



- (51) **International Patent Classification:**
A61B 8/08 (2006.01)
- (21) **International Application Number:**
PCT/IB2016/050308
- (22) **International Filing Date:**
22 January 2016 (22.01.2016)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
62/109,209 29 January 2015 (29.01.2015) US
- (71) **Applicant:** KONINKLIJKE PHILIPS N.V. [NL/NL];
High Tech Campus 5, 5656 AE Eindhoven (NL).
- (72) **Inventors:** PATIL, Abhay Vijay; c/o High Tech Campus,
Building 5, 5656 AE Eindhoven (NL). INGLE, Atul; c/o
High Tech Campus, Building 5, 5656 AE Eindhoven (NL).
THIELE, Karl Erhard; c/o High Tech Campus, Building
5, 5656 AE Eindhoven (NL).
- (74) **Agents:** STEFFEN, Thomas et al.; High Tech Campus
Building 5, 5656 AE Eindhoven (NL).
- (81) **Designated States** (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,

AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

- (84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))

Published:

- with international search report (Art. 21(3))



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

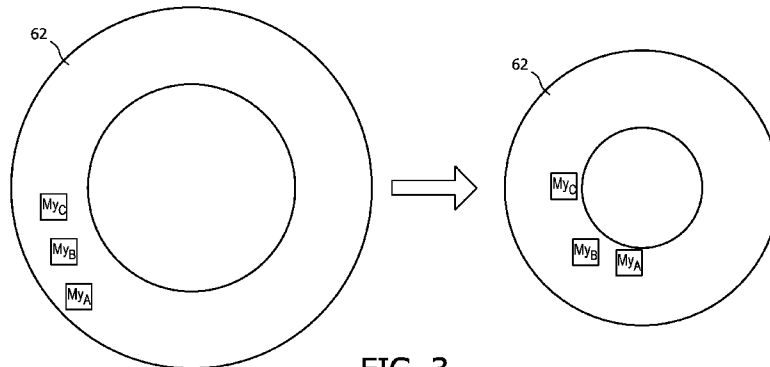


FIG. 3

(57) **Abstract:** Real time strain imaging is provided by acquiring a sequence of cardiac image frames and estimating tissue displacement in the myocardium over a heart cycle. The displacements may be estimated using speckle tracking and are used to calculate strain over the myocardium. A color map is formed of the strain values. During the next heart cycle the color map is warped to fit the myocardium in each image frame and the warped color map is displayed as a color overlay over the myocardium of each image of the new heart cycle as they are displayed in real time. A new color map is also produced over the new heart cycle of the following heart cycle. An ultrasound system which performs real time strain imaging is also described.

EVALUATION OF CARDIAC INFARCTION
BY REAL TIME ULTRASONIC STRAIN IMAGING

5 This application claims priority to U.S. Prov.
Appl. No. 62/109,209, filed on January 29, 2015,
which is incorporated by reference herein.

10 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.

15 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
20 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
25 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
30 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
35 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
5 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
10 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.

In some aspects, the present invention includes
15 ultrasound systems, such as an ultrasonic diagnostic imaging system for real time strain imaging that includes an ultrasound imaging probe having an array transducer which acquires ultrasound echo signals, an image processor, coupled to the imaging probe, which
20 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
25 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
30 a display which displays an image frame in combination with the warped color map.

In certain aspects, the present invention can include an ultrasound imaging system having
instructions thereon, which when executed, cause the system to acquire ultrasound echo signals using an
35 ultrasound imaging probe having an array transducer,

produce a first sequence of image frames in real time, process image frame data of the image frames to estimate strain during the image frame sequence, produce a color map based at least in-part on the strain values, warp or fit the color map to an image frame of a new sequence of images to generate a warped color map, and display an image frame in combination with the warped color map.

In some aspects, the present invention includes methods of ultrasound imaging, such as 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 warped color maps.

In the drawings:

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

5 In accordance with the principles of 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
10 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
15 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
20 spatial strain variation, and corresponding contractility characteristics.

In some aspects, the present invention provides ultrasonic diagnostic imaging systems for real time strain imaging. The ultrasound systems can include a
25 variety of components, such as an ultrasound imaging probe. The probe can include an array transducer which acquires ultrasound echo signals. The systems can include an image processor. The image processor can be coupled to the imaging probe and configured to
30 produce a first sequence of image frames in real time. The systems can include a strain calculator coupled to the image processor. The strain calculator can be configured to process image frame data to estimate strain during the image frame
35 sequence. The systems can 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 can be configured to produce a color map based on the strain values. The systems can include a color map warper. The systems can 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 map warper. The color map warper can be 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 can also include a display which displays an image frame in combination with the warped color map.

