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(54) EVALUATION OF CARDIAC INFARCTION BY REAL TIME ULTRASONIC STRAIN IMAGING

AUSWERTUNG EINES HERZINFARKTS DURCH ECHTZEIT-ULTRASCHALLBILDGEBUNG DER VERFORMUNG

ÉVALUATION D'INFARCTUS CARDIAQUE PAR IMAGERIE ÉLASTOGRAPHIQUE ULTRASONORE EN TEMPS RÉEL

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Description

[0001] This invention relates to ultrasonic diagnostic imaging systems and, in particular, to the use of ultrasonic strain imaging to evaluate ischemic areas of the heart which have suffered an infarct.

[0002] One of the uses of cardiology ultrasound is to evaluate the heart of a patient who has suffered an infarct. It would be desirable, for instance, to be able to image the coronary arteries to look for blockages that may have caused an ischemic event. Ultrasound, however, is generally not capable of directly visualizing the coronary arteries due their motion, location outside the heart, proximity to the lungs, and other characteristics. Thus, arterial functions are indirectly diagnosed with ultrasound by assessing myocardial wall motion. An abnormal or asynchronous wall motion suggests reduced arterial flow, probably due an occlusion of a coronary artery by an arterial plaque or blood clot. Abnormal functioning of the myocardium due to an occlusion can be diagnosed by visualizing the contractility of the myocardium. Contractility can be assessed by calculating myocardial mural strains throughout the heart muscle as the heart contracts, looking for areas where the deformation during contraction is minimal or erratic. Unfortunately, most current approaches lack the resolution to image local strains and are not real-time. Existing strain imaging can only measure global strains (longitudinal, circumferential and radial) over the heart cycle. While useful, they cannot be used to localize and reliably visualize an infarct or demarcate an ischemic region. These applications lack the sensitivity required to diagnose local heart functions. Furthermore, since strain is determined by tracking myocardial motion over the full heart cycle or at least its contraction phase, only one strain image can be produced for a heart cycle.

These images are viewed statically and not as real time motional images. Accordingly it is desirable to be able to determine cardiac contractility characteristics with high resolution and to be able to view them in real time cardiac images.

[0003] US 2013/0286023 A1 discloses an ultrasound system configured to display a moving image of a heart, including a color coded overlay displayed as a function of time. The overlaid information may be a local instantaneous strain value displayed as a function of time. The strain value may be calculated in a strain sub-module.

[0004] In accordance with the present invention an ultrasonic diagnostic imaging system for real time strain imaging is provided that includes an ultrasound imaging probe having an array transducer which acquires ultrasound echo signals, an image processor, coupled to the imaging probe, which produces a first sequence of image frames in real time, a strain calculator coupled to the image processor which processes image frame data to estimate strain during the image frame sequence, a color mapper which produces a color map from strain values, a color map warper that is responsive to the color map and a new sequence of image frames and configured to warp the color map to an image frame of the new sequence to generate a warped color map, and a display which displays an image frame in combination with the warped color map.

[0005] The present invention further provides a method of producing real time ultrasonic strain images, which includes acquiring frames of echo image data, estimating tissue displacements between acquired frames from the echo image data, calculating strain values from the displacements, forming a color map of the strain values, acquiring additional frames of echo image data, warping the color map to the additional frames, and displaying the additional frames in combination with the warped color map.

[0006] Preferred embodiments are defined in the dependent claims.

[0007] In the drawings:

FIGURE 1 is a block diagram of an ultrasound system constructed in accordance with the present invention.

FIGURES 2a - 2d illustrate the motion of points in the myocardium during the contraction of the heart.

FIGURE 3 illustrates motion of points in the myocardium when observed in a short axis view of the heart.

FIGURE 4 is a flowchart of strain imaging of the heart in accordance with the present invention.

FIGURE 5 illustrates cross-correlation functions of the echo data of consecutive images of the heart.

FIGURE 6 graphically illustrates a typical cross-correlation distribution of speckle from a moving heart in an embodiment of the present invention.

[0008] In accordance with the present invention, an ultrasonic diagnostic imaging system is described which is able to image the heart at a high frame rate and calculate strain over localized areas of the myocardium. For each pixel on the image, a strain parameter is determined which is representative of the local strain, and these pixel values are then mapped spatially to the anatomical image. The strain map is then fitted to the first image of the next heart cycle and displayed as a parametric color overlay over the image frames of the next cycle of heart images. As the images change with the contraction and relaxation of the myocardium, the color overlay is warped to continually fit over each cardiac image. The user is thus given a real time display of the heart, its spatial strain variation, and corresponding contractility characteristics.

[0009] The present invention provides ultrasonic diagnostic imaging systems for real time strain imaging. The ultrasound systems include a variety of components, such as an ultrasound imaging probe. The probe includes an array transducer which acquires ultrasound echo signals. The systems further include an image processor. The image processor is coupled to the imaging probe and configured to produce a first sequence of image frames in real time. The systems include a strain calcu-

lator coupled to the image processor. The strain calculator is configured to process image frame data to estimate strain during the image frame sequence. The systems further include a color mapper.
The systems can be configured to include processors, memory, and other structures that can be programmed to serve as a color mapper. The color mapper is configured to produce a color map based on the strain values. The systems further include a color map warper. The systems can be configured to include processors, memory, and other structures that can programmed to serve as a color map warper. The color map warper is responsive to the color map and a new sequence of image frames and configured to warp the color map to an image frame of the new sequence, thereby generating a warped color map. The systems also include a display which displays an image frame in combination with the warped color map.

[0010] In some embodiments, the image frames can include cardiac image frames. The first sequence of image frames can be acquired during a first heart cycle, and a new sequence of image frames can be acquired during a subsequent heart cycle. The systems can include a frame memory, coupled to the image processor, which stores sequences of image frames.

[0011] In certain embodiments, the systems can include a displacement estimator. The systems can be configured to include processors, memory, and other structures that can be programmed to serve as a displacement estimator and the color mapper. The displacement estimator is responsive to a sequence of image frames to estimate tissue displacements over the image frame sequence. The displacement estimator can include a displacement cross-correlator which estimates displacements by cross-correlating echo data, and a displacement integrator which performs Lagrangian integrated displacement values.

[0012] In some embodiments, the systems can include a speckle tracker which identifies tissue displacements. The systems can be configured to include processors, memory, and other structures that can be programmed to operate as the speckle tracker and the color mapper. In certain embodiments, the systems can be coupled to an ECG sensor, which senses a patient ECG waveform. The systems can further include a beamformer, coupled to the array transducer, which operates to acquire image frame sequences in relation to the ECG waveform.

