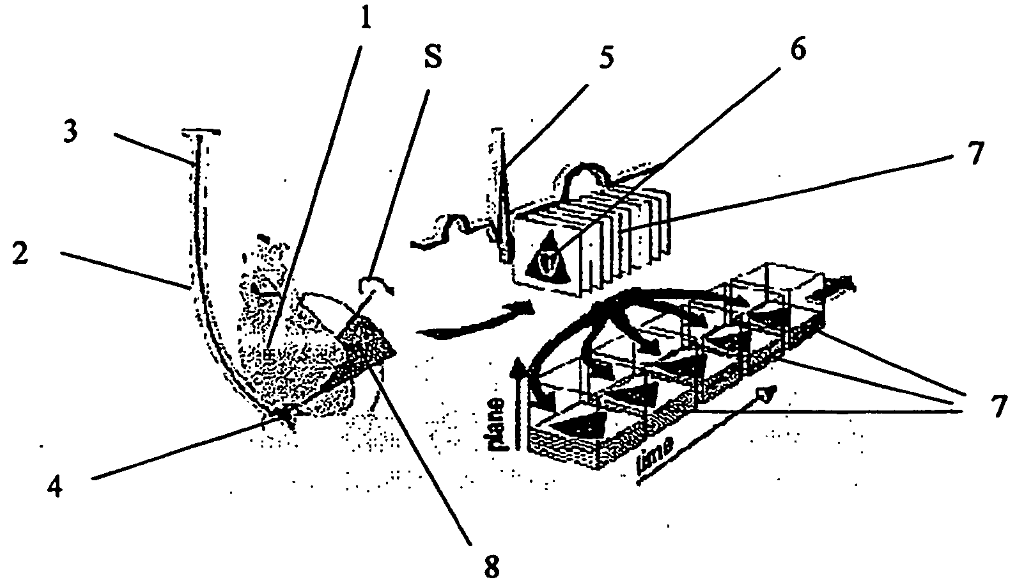


Fig. 1b

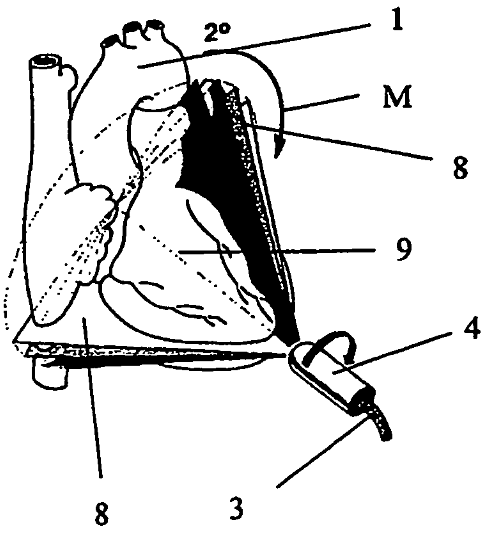


Fig. 2

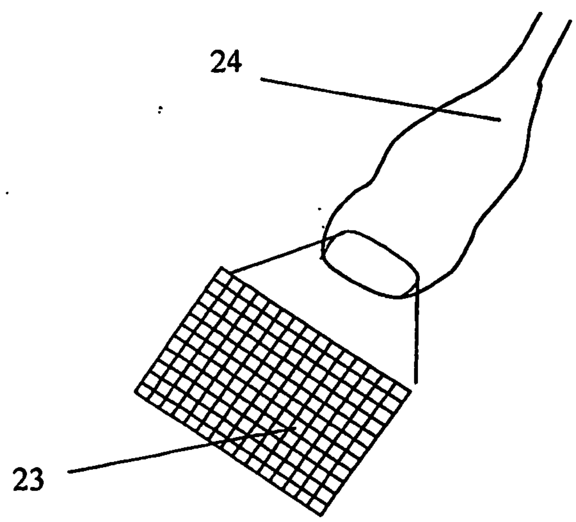