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.

In certain embodiments, the systems can include a displacement estimator. The systems can include a color mapper. 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 can be responsive to a sequence of image frames and configured 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.

In some embodiments, the systems can include a speckle tracker which identifies tissue
5 displacements. The systems can include a color mapper. 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
10 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.

15 Referring first to FIGURE 1, an ultrasound system constructed in accordance with the principles of 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
20 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
25 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
30 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
35 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.

5 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 10 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, 15 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 20 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 25 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 30 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 35 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

5 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

10 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

15 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

20 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

25 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

30 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.

35 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
5 calculated.

In accordance with the principles of 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
10 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
15 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
20 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
25 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
30 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.

As successive image frames of the new heart
35 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
5 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
10 cycle thus includes the fitted strain color overlay which thereby displays a dynamic real time image sequence of the strain characteristics of the myocardium.

Optionally, the tracked speckle values of each
15 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
20 are continually repositioned to match with their changing corresponding speckle locations in each new image frame.

At the same time that this display methodology is ongoing, elements 32-40 of the ultrasound system
25 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.

FIGURE 2 illustrates how individual points of
30 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.
35 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 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.

In certain aspects, the present invention includes methods of producing real time ultrasonic strain images. The methods can 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, displaying the additional frames in combination with
5 warped color maps generated by warping the color map to the additional frames.

In some aspects, acquiring frames of echo image data can include acquiring image frames of a heart. Estimating tissue displacements can include
10 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
15 acquiring the frames of echo image data in relating to the timing of the ECG waveform.

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
20 include fitting the color map to the speckle pattern in each of the additional frames.

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
25 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
30 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
35 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
5 calculated as the spatial derivatives of the displacements. The strain values are then used to form a color map in step 108.

In step 110 image frames of the next heartbeat are acquired. The color map is then warped to fit
10 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
15 heartbeat are processed to form a color map to be used as a warped overlay with the image frames of the following heart cycle.

It will be understood that each block of the block diagram illustrations, and combinations of
20 blocks in the block diagram illustrations, as well as any portion of the systems and methods disclosed herein, can be implemented by computer program instructions. These program instructions may be provided to a processor to produce a machine, such
25 that the instructions, which execute on the processor, create means for implementing the actions specified in the block diagram block or blocks or described for the systems and methods disclosed herein. The computer program instructions may be
30 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.
35 Moreover, some of the steps may also be performed

across more than one processor, such as might arise
in a multi-processor computer system. In addition,
one or more processes may also be performed
concurrently with other processes, or even in a
5 different sequence than illustrated without departing
from the scope or spirit of the invention.

The computer program instructions can be stored
on any suitable computer-readable hardware medium
including, but not limited to, RAM, ROM, EEPROM,
10 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
15 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.

20

WHAT IS CLAIMED IS:

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

5 an ultrasound imaging probe having an array transducer and being configured to acquire ultrasound echo signals;

10 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;

15 a color mapper configured to produce a color map based at least in-part on strain values generated by the strain calculator; and

20 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

25 a display for displaying an image frame in combination with the warped color map.

2. The ultrasonic diagnostic imaging system of Claim 1, wherein the image frames further comprise cardiac image frames;

30 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.

35 3. The ultrasonic diagnostic imaging system of

Claim 2, further comprising a displacement estimator responsive to a sequence of image frames which estimates tissue displacements over the image frame sequence.

5

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

10 a displacement cross-correlator which estimates displacements by cross-correlating echo data; and
a displacement integrator which performs Lagrangian integrated displacement values.

15 5. The ultrasonic diagnostic imaging system of Claim 4, further comprising a speckle tracker which identifies tissue displacements.

20 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.

25 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.

30 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.

35 9. 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
5 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;
10 and
displaying the additional frames in combination
with warped color maps.

10. The method of Claim 9, wherein acquiring
15 frames of echo image data further comprises acquiring
image frames of a heart.

