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(54) **Correlation of ultrasound images and gated position measurements**

Korrelation von Ultraschallbildern und torgesteuerten Positionsmessungen

Corrélation d'images à ultrasons et mesures de positions commandées par porte

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Description

FIELD OF THE INVENTION

[0001] The present invention relates generally to medical imaging systems, and particularly to imaging using ultrasound and position tracking systems.

BACKGROUND OF THE INVENTION

[0002] Some medical imaging systems track the position of a probe, such as a catheter, which is fitted with a position sensor and an ultrasonic transducer. The position measurements of the probe, coupled with the images produced by the ultrasonic transducer, are used for imaging and/or modeling of a target organ. An exemplary system of this sort is described in U.S. Patent Application Publication 2006/0241445.

[0003] Several methods and systems are known in the art for calibrating probes that include ultrasound transducers and position sensors. For example, U.S. Patent Application Publication 2004/0254458. describes an apparatus for calibrating a probe comprising an ultrasonic transducer and a position measurement device. The apparatus includes a test fixture comprising an ultrasonic target that is disposed therein at a known position. A processor receives a position signal from the position sensor while the transducer aligned to the ultrasonic target determines the orientation of the probe in the frame of reference of the test fixture. The processor determines the calibrated data of the probe related to the orientation.

[0004] Additional methods and systems for calibrating ultrasound and position tracking probes are described, for example, in U.S. Patents 6,192,735 , 6,517,484 and 6,585,651.

[0005] A paper entitled "Development of a Portable 3D Ultrasound Imaging System for Musculoskeletal Tissues" by Huong *et al.*, discloses a calibration apparatus having a motion assembly and a processor to calculate timing offset of ultrasound images produced by an ultrasound transducer and marked by placing a cross-wire phantom recognisable by the ultrasound transducer in a water tank to mark an ultrasound image for calibration purposes. This apparatus forms the closest prior art for the present invention.

[0006] A paper entitled "Stradx: real-time acquisition and visualisation of freehand ultrasound" by Prager *et al.*, discloses a system capable of using a difference measure to examine incoming image streams.

SUMMARY OF THE INVENTION

[0007] There is therefore provided, in accordance with the present invention, a calibration apparatus according to claim 1.

[0008] In some embodiments, the imaging probe includes an electrode that captures a signal for gating the ultrasound images and the position measurements, the marking circuit is arranged to mark the signal that is captured by the electrode when the imaging probe is at the calibration point, and the processor is arranged to calibrate a time delay between the signal and between the first and second sequences using the marked signal. In an embodiment, the signal includes an electrocardiogram (ECG) signal, and the electrode includes an intracardiac ECG-sensing electrode.

[0009] In another embodiment, the motion assembly includes a wheel and a movable arm, such that a first end of the arm is connected to the wheel and a second end of the arm is attached to the imaging probe, and the wheel is arranged to rotate so as to move the imaging probe through the calibration point.

[0010] In yet another embodiment, the marking circuit includes a modulation circuit, which is arranged to generate an ultrasonic marking signal, which has a frequency that can be sensed by the ultrasound transducer, responsively to the electrical signal and to mark the ultrasound image using the ultrasonic marking signal. In still another embodiment, the modulation circuit includes an induction coil, which is located in a vicinity of the imaging probe and is arranged to induce a Radio Frequency (RF) signal in the ultrasound transducer so as to mark the ultrasound image.

[0011] In a disclosed embodiment, the processor is arranged to identify the marked ultrasound image by comparing intensity values of the images in the first sequence to a predetermined threshold.

[0012] In some embodiments, the calibration point includes two or more different calibration points having known coordinates, the motion assembly is arranged to move the imaging probe through the two or more calibration points, the marking circuit is arranged to mark the ultrasound images acquired by the ultrasound transducer when the imaging probe is at the two or more calibration points, and the processor is arranged to calibrate the time offset between the first and second sequences by associating the marked ultrasound images with respective position measurements whose coordinates match the coordinates of the respective calibration points. Additionally or alternatively, the motion assembly is arranged to move the imaging probe across the calibration point in at least two instances, and the processor is arranged to measure respective values of the time offset at the at least two instances and to average the measured values.

[0013] There is additionally provided, in accordance with the present invention, a method for calibration according to claim 10.

[0014] There is also provided, in accordance with the present invention, a computer software product for use in a calibration apparatus according to claim 19.