Fig. 3

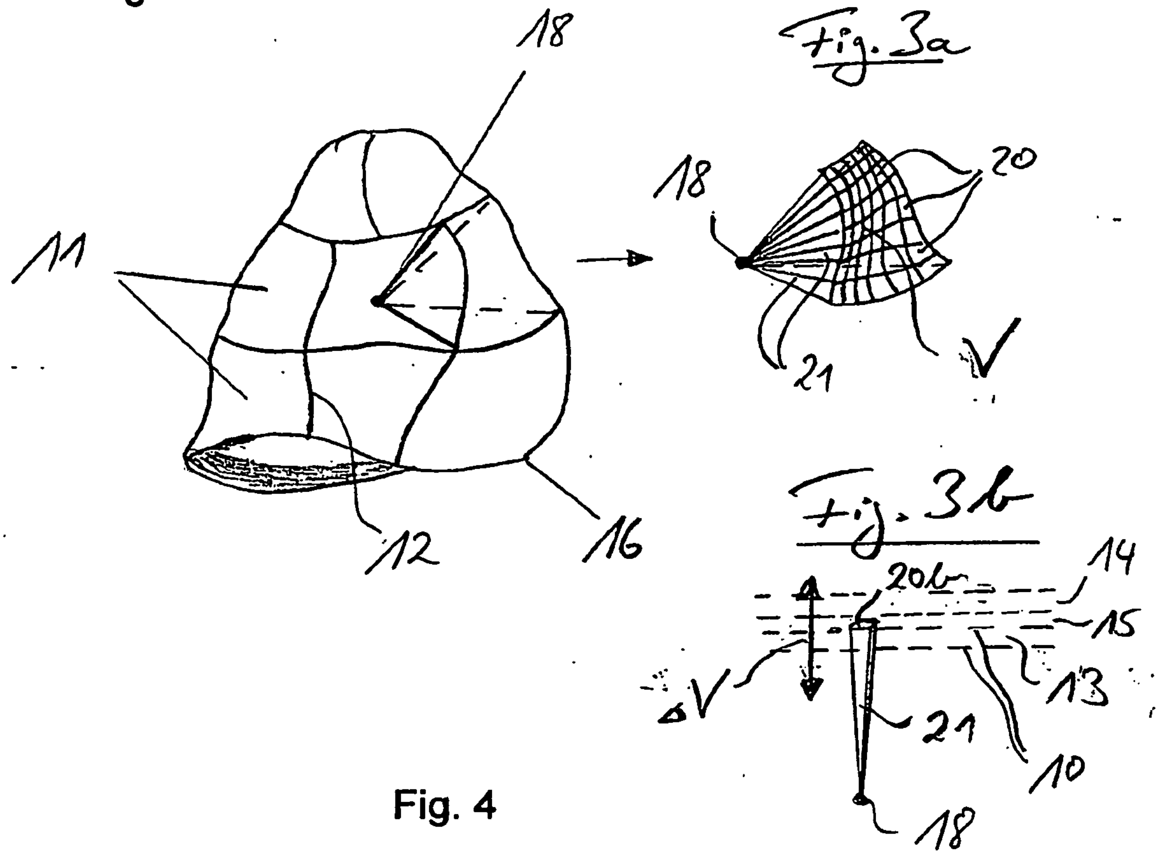


Fig. 3a
18
11
12
16
18
20
21
V
Fig. 3b
14
20b
15
13
ΔV