11. The method of Claim 10, wherein estimating
tissue displacements further comprises performing
20 speckle tracking.

12. The method of Claim 11, wherein speckle
tracking further comprises:
estimating displacements by cross-correlation;
25 and
performing Lagrangian integration of
displacements.

13. The method of Claim 12, further comprising:
30 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
35 color map further comprises fitting the color map to

the boundaries of the myocardium in each of the additional frames.

5 15. The method of Claim 13, wherein warping the color map further comprises fitting the color map to the speckle pattern in each of the additional frames.

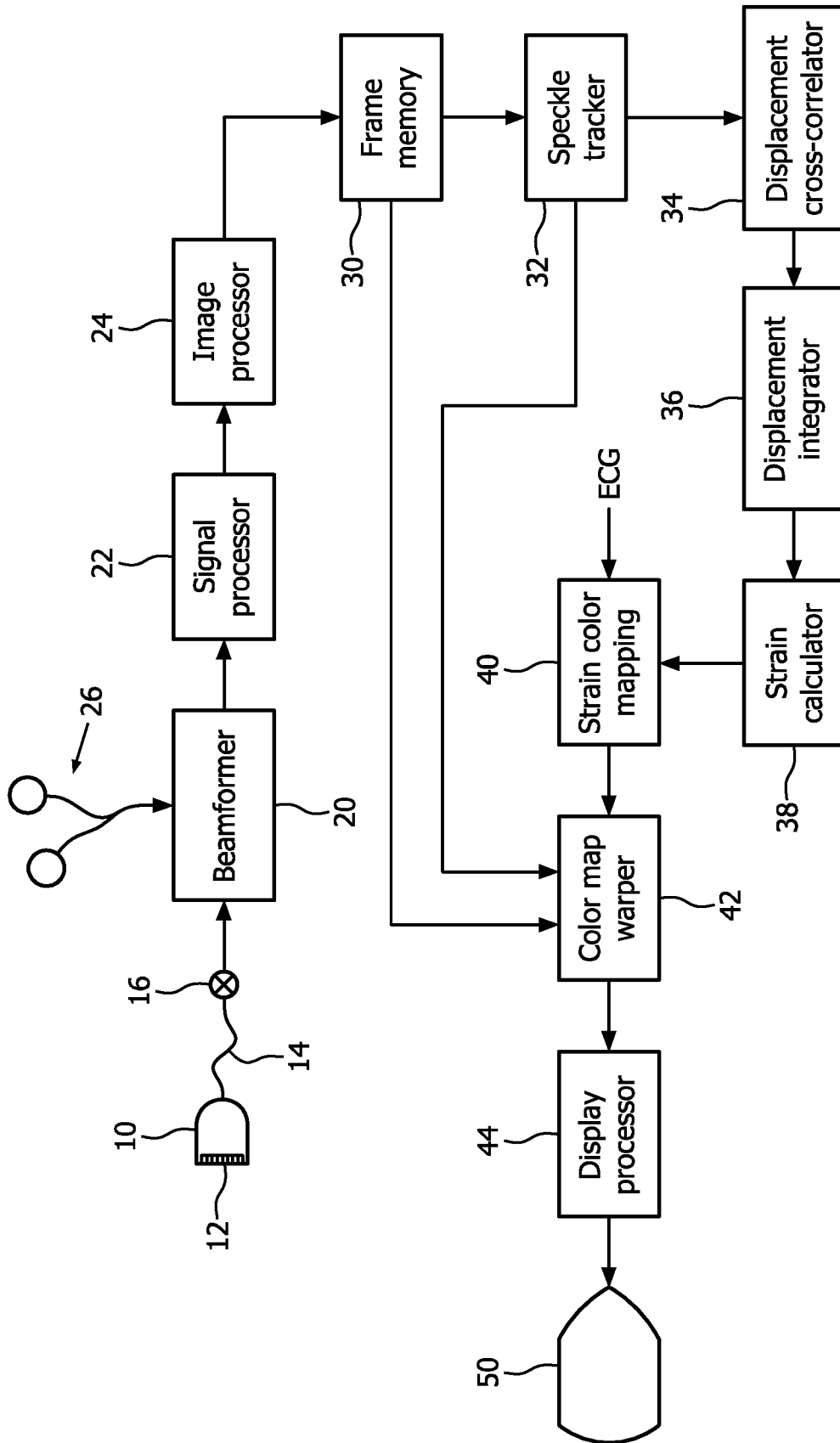
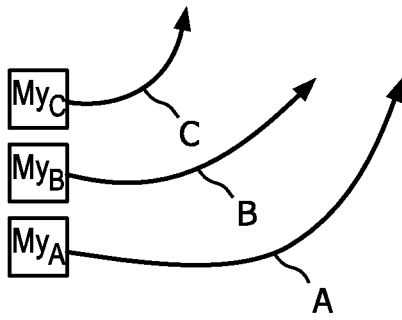
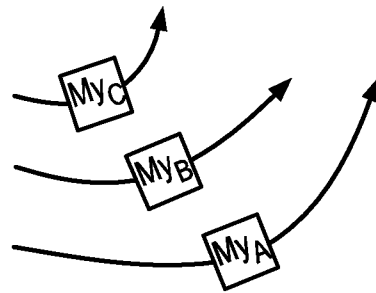