[0015] The present invention will be more fully understood from the following detailed description of the embodiments thereof, taken together with the drawings in which:

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

Fig. 1 is a schematic, pictorial illustration of a system for cardiac mapping and imaging, in accordance with an embodiment of the present invention;
Fig. 2 is a schematic, pictorial illustration of a catheter, in accordance with an embodiment of the present invention;
Fig. 3 is a block diagram that schematically illustrates elements of a system for cardiac mapping and imaging, in accordance with an embodiment of the present invention;
Fig. 4 is a schematic, pictorial illustration of a electromechanical calibration assembly, in accordance with an embodiment of the present invention;
Fig. 5 is a signal timing diagram showing correlation of position measurements with ultrasound images, in accordance with an embodiment of the present invention; and
Fig. 6 is a flow chart that schematically illustrates a method for correlating position measurements with ultrasound images, in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

OVERVIEW

[0017] Some medical imaging procedures use combined ultrasound imaging and position tracking. In such procedures, an intra-body probe, such as a catheter, performs ultrasound imaging of a target organ using an ultrasound transducer. In parallel, the position of the probe in or around the target organ is determined using a position sensor.

[0018] When the probe is moved through multiple positions in or around the target organ, an ultrasound imaging subsystem outputs a sequence of two-dimensional (2-D) ultrasound images, which are generated by the ultrasound transducer. In parallel, a position tracking subsystem outputs a sequence of position measurements, which are generated by the position sensor. The position measurements are then used to determine the location and orientation of each of the 2-D ultrasound images in the three-dimensional (3-D) space of the target organ.

[0019] In many practical cases, however, the sequence of ultrasound images and the sequence of position measurements are uncorrelated. Generally, the rate at which ultrasound images are acquired may be different from the rate of position measurements, and the two sequences may have an unknown time offset with respect to one another. In order to perform imaging of the target organ, the ultrasound images and position measurements should be correlated with one another, so as to correctly determine the position (location and orientation) of the probe at the time each ultrasound image was acquired.

[0020] Embodiments of the present invention provide methods and systems for correlating the sequences of ultrasound images and position measurements. In some embodiments, the probe is placed in a calibration subsystem, which moves the probe through one or more calibration points, whose coordinates are known *a-priori.* For example, the calibration subsystem may comprise a rotating wheel connected to a moving arm, wherein the probe is attached to the arm. When the probe reaches one of the calibration points, the calibration subsystem produces a pulse, which is used for marking the ultrasound image acquired at this position.

[0021] The calibration subsystem further comprises a calibration processor, which identifies the marked ultrasound images and associates them with corresponding position measurements measured at the calibration points. The calibration processor calculates the time offset between the ultrasound images and the corresponding position measurements. The calculated time offset value is stored and used to correlate between the ultrasound images and the position measurements.

SYSTEM DESCRIPTION

[0022] Fig. 1 is a schematic, pictorial illustration of a system 20 for imaging and mapping a heart 24 of a patient, in accordance with an embodiment of the present invention. The system comprises a catheter 28, which is inserted by a physician into a chamber of the heart through a vein or artery. The physician can steer, position and orient the distal end of the catheter as desired.

[0023] System 20 comprises a position tracking subsystem and an ultrasound imaging subsystem. The position tracking subsystem measures the position (i.e., location and orientation) coordinates of catheter 28. In some embodiments, for example, the position tracking subsystem comprises a magnetic position tracking system. The magnetic position tracking system comprises a set of external radiators, such as field generating coils 30, which are located in fixed, known positions external to the patient. Coils 30 generate magnetic fields in the vicinity of heart 24. A position sensor fitted inside catheter 28 senses the generated magnetic, fields and produces position signals in response to the sensed fields. A console 34 comprises a positioning processor 36, which accepts the position signals from catheter 28 and calculates the location and orientation of the catheter based on these signals. In alternative embodiments, the positioning subsystem may comprise any other suitable type of position tracking system, such as impedance-based systems.

[0024] The ultrasound imaging subsystem acquires multiple ultrasound images of heart 24. An ultrasound transducer fitted in catheter 28 acquires the ultrasound images, typically comprising 2-D sector-shaped images. Console 34 comprises an image processor 42, which accepts the 2-D ultrasound images and uses them to image heart 24. The output of processor 42 is displayed on a display 44.