[0013] Referring first to FIGURE 1, an ultrasound system constructed in accordance with the present invention is shown in block diagram form. A probe 10 has a transducer array of elements 12 which scans the region of the body in front of the array. The array may be a one-dimensional or a two-dimensional array for 2D or 3D scanning. Typically in cardiology the array transducer is operated as a phased array. The probe is operated by a beamformer 20 which controls the timing of transmit pulses and processes received echo signals. The probe 10 is coupled to the mainframe ultrasound system by a probe cable 14 and a transmit/receive switch 16 which protects sensitive electronics of the beamformer during high voltage transmission. The beamformer delays and combines signals received from the transducer elements to form coherent echo signals from points in the image field. The echo signals are coupled to a signal processor 22 which enhances the signals as by filtering and produces detected echo signals. The processed echo signals are then formed into a spatial image of the desired format by an image processor 24. Successively produced image frames are stored in a frame memory 30.

[0014] Since it is not possible to determine stress in the myocardium by ultrasound directly, the force applied by the heart muscle, the effect of such force is estimated by measuring strain, the deformation of the heart resulting from contractile stress. The strain measurement process begins by tracking the motion of the myocardium as it contracts. Since ultrasound produces coherent signals, it exhibits a phenomenon known as speckle. So long as the probe remains stationary, the speckle pattern will persist from one image frame to the next. The detailed speckle pattern is tracked by a speckle tracker 32, which thereby follows small regions of myocardial tissue by following the change in position of their speckle pattern from one image frame to the next. Since the echo signal intensity variation resulting from speckle is at a very low level and thus susceptible to being masked by noise, the system of FIGURE 1 estimates displacements of the speckle pattern from one image to the next by cross-correlation. The echoes of consecutive image frames are cross-correlated by a displacement cross-correlator 34 to locate the peak of the cross-correlation function. A typical cross-correlation function is shown in FIGURE 6. FIGURE 7 illustrates one cross-correlation function 52 from the cross-correlation of first and second consecutive image frames, and a second cross-correlation function 54 from the cross-correlation of the second and the next consecutive image frames. As seen there is a lag d between the peaks of the two functions. This lag d is the displacement of the tissue in the image sequence from one frame to the next. Because this lag signal is susceptible to noise, the displacements over a plurality of consecutive frames are integrated by a displacement integrator 36. Preferably Lagrangian integration is used to produce a single value for each point in the myocardium which is representative of the displacements over the plurality of consecutive frames. Because the heart motion is cyclic and hence it will return to its original starting point each heart cycle (the heart in frame 1 is in the same position as it is in the last frame N), it is possible to get two independent estimates for the displacement over the contractile and relaxation phases. For example, instantaneous displacements are integrated forward in time from frames 1 to M (denoted by I_{1-M}) and reverse in time from frame N to M (denoted by I_{M-N}). Note that frame M corresponds to end systole; this is the phase of the heart cycle at which the strains should be at a maximum. The integrated displacements are then averaged to create a Lagrangian integrated composite displacement map: $I_G = (I_{1-M} + I_{M-N})/2$. The integrated displacements are then used by a strain calculator 38 to produce spatial derivatives which are spatial strain values for each pixel location. A weighted combination of nominal and shear strain values is used to create a parametric image. One example of such combination is: $(0.5E_{yy} + 0.25E_{xy} + 0.25E_{xx})$, where E_{xx} is the strain perpendicular to an A-line, E_{yy} is strain along the A-line and E_{xy} is the shear strain extracted from axial displacements. This is a measure of rotation. These strain values are then mapped as color values in a two-dimensional or three-dimensional color map by strain color mapping 40. The color map spatially corresponds to the myocardium as it appears in the image frames over which the strain values were calculated. The color map could be displayed as a static color map of strain for the heart cycle over which the strain values were calculated.

[0015] In accordance with the present invention, the strain color map is stored in the strain color mapping processor 40 and frames are acquired over a subsequent heart cycle. Preferably frames of each heart cycle are acquired at known phases of the heart cycle in relation to the R-wave of the heart's ECG signal. As is well known, physiological electrodes 26 are attached to the patient's body during scanning for the production of an ECG waveform and image frame acquisition timing can thereby be based upon the timing of the R-wave of the ECG signal. When the R-wave of the subsequent heart signal is produced, it triggers the strain color mapping processor 40 to couple the color map to a color map warper 42. The color map warper receives an image frame produced during the new heart cycle and may optionally also receive spatial information on the tracked speckle in the new image from the speckle tracker 32. The color map warper then warps or fits the color map from the previous heart cycle to the cardiac image of the new heart cycle. With the color map thus spatially aligned to the myocardium in the new image frame, the warped color map and the new image frame are coupled to the display processor, where the color map is applied as a color overlay over the image frame. The new image frame and its color overlay of the warped color map are then displayed on a display 50.

[0016] As successive image frames of the new heart cycle are received they are coupled to the color map warper 42 and the color map produced during the previous heart cycle is warped or fit to the myocardium in each image. The color map of the myocardial strain is thereby fit within the boundary of the myocardium in each image of the new heart cycle. Each warped color map is then displayed as a color overlay superimposed over each successive cardiac image frame of the new heart cycle. The real time display of the image frames of the new heart cycle thus includes the fitted strain color overlay which thereby displays a dynamic real time image sequence of the strain characteristics of the myocardium.

[0017] Optionally, the tracked speckle values of each new image frame of the new heart cycle can be used by the color map warper 42 to fit the strain values of the color map to corresponding speckle locations in each new image frame. Rather than warping the color map as a whole, the strain values of the color map are continually repositioned to match with their changing corresponding speckle locations in each new image frame.

[0018] At the same time that this display methodology is ongoing, elements 32-40 of the ultrasound system are calculating strain values over the new heart cycle so that a new color map is produced for the new heart cycle. The new color map is then used as a new warped color overlay for the following cardiac cycle.

[0019] FIGURE 2 illustrates how individual points of the myocardium can move during a contraction of the heart and how this movement manifests itself in ultrasound images. FIGURE 2a) shows three points in the myocardium, My_A, My_B, and My_C, which move during heart contraction along respective paths A, B and C. After an initial period of time, the time between successive image frames in this example, the points in the myocardium have contracted to the positions along paths A, B, and C as shown in FIGURE 2b). After the next inter-frame period of time the myocardial points have moved further to the positions shown in FIGURE 2c). The continual motion of this movement is now captured by ultrasonic imaging, but only the myocardial point locations at the time an image frame is acquired. Thus, the motion as captured by ultrasound imaging is a succession of straight-line displacements 60 as shown in FIGURE 2d). This displacement, when depicted in the larger context of myocardial contraction, would appear as shown in FIGURE 3. This drawing shows a short axis view of the myocardium in which the myocardial slice through the heart appears like a donut. At the starting point of the myocardial points in FIGURE 2a) these points are arrayed as shown at the left side of FIGURE 3. After the heart has contracted, the points have moved inward and are closer together as shown on the right side of FIGURE 3. In a typical healthy heart, points of myocardial muscle can be expected to move 20% closer together over the contractile phase of the heart. This displacement of each myocardial point is represented by a single value after Lagrangian integration and strain calculation in the ultrasound system. The resulting strain values are then used in the spatially arranged color map of strain values.