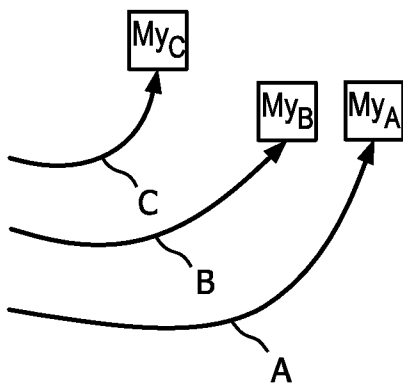
FIG. 1



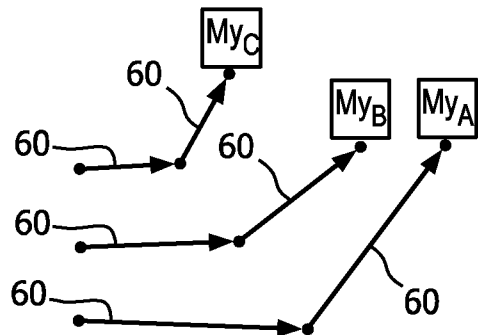
a)



b)



c)



d)

FIG. 2

4/5

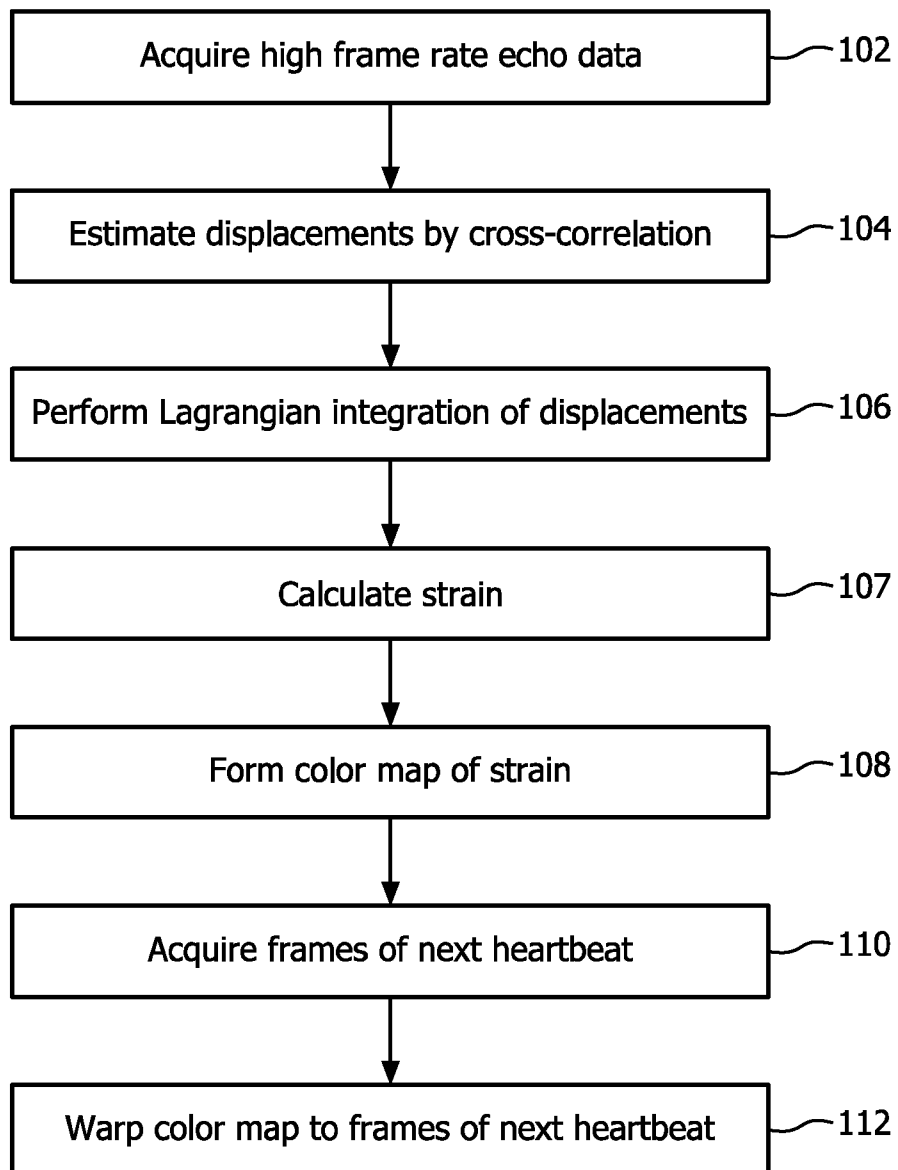


FIG. 4

5/5

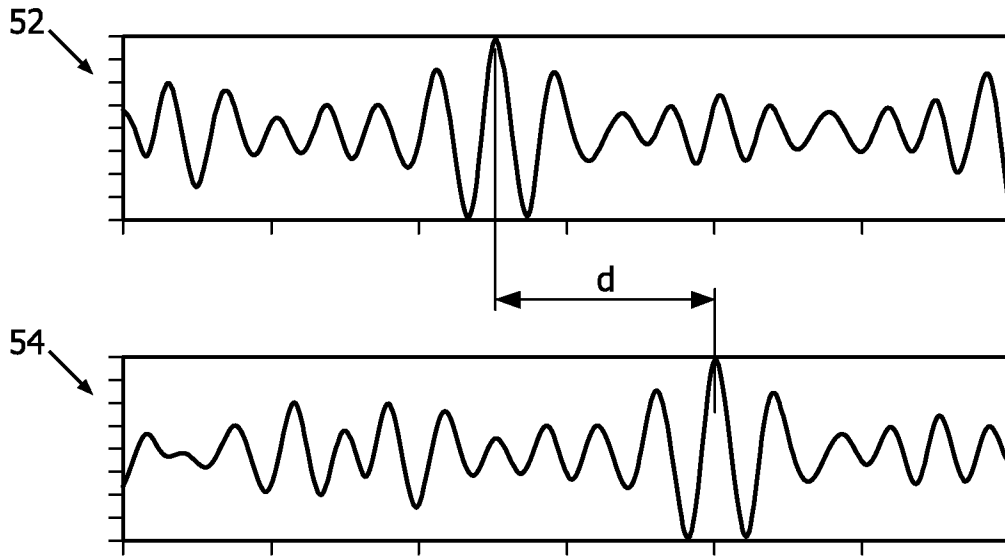


FIG. 5

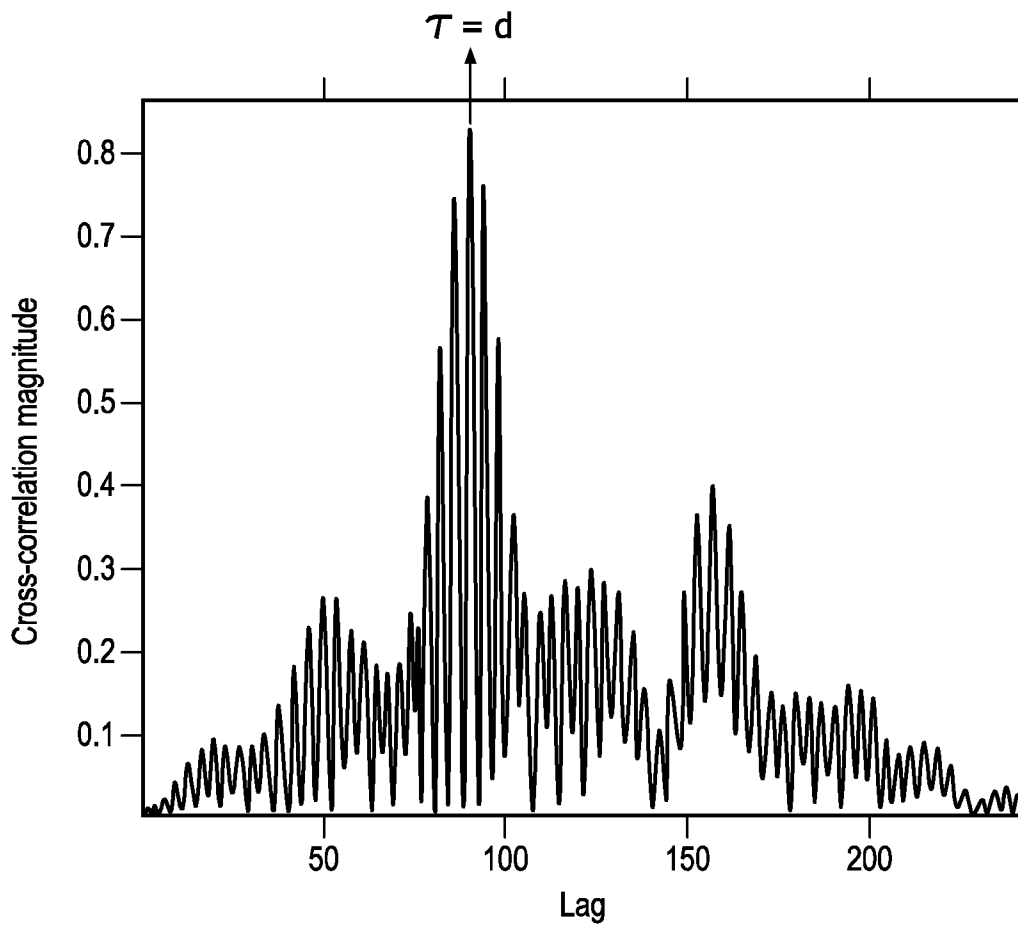


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No PCT/IB2016/050308
--

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B8/08
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61B G01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013/286023 A1 (FRIEDMAN ZVI [IL] ET AL) 31 October 2013 (2013-10-31) paragraphs [0016] - [0026], [0032]; figures -----	1-15
A	US 2005/288589 A1 (HOULE HELENE C [US] ET AL) 29 December 2005 (2005-12-29) paragraphs [0017] - [0018], [0023], [0030] - [0040]; figures -----	1-15
A	US 2003/083578 A1 (ABE YASUHIKO [JP] ET AL) 1 May 2003 (2003-05-01) paragraphs [0042] - [0081], [0126] - [0128]; figures ----- -/--	1-15

Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents :

<p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier application or patent but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p>	<p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&" document member of the same patent family</p>
---	---

Date of the actual completion of the international search 21 April 2016	Date of mailing of the international search report 06/05/2016
---	---

Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Küster, Gunilla
--	--

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2016/050308

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2009/318803 A1 (ABE YASUHIKO [JP] ET AL) 24 December 2009 (2009-12-24) paragraphs [0003], [0050], [0054] - [0061], [0065] - [0086]; figures -----	1-15
A	JP 2006 141451 A (TOSHIBA CORP; TOSHIBA MEDICAL SYS CORP) 8 June 2006 (2006-06-08) the whole document -----	1-15
A	LUO J ET AL: "Detection of murine infarcts using myocardial elastography at both high temporal and spatial resolution", CONFERENCE PROCEEDINGS OF THE 28TH IEEE EMBS ANNUAL INTERNATIONAL CONFERENCE; 30 AUG.-3 SEPT. 2006; NEW YORK, NY, USA, 30 August 2006 (2006-08-30), pages 1552-1555, XP031339390, ISBN: 978-1-4244-0032-4 the whole document -----	1-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No PCT/IB2016/050308

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013286023	A1	31-10-2013	CN 101066212 A
			DE 102007021515 A1
			JP 2007296335 A
			US 2007258632 A1
			US 2013286023 A1
			US 2014347388 A1

US 2005288589	A1	29-12-2005	NONE

US 2003083578	A1	01-05-2003	JP 4734395 B2
			JP 2009011861 A
			US 2003083578 A1

US 2009318803	A1	24-12-2009	CN 101606850 A
			JP 5259267 B2
			JP 2010000199 A
			US 2009318803 A1

JP 2006141451	A	08-06-2006	JP 4795672 B2
			JP 2006141451 A