21
10
18

Fig. 4

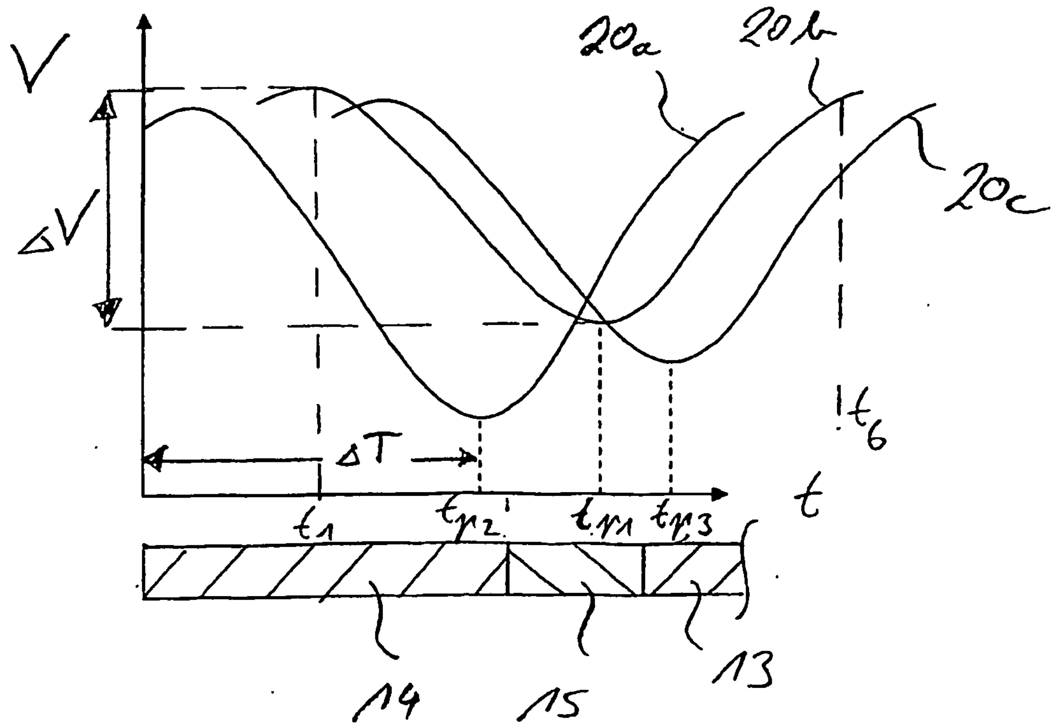

V
20a
20b
20c
ΔV
ΔT
t6
t
t1
tr2
tr1
tr3
14
15
13

Fig. 5