[0020] The present invention provides methods of producing real time ultrasonic strain images. The methods include acquiring frames of echo image data, estimating tissue displacements between acquired frames from the echo image data, calculating strain values from the displacements, forming a color map of the strain values, acquiring additional frames of echo image data, warping the color map to the additional frames, and displaying the additional frames in combination with the warped color map.

[0021] In some aspects, acquiring frames of echo image data can include acquiring image frames of a heart. Estimating tissue displacements can include performing speckle tracking. The speckle tracking can include estimating displacements by cross-correlation, and performing Lagrangian integration of displacements. In certain embodiments, the methods can include acquiring a patient ECG waveform, and acquiring the frames of echo image data in relating to the timing of the ECG waveform.

[0022] Warping the color map can include fitting the color map to the boundaries of the myocardium in each of the additional frames. Warping the color map can include fitting the color map to the speckle pattern in each of the additional frames.

[0023] The method of the present invention is depicted in the flowchart of FIGURE 4. The first step 102 is to acquire high frame rate echo data. The higher the frame rate of the image frames, the smaller the displacement increments of the points in the myocardium (see FIGURE 2d)). Preferably image frames are acquired at a rate of 100 Hz or greater. A higher frame rate will provide improved performance when 2D images are used which are subject to movement of myocardial points out of the image plane. The higher frame rate will help assure that a myocardial point is sampled at least two times before it leaves the image plane, enabling a strain estimation to be made for the point. Next, speckle tracking is begun by estimating displacements of features in the image frame such as speckle by cross-correlation at 104. In step 106 Lagrangian integration of the displacements is performed. In step 106 strain is calculated as the spatial derivatives of the displacements. The strain values are then used to form a color map in step 108.

[0024] In step 110 image frames of the next heartbeat are acquired. The color map is then warped to fit the myocardium in the image frames of the next heartbeat, and displayed as a color overlay over the myocardium in the new image. The warping and overlay process is continued throughout the next heartbeat while, as the same time, image frames of the next heartbeat are processed to form a color map to be used as a warped overlay with the image frames of the following heart cycle.

[0025] It will be understood that each block of the block diagram illustrations, and combinations of blocks in the block diagram illustrations, can be implemented by computer program instructions. The computer program instructions may be executed by a processor to cause a series of operational steps to be performed by the processor to produce a computer implemented process. The computer program instructions may also cause at least some of the operational steps to be performed in parallel. Moreover, some of the steps may also be performed across more than one processor, such as might arise in a multi-processor computer system.

[0026] The computer program instructions can be stored on any suitable computer-readable hardware medium including, but not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by a computing device. Processors can include hardware such as microprocessors, field programmable gate arrays (FPGAs), integrated circuits, or the like.

Claims

1. An ultrasonic diagnostic imaging system for real time strain imaging comprising:

an ultrasound imaging probe having an array transducer and being configured to acquire ultrasound echo signals;
an image processor, coupled to the imaging probe, which is configured to produce a first sequence of image frames;
a strain calculator coupled to the image processor and configured to process the image frames to estimate strain during the first image frame sequence;
a color mapper configured to produce a color map based at least in part on strain values generated by the strain calculator; and
a color map warper that is responsive to the color map and a new sequence of image frames generated by the image processor, wherein the color map warper is configured to warp the color map to an image frame of the new sequence to generate a warped color map; and
a display for displaying the image frame of the new sequence in combination with the warped color map.

2. The ultrasonic diagnostic imaging system of Claim 1, wherein the image frames comprise cardiac image frames;
wherein the first sequence of image frames is acquired during a first heart cycle; and
wherein the new sequence of image frames is acquired during a subsequent heart cycle.

3. The ultrasonic diagnostic imaging system of Claim 2, further comprising a displacement estimator responsive to a sequence of image frames which is configured to estimate tissue displacements over the image frame sequence.

4. The ultrasonic diagnostic imaging system of Claim 3, wherein the displacement estimator further comprises:

a displacement cross-correlator which is configured to estimate displacements by cross-correlating echo data; and
a displacement integrator which is configured to perform Lagrangian integration of displacement

values.

5. The ultrasonic diagnostic imaging system of Claim 4, further comprising a speckle tracker which identifies tissue displacements ; and
wherein preferably the strain calculator is configured to estimate the strain as the spatial derivatives of the tissue displacements of the image frames.

6. The ultrasonic diagnostic imaging system of Claim 5, further comprising an ECG sensor, coupled to the ultrasound system, which senses a patient ECG waveform.

7. The ultrasonic diagnostic imaging system of Claim 6, further comprising a beamformer, coupled to the array transducer, which operates to acquire image frame sequences in relation to the ECG waveform.

8. The ultrasonic diagnostic imaging system of Claim 7, further comprising a frame memory, coupled to the image processor, which stores sequences of image frames.

9. The ultrasonic diagnostic imaging system of Claim 1, wherein the strain calculator is configured to estimate the strain for each pixel of the image frame as a representation of a local strain.

10. A method of producing real time ultrasonic strain images comprising:

acquiring image frames comprising echo image data;
estimating tissue displacements between acquired frames from the echo image data;
calculating strain values based at least in part on the tissue displacements;
forming a color map of the strain values;
acquiring additional image frames comprising echo image data;
warping the color map to the additional frames; and
displaying the additional frames in combination with the warped color map.

11. The method of Claim 10, wherein acquiring frames of echo image data comprises acquiring image frames of a heart.

12. The method of Claim 11, wherein estimating tissue displacements further comprises performing speckle tracking, and
wherein preferably speckle tracking further comprises:

estimating displacements by cross-correlation; and
performing Lagrangian integration of displacements.

13. The method of Claim 12, further comprising:

acquiring a patient ECG waveform; and
acquiring the frames of echo image data in relating to the timing of the ECG waveform.

14. The method of Claim 13, wherein warping the color map further comprises:

- fitting the color map to the boundaries of the myocardium in each of the additional frames; or
- fitting the color map to the speckle pattern in each of the additional frames.

15. The method of Claim 10, wherein the image frames comprise cardiac image frames, and wherein the additional frames in combination with the warped color map are displayed as a dynamic real time image sequence of the strain characteristics.