[0025] Image processor 42 may image heart 24 in a variety of ways. For example, the image processor may use the multiple 2-D images to construct a three-dimensional (3-D) model of the heart. The image processor may also project the acquired 2-D images in 3-D space and present the projected images to a user. Additionally or alternatively, the image processor may register the 2-D ultrasound images with a 3-D image of a different modality, such as a Computerized Tomography (CT) or Magnetic Resonance Imaging (MRI) image, and present the overlaid images to the user. Some aspects of 3-D imaging based on 2-D ultrasound images are described, for example, in U.S. Patent Application Publication 2006/0241445, cited above. Further additionally or alternatively, the image processor may perform any other suitable imaging and/or mapping procedure of heart 24 based on the acquired 2-D ultrasound images.

[0026] Fig. 2 is a schematic, pictorial illustration showing the distal end of catheter 28, in accordance with an embodiment of the present invention. Catheter 28 comprises an ultrasound transducer 39, which comprises an array of sensor elements 40. In one embodiment, elements 40 comprise piezo-electric devices. Transducer 39 is positioned in or adjacent to a window 41, which defines an opening within the body or wall of the catheter.

[0027] Elements 40 of transducer 39 operate as a phased array, jointly transmitting an ultrasound beam from the array aperture through window 41. In some embodiments, the array transmits a short burst of ultrasound energy and then switches to a receiving mode for receiving the ultrasound signals, or echoes, reflected from the surrounding tissue. After receiving the reflected ultrasound echoes, electric signals based on the reflected echoes are sent by elements 40 over cables 33 through catheter 28 to image processor 42 in console 34, which transforms them into 2-D ultrasound images.

[0028] Since some features of the heart change their shape and position during the heart's periodic contraction and relaxation, the imaging methods carried out by image processor 42 are often performed at a particular timing with respect to this period. This process is commonly referred to as gating. In order to perform gated imaging, both the ultrasound images and the position measurements are typically synchronized to an electrocardiogram (ECG) signal. The ECG signal, also referred to as a gating signal, may be produced by a body-surface or intra-cardiac electrode, such as an electrode 46 fitted in catheter 28. In some embodiments, electrode 46 may also be used for performing intra-cardiac ablation for treatment purposes.

[0029] As noted above, image processor 42 may perform 3-D imaging of the heart using the 2-D ultrasound images. As part of performing this task, processor 42 positions the 2-D ultrasound images at their appropriate locations and orientations in 3-D space. In order to properly position the ultrasound images, each 2-D ultrasound image should be associated with the position measurement produced by the catheter at the exact time the image was acquired. Inaccurate positioning of the 2-D images would introduce errors and distortion into the 3-D imaging process.

[0030] In many practical cases, however, the sequence of ultrasound images generated by the ultrasound imaging subsystem and the sequence of position measurements generated by the positioning subsystem are asynchronous and uncorrelated. For example, in some cases the ultrasound imaging subsystem comprises a standalone unit, such as a commercial imager, which is separate from the position tracking subsystem. The rate of position measurements may be different from the rate of ultrasound image acquisition. Furthermore, the ultrasound imaging subsystem and the positioning subsystem generally have different processing delays. Consequently, the sequence of ultrasound images and the sequence of position measurements usually have a relative time offset, which is not known *a-priori.*

[0031] The methods and systems described herein correlate the ultrasound images with the corresponding position measurements, so that each ultrasound image is associated with the position measurement taken at the time the image was acquired. In some embodiments, such as when the image sequence and the position measurement sequence have a constant relative time offset, this time offset is calculated and used for correlating images and position measurements.

[0032] In some embodiments, catheter 28 comprises an ECG-sensing electrode such as electrode 46. The intra-cardiac ECG signal, which is produced by the heart tissue and sensed by electrode 46, may also have a certain time offset with respect to the ultrasound images and/or the position measurements. In these embodiments, a marking signal is also inserted into the gating signal produced by the ECG sensing electrode. The methods and systems described herein can also measure and calibrate the time offset between the ECG signal and between the ultrasound images and position measurements, so that ECG gating can be performed accurately, i.e., at the desired phase of the cardiac cycle.

[0033] Fig. 3 is a block diagram that schematically illustrates elements of system 20, in accordance with an embodiment of the present invention. System 20 comprises a calibration subsystem 50, which comprises an electro-mechanical calibration assembly 59 (also referred to as a motion assembly) and a calibration processor 57. When performing calibration, catheter 28 is placed in the electro-mechanical assembly. Assembly 59 moves the catheter through one or more calibration points having known *a-priori* position coordinates. When the calibration subsystem senses that the catheter passes through one of the calibration points, it inserts a distinctive mark into the ultrasound image that is currently acquired by the catheter. When catheter 28 comprises an ECG-sensing electrode, a mark can also be inserted onto the ECG signal produced by this electrode.