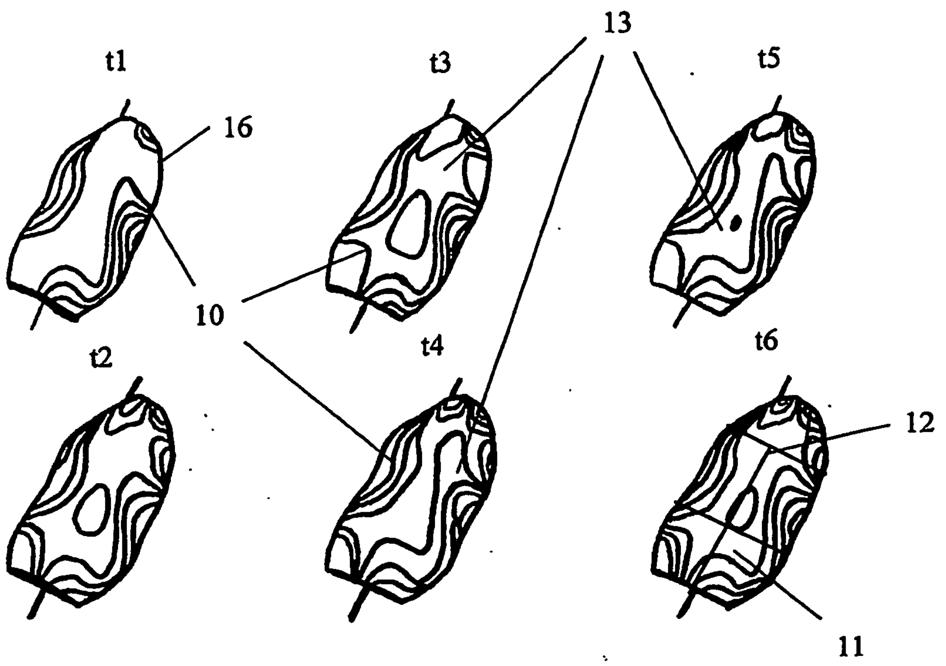


Fig. 6

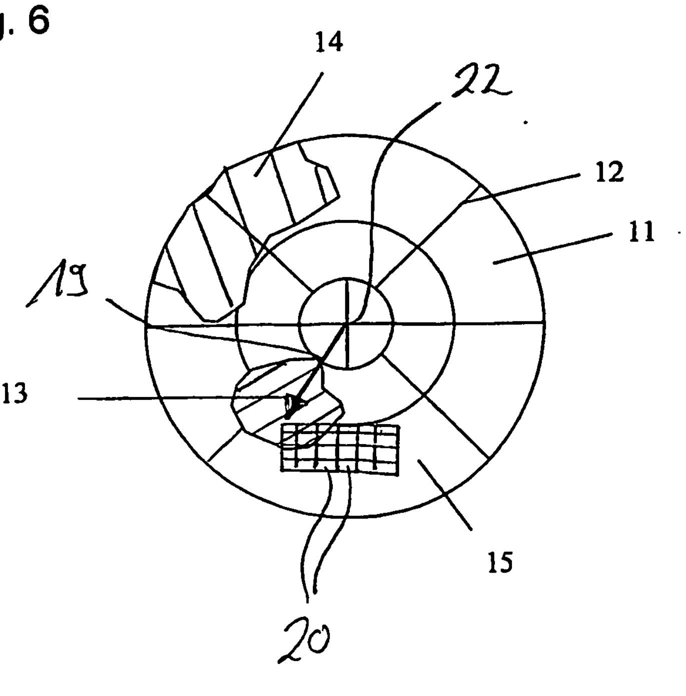
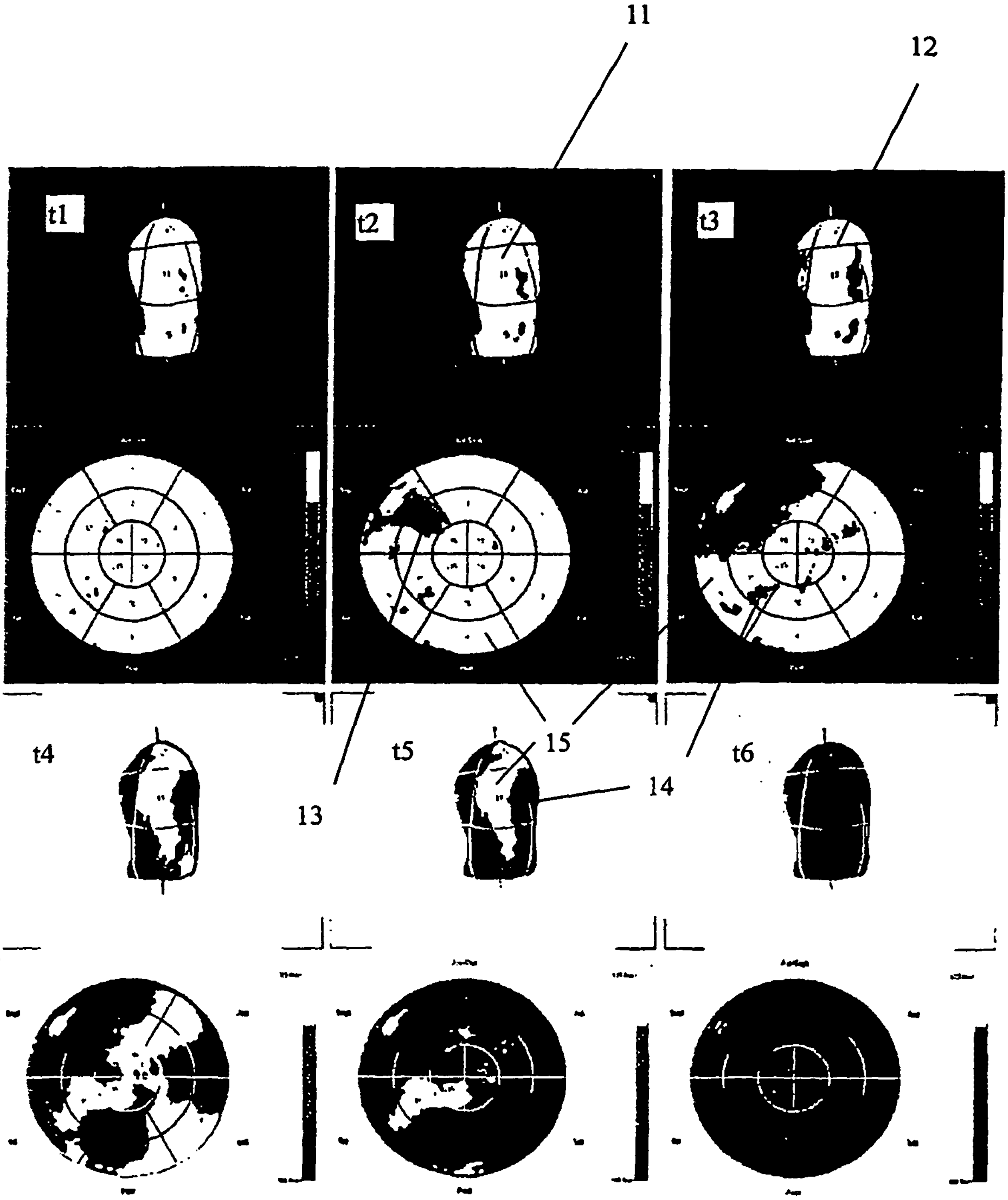