Patentansprüche

1. Ultraschallsystem zur diagnostischen Bildgebung zur Echtzeitbildgebung der Verformung (engl. strain), umfassend:

eine Ultraschallbildgebungssonde, die einen Arraywandler aufweist und dafür eingerichtet ist, Ultraschallechosignale zu erfassen;
einen Bildprozessor, der mit der Bildgebungssonde gekoppelt ist und dafür eingerichtet ist, eine erste Sequenz von Einzelbildern zu erzeugen;
einen Verformungsrechner, der mit dem Bildprozessor gekoppelt ist und dafür eingerichtet ist, die Einzelbilder zu verarbeiten, um eine Verformung während der ersten Einzelbildsequenz zu schätzen;
einen Farbkarteneinheit, die dafür eingerichtet ist, zumindest teilweise basierend auf durch den Verformungsrechner erzeugten Verformungswerten eine Farbkarte zu erstellen; und
einen Farbkartenverzerrer, der auf die Farbkarte und eine durch den Bildprozessor erzeugte neue Sequenz von Einzelbildern reagiert, wobei der Farbkartenverzerrer dafür eingerichtet ist, die Farbkarte zu einem Einzelbild der neuen Sequenz zu verzerren, um eine verzerrte Farbkarte zu erzeugen; und
eine Anzeige zum Anzeigen des Einzelbilds der neuen Sequenz in Kombination mit der verzerrten Farbkarte.

2. Ultraschallsystem zur diagnostischen Bildgebung

nach Anspruch 1, wobei die Einzelbilder kardiale Einzelbilder umfassen;
wobei die erste Sequenz von Einzelbildern während eines ersten Herzzyklus erfasst wird; und
wobei die neue Sequenz von Einzelbildern während eines nachfolgenden Herzzyklus erfasst wird.

3. Ultraschallsystem zur diagnostischen Bildgebung nach Anspruch 2, ferner umfassend eine Verschiebungsschätzeinheit, die auf eine Sequenz von Einzelbildern reagiert und die dafür eingerichtet ist, Gewebeverschiebungen über die Einzelbildsequenz zu schätzen.

4. Ultraschallsystem zur diagnostischen Bildgebung nach Anspruch 3, wobei die Verschiebungsschätzeinheit ferner Folgendes umfasst:

einen Verschiebungskreuzkorrelator, der dafür eingerichtet ist, die Verschiebungen zu schätzen, indem er eine Kreuzkorrelation der Echodaten herstellt; und
einen Verschiebungsintegrator, der dafür eingerichtet ist, eine Lagrange-Integration der Verschiebungswerte durchzuführen.

5. Ultraschallsystem zur diagnostischen Bildgebung nach Anspruch 4, ferner umfassend einen Speckle-Verfolger, der Gewebeverschiebungen identifiziert; und
wobei vorzugsweise der Verformungsrechner dafür eingerichtet ist, die Verformung als die räumlichen Ableitungen der Gewebeverschiebungen der Einzelbilder zu schätzen.

6. Ultraschallsystem zur diagnostischen Bildgebung nach Anspruch 5, ferner umfassend einen EKG-Sensor, der mit dem Ultraschallsystem gekoppelt ist und der eine Patienten-EKG-Wellenform erfasst.

7. Ultraschallsystem zur diagnostischen Bildgebung nach Anspruch 6, ferner umfassend einen Strahlformer, der mit dem Arraywandler gekoppelt ist und der arbeitet, um Einzelbildsequenzen in Zusammenhang mit der EKG-Wellenform zu erfassen.

8. Ultraschallsystem zur diagnostischen Bildgebung nach Anspruch 7, ferner umfassend einen Einzelbildspeicher, der mit dem Bildprozessor gekoppelt ist und der Sequenzen von Einzelbildern speichert.

9. Ultraschallsystem zur diagnostischen Bildgebung nach Anspruch 1, wobei der Verformungsrechner dafür eingerichtet ist, die Verformung von jedem Pixel des Einzelbilds als eine Darstellung einer lokalen Verformung zu schätzen.

10. Verfahren zum Erzeugen von Echtzeit-Ultraschallbildern der Verformung, umfassend:

Erfassen von Einzelbildern, die Echobildsignale umfassen;
Schätzen von Gewebeverschiebungen zwischen erfassten Einzelbildern anhand der Echobilddaten;
Berechnen von Verformungswerten zumindest teilweise basierend auf den Gewebeverschiebungen;
Bilden einer Farbkarte der Verformungswerte;
Erfassen zusätzlicher Einzelbilder umfassend Echobilddaten;
Verzerren der Farbkarte zu den zusätzlichen Einzelbildern; und
Anzeigen der zusätzlichen Einzelbilder in Kombination mit der verzerrten Farbkarte.

11. Verfahren nach Anspruch 10, wobei das Erfassen von Einzelbildern von Echobilddaten das Erfassen von Einzelbildern eines Herzens umfasst.

12. Verfahren nach Anspruch 11, wobei das Schätzen von Gewebeverschiebungen ferner das Durchführen von Speckle-Verfolgung umfasst, und
wobei vorzugsweise die Speckle-Verfolgung ferner Folgendes umfasst:

Schätzen von Verschiebungen durch Kreuzkorrelation; und
Durchführen einer Lagrange-Integration von Verschiebungen.

13. Verfahren nach Anspruch 12, ferner umfassend:

Erfassen einer Patienten-EKG-Wellenform; und
Erfassen der Einzelbilder von Echobilddaten in Zusammenhang mit dem Timing der EKG-Wellenform.

14. Verfahren nach Anspruch 13, wobei das Verzerren der Farbkarte ferner Folgendes umfasst:

- Anpassen der Farbkarte an die Ränder des Myokards in jedem der zusätzlichen Einzelbilder; oder
- Anpassen der Farbkarte an das Speckle-Muster in jedem der zusätzlichen Einzelbilder.

15. Verfahren nach Anspruch 10, wobei die Einzelbilder kardiale Einzelbilder umfassen, und wobei die zusätzlichen Einzelbilder in Kombination mit der verzerrten Farbkarte als eine dynamische Echtzeit-Bildsequenz der Verformungseigenschaften angezeigt werden.

Revendications

1. Système d'imagerie de diagnostic ultrasonore pour une imagerie élastographique en temps réel comprenant :

une sonde d'imagerie ultrasonore ayant un transducteur matriciel et configurée pour acquérir des signaux d'écho ultrasonores ;
un processeur d'images couplé à la sonde d'imagerie et qui est configuré pour produire une première séquence de trames d'images ;
un calculateur d'élastographie couplé au processeur d'images et configuré pour traiter les trames d'images afin d'estimer l'élastographie au cours de la première séquence de trames d'images ;
un mappeur de couleurs configuré pour produire une carte de couleurs sur la base au moins en partie de valeurs élastographiques générées par le calculateur d'élastographie ; et
un dispositif de distorsion de carte de couleurs qui est sensible à la carte de couleurs et à une nouvelle séquence de trames d'images générées par le processeur d'images, dans lequel le dispositif de distorsion de carte de couleurs est configuré pour distordre la carte de couleurs en une trame d'image de la nouvelle séquence pour générer une carte de couleurs distordue ; et

un appareil d'affichage pour afficher la trame d'image de la nouvelle séquence en combinaison avec la carte de couleurs distordue.

2. Système d'imagerie de diagnostic ultrasonore selon la revendication 1, dans lequel les trames d'images comprennent des trames d'images cardiaques ;
dans lequel la première séquence de trames d'images est acquise au cours d'un premier cycle cardiaque ; et
dans lequel la nouvelle séquence de trames d'images est acquise au cours d'un cycle cardiaque ultérieur.

3. Système d'imagerie de diagnostic ultrasonore selon la revendication 2, comprenant en outre un estimateur de déplacement sensible à une séquence de trames d'images qui est configurée pour estimer des déplacements tissulaires sur la séquence de trames d'images.

4. Système d'imagerie de diagnostic ultrasonore selon la revendication 3, dans lequel l'estimateur de déplacement comprend en outre :

un corrélateur croisé de déplacement qui est configuré pour estimer les déplacements par corrélation croisée de données d'écho ; et
un intégrateur de déplacement qui est configuré pour effectuer une intégration de Lagrange de valeurs de déplacement.

5. Système d'imagerie de diagnostic ultrasonore selon la revendication 4, comprenant en outre un suiveur de granularité qui identifie des déplacements tissulaires et
dans lequel, de préférence, le calculateur d'élastographie est configuré pour estimer l'élastographie en tant que dérivés spatiaux des déplacements tissulaires des trames d'images.

6. Système d'imagerie de diagnostic ultrasonore selon la revendication 5, comprenant en outre un capteur ECG couplé au système ultrasonore et qui détecte une forme d'onde ECG de patient.

7. Système d'imagerie de diagnostic ultrasonore selon la revendication 6, comprenant en outre un formateur de faisceau couplé au transducteur matriciel et qui opère pour acquérir des séquences de trames d'images en rapport avec la forme d'onde ECG.

8. Système d'imagerie de diagnostic ultrasonore selon la revendication 7, comprenant en outre une mémoire de trames couplée au processeur d'images et qui stocke des séquences de trames d'images.

9. Système d'imagerie de diagnostic ultrasonique selon la revendication 1, dans lequel le calculateur d'élastographie est configuré pour estimer l'élastographie pour chaque pixel de la trame d'image en tant que représentation d'une élastographie locale.

10. Procédé de production d'images élastographiques ultrasonores en temps réel comprenant :

l'acquisition de trames d'images comprenant des données d'images d'écho ;
l'estimation de déplacements tissulaires entre des trames acquises à partir des données d'images d'écho ;
le calcul de valeurs élastographiques sur la base au moins en partie des déplacements tissulaires ;
la formation d'une carte de couleurs des valeurs élastographiques ;
l'acquisition de trames d'images supplémentaires comprenant des données d'images d'écho ;
la distorsion de la carte de couleurs en trames supplémentaires ; et
l'affichage des trames supplémentaires en combinaison avec la carte de couleurs distordue.

11. Procédé selon la revendication 10, dans lequel l'acquisition de trames de données d'images d'écho comprend l'acquisition de trames d'images d'un coeur.

12. Procédé selon la revendication 11, dans lequel l'estimation de déplacements tissulaires comprend en outre le suivi de granularité et
dans lequel, de préférence, le suivi de granularité comprend en outre :

l'estimation de déplacements par corrélations croisées ; et
la réalisation d'une intégration de déplacements de Lagrange.

13. Procédé selon la revendication 12, comprenant en outre :

l'acquisition d'une forme d'onde ECG de patient ; et
l'acquisition des trames de données d'images d'écho en rapport avec la synchronisation de la forme d'onde ECG.

14. Procédé selon la revendication 13, dans lequel la distorsion de la carte de couleurs comprend en outre :

- l'adaptation de la carte de couleurs aux limites du myocarde dans chacune des trames supplémentaires ; ou
- l'adaptation de la carte de couleurs au motif de granularité dans chacune des trames supplémentaires.

15. Procédé selon la revendication 10, dans lequel les trames d'images comprennent des trames d'images cardiaques et dans lequel les trames supplémentaires en combinaison avec la carte de couleurs distordue sont affichées sous la forme d'une séquence d'images dynamiques en temps réel des caractéristiques élastographiques.

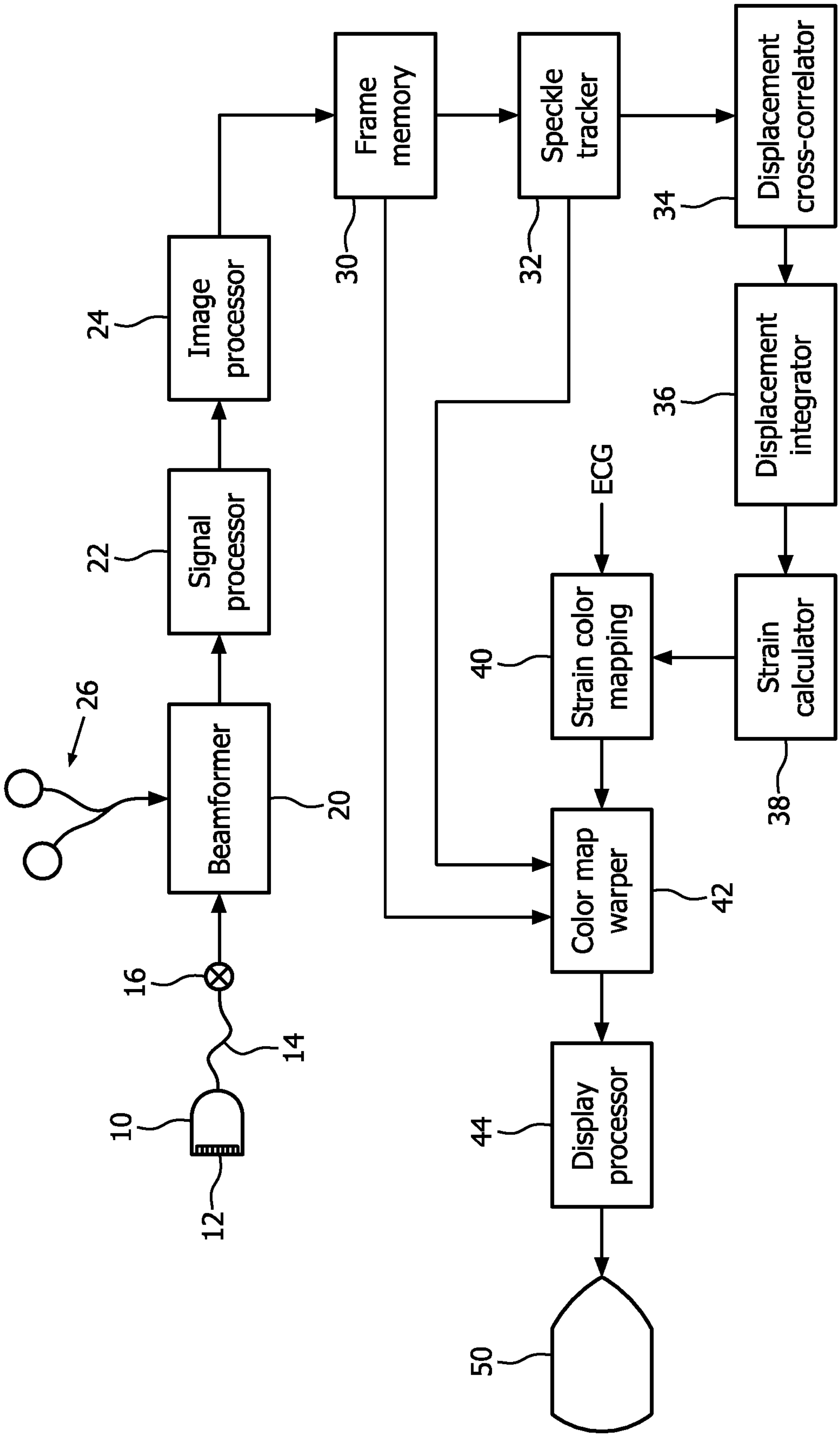
10
12
14
16
26
Beamformer
20
22
Signal processor
24
Image processor
Frame memory
30
Speckle tracker
32
Displacement cross-correlator
34
Displacement integrator
36
Strain calculator
38
ECG
Strain color mapping
40
Color map warper
42
Display processor
44
50