Fig. 7



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- EP 0961135 A1 **[0003]**
- EP 1430837 A **[0006]**
- US 5568811 A **[0007]**

专利名称(译)	用于检测物体运动的超声波方法和设备		
公开(公告)号	EP1680690B1	公开(公告)日	2010-09-15
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当前申请(专利权)人(译)	TOMTEC成像系统GMBH		
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发明人	SCHRECKENBERG, MARCUS ROSSMANITH, ALEXANDER BAUMANN, ROLF KAPETANAKIS, STAM MONAGHAN, MARK		
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其他公开文献	EP1680690A1		
外部链接	Espacenet		

摘要(译)

本发明涉及一种用于检测物体的运动的方法和装置，优选地用于检测心动周期期间血管的运动的超声波方法和装置，包括以下步骤：通过二维或三维扫描物体（1）超声图像扫描装置（4）在离散采集时间（t1-t6）通过使用表面重构和/或体绘制技术采集数据集，将三维数据集划分为多个体积单位（21），其中每个体积单元（21）具有单元表面（20），在所述获取时间（t1-t6）上计算每个体积单元（21）的体积变化，以获得每个相应单元表面（20）的水平信息（13-15）随着时间的过去和/或三维地显示具有其水平信息（13-15）的所述三维数据集。

Fig. 1a

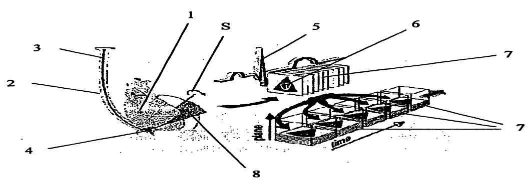

Fig. 1b

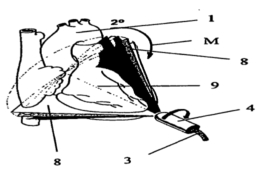

Fig. 2