FIG. 1

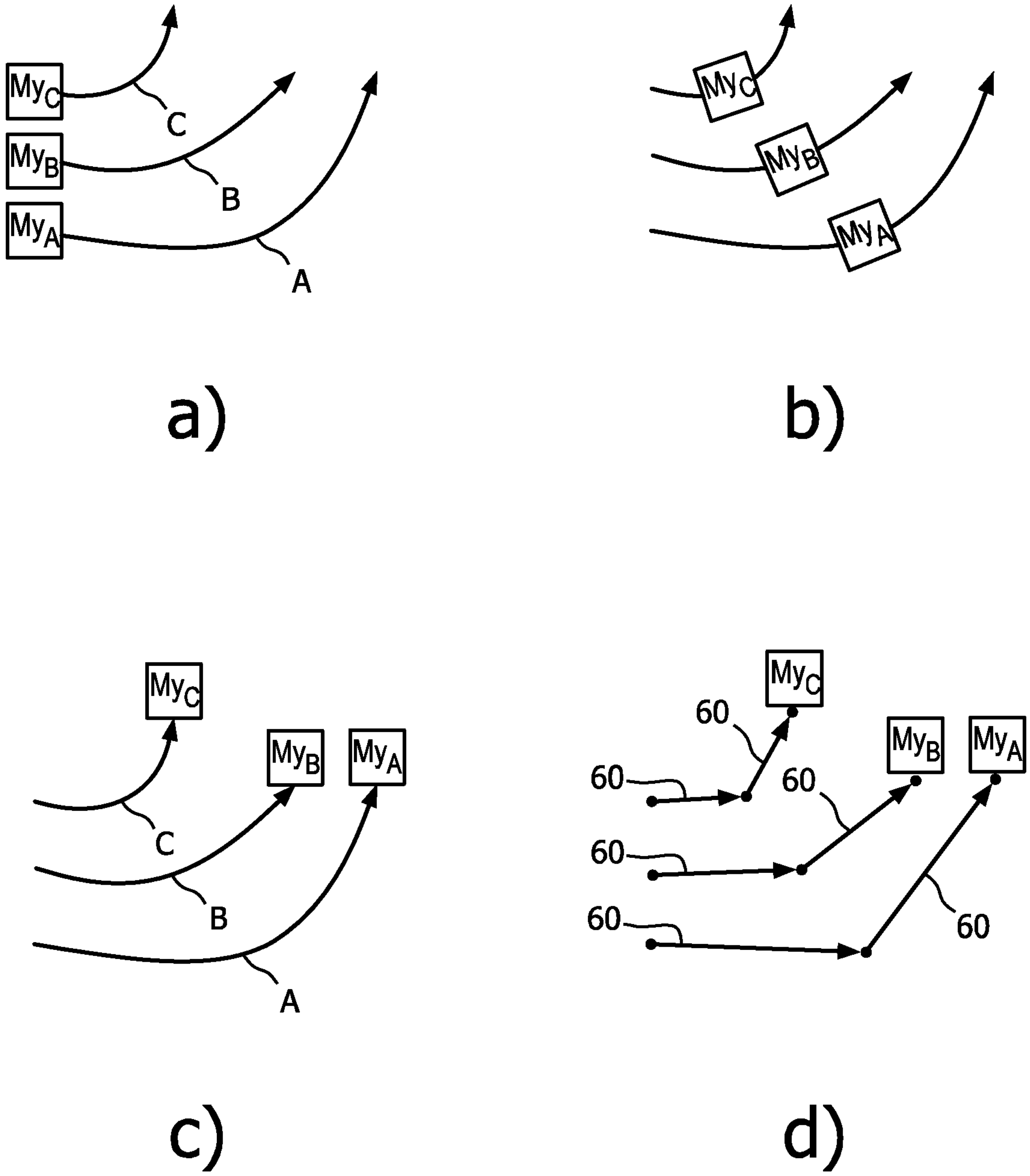
MyC
MyB
MyA
C
B
A
a)
MyC
MyB
MyA
b)
MyC
MyB
MyA
C
B
A
c)
MyC
MyB
MyA
60
60
60
60
60
60
d)

FIG. 2

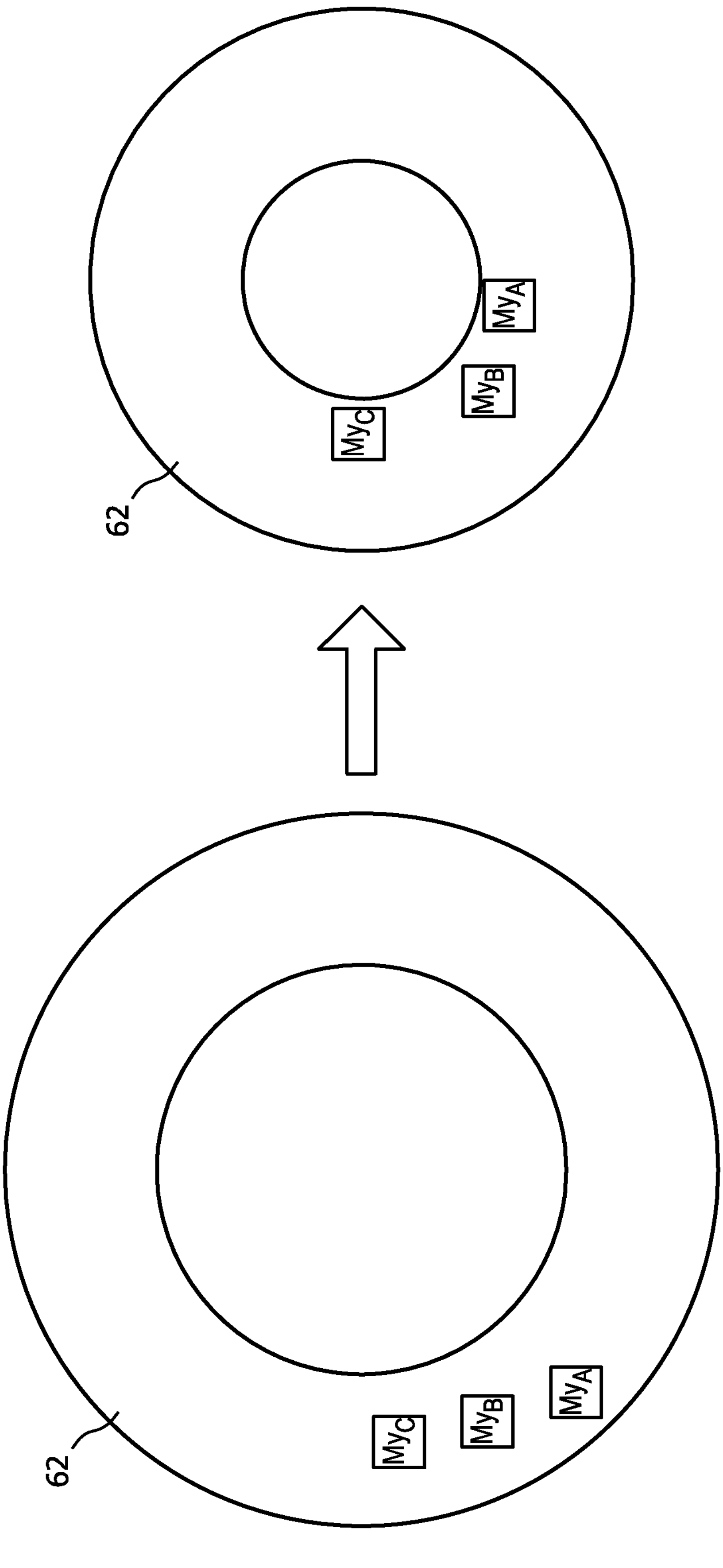

FIG. 3

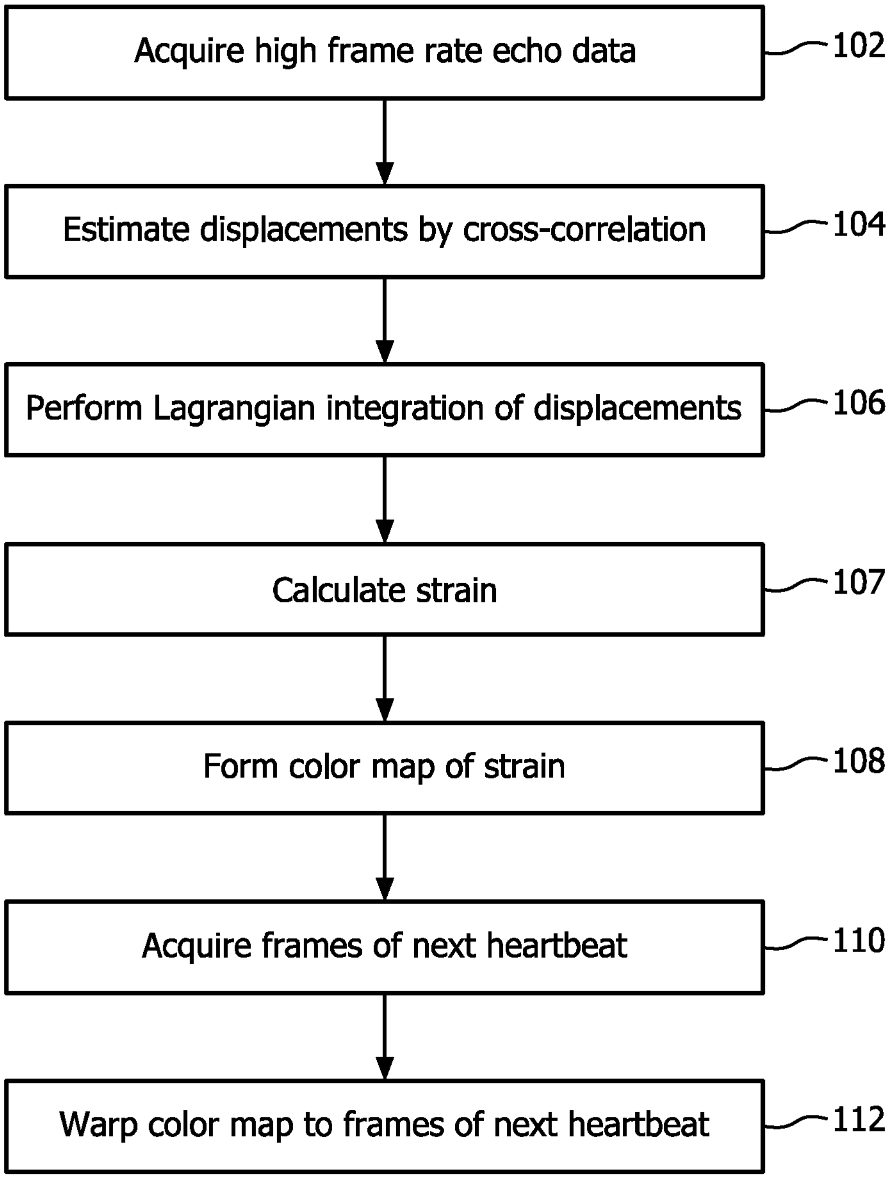
Acquire high frame rate echo data
102
Estimate displacements by cross-correlation
104
Perform Lagrangian integration of displacements
106
Calculate strain
107
Form color map of strain
108
Acquire frames of next heartbeat
110
Warp color map to frames of next heartbeat
112

FIG. 4

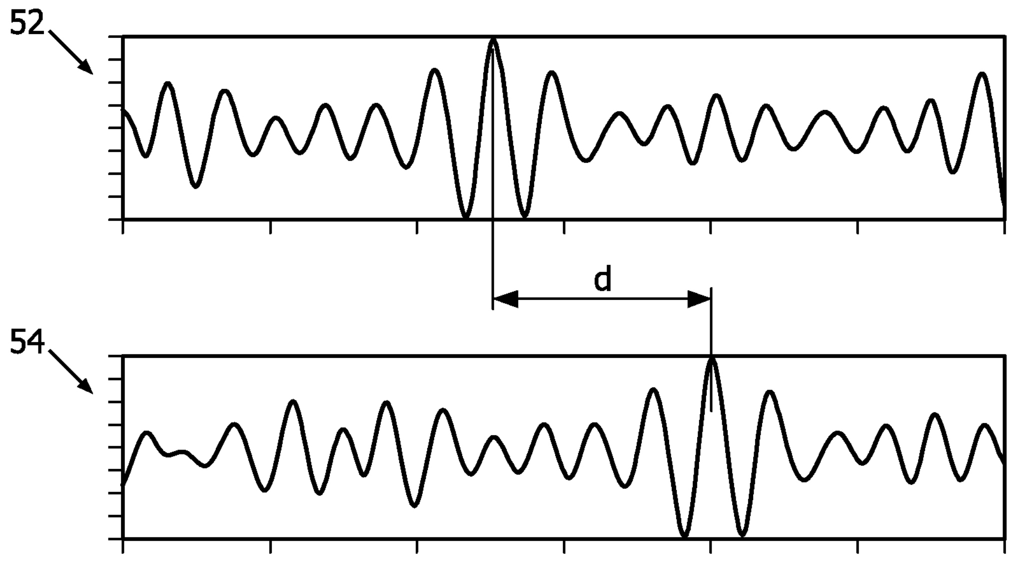
52
54
d

FIG. 5

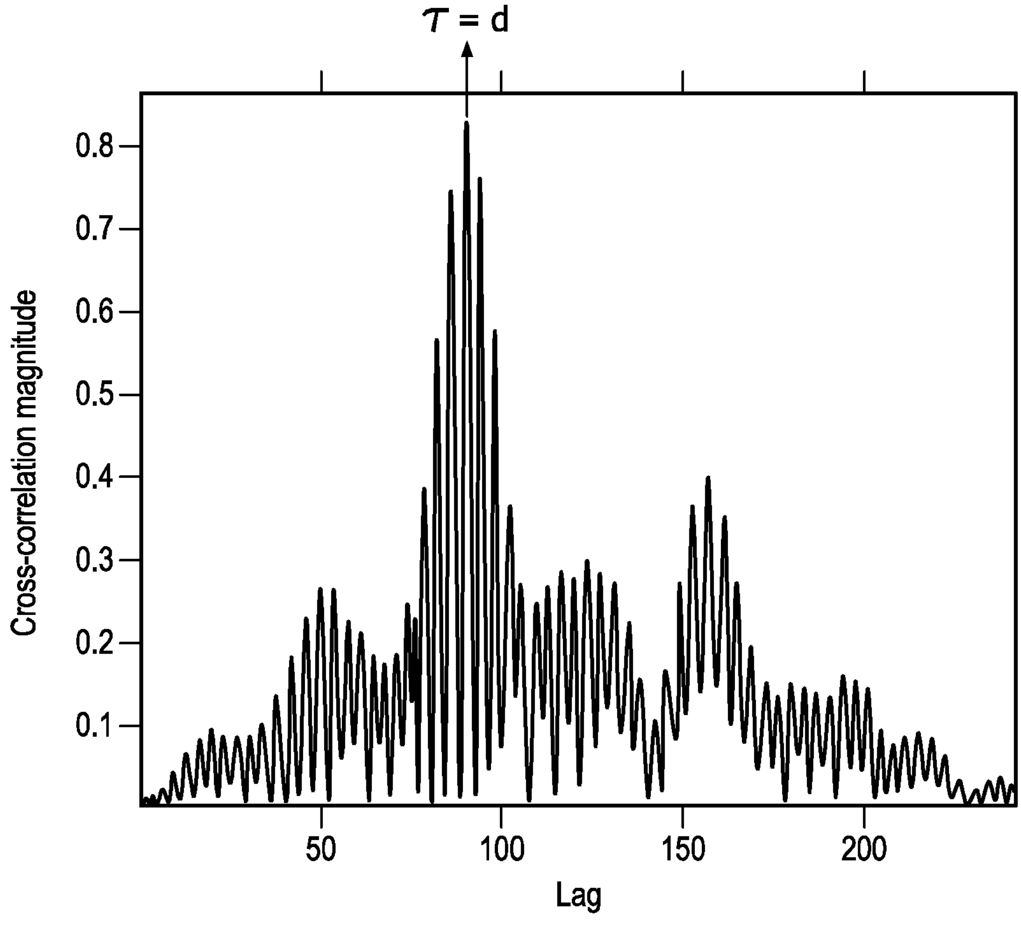
τ = d
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Cross-correlation magnitude
50
100
150
200
Lag

FIG. 6

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 20130286023 A1 **[0003]**

专利名称(译)	实时超声应变成像评价心肌梗死		
公开(公告)号	EP3250131B1	公开(公告)日	2018-12-19
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[标]申请(专利权)人(译)	皇家飞利浦电子股份有限公司		
申请(专利权)人(译)	皇家飞利浦N.V.		
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发明人	PATIL, ABHAY VIJAY INGLE, ATUL THIELE, KARL ERHARD		
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CPC分类号	A61B8/0883 A61B8/461 A61B8/485 A61B8/5246 A61B8/543		
代理机构(译)	STEFFEN，THOMAS		
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外部链接	Espacenet		

摘要(译)

通过获取心脏图像帧序列并估计心脏周期中心肌组织位移来提供实时应变成像。可以使用斑点追踪来估计位移，并且该位移用于计算心肌上的应变。颜色图由应变值形成。在下一个心动周期期间，颜色图被扭曲以适合每个图像帧中的心肌，并且当实时显示时，变形的颜色图显示为新心动周期的每个图像的心肌上的颜色覆盖。还在新的心脏周期上产生新的颜色图，以用于以下心脏周期。还描述了执行实时应变成像的超声系统。

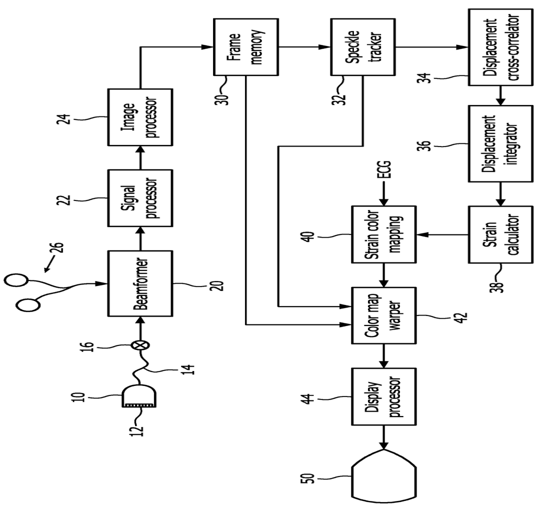

FIG. 1