[0034] Calibration processor 57 accepts the sequence of position measurements from positioning processor 36 and the sequence of 2-D ultrasound images from image processor 42. Processor 57 may also accept the ECG signals produced by electrode 46. The calibration processor associates the marked ultrasound image with the position measurement having the position coordinates of the calibration point in which the image was acquired. Thus, the calibration processor can calculate the time offset between the sequence of ultrasound images and the sequence of position measurements, and to correlate the two sequences. When an ECG signal is also provided, the calibration processor can calculate the time offset between this signal and either the position measurements or the ultrasound images. Generally, the accuracy of the time offset calculation improves with the rate of position measurements and with the rate of the ultrasound images.

[0035] Typically, calibration processor 57 is implemented using a general-purpose computer, which is programmed in software to carry out the functions described herein. The software may be downloaded to the computer in electronic form, over a network, for example, or it may alternatively be supplied to the computer on tangible media, such as CD-ROM. In some embodiments, the functionality of calibration processor 57 may be carried out by image processor 42, by another processor in the ultrasound imaging subsystem, by positioning processor 36 or by another processor in the positioning subsystem.

[0036] Calibration subsystem 50 may be integrated as part of system 20 and carry out the calibration procedure when the system is initialized. Alternatively, the calibration subsystem may be a separate subsystem, which is connected to system 20 only when calibration is needed. The output of subsystem 50, i.e., the calculated relative time offset value, may be stored in memory and/or provided to image processor 42 or to positioning processor 36 using any suitable interface. Typically, subsystem 50, or at least assembly 59, is located in the working volume of the position tracking subsystem, in order to measure the position coordinates of catheter 28 during calibration.

[0037] Fig. 4 is a schematic, pictorial illustration that shows electro-mechanical assembly 59, in accordance with an exemplary embodiment of the present invention. In the exemplary embodiment of Fig. 4, assembly 59 comprises a movable arm (denoted 55A and 55B when positioned at two different positions, as explained below), which is connected to a rotating wheel 51. Catheter 28 is attached to the distal end of the arm during the calibration procedure.

[0038] When wheel 51 rotates, such as using a suitable motor, the arm moves catheter 28 through multiple positions. In particular, the catheter passes through two calibration points, or calibration positions, which are denoted "-Position A" and "Position B" in the figure. The position coordinates of the calibration points are premeasured and known in advance. The movable arm is labeled 55A when the catheter is at calibration point A and labeled 55B (dashed) when the catheter is at calibration point B.

[0039] An optical emitter, such as a light-emitting diode (LED), is mounted on the perimeter of wheel 51. The optical emitter is shown at two positions in the figure: when the catheter is at calibration point A the emitter is labeled 52A, and when the catheter is at calibration point B the emitter is labeled 52B (dashed). The optical emitter typically emits a narrow light beam outwards from the wheel.

[0040] Optical sensors 53 and 54 are mounted adjacently to the external circumference of the rotating wheel, such that when the catheter reaches calibration point A, the emitter is at position 52A and is aligned with optical sensor 53. Similarly, when the catheter reaches calibration point B, the emitter is at position 52B and is aligned with optical sensor 54. Each of the optical sensors generates a short electrical pulse when illuminated by the optical emitter. Thus, sensor 53 generates a pulse when catheter 28 is at calibration point A, and sensor 54 generates a pulse when the catheter is at calibration point B. In some embodiments, sensor 53 emits a positive pulse and sensor 54 emits a negative pulse.

[0041] The pulses generated by optical sensors 53 and 54 are provided to a Radio Frequency (RF) modulator 58. Modulator 58 modulates the pulses generated by the emitters onto an RF carrier, whose frequency is in the range used by the ultrasound imaging subsystem. The RF pulses generated by modulator 58 are used to drive an induction coil 56, which is positioned in the vicinity of catheter 28. When triggered, coil 56 induces an RF pulse that is sensed by ultrasound transducer 39 of catheter 28. As a result, the video signal of the ultrasound image that is currently acquired by catheter 28 is marked with a distinct calibration mark. The magnitude of the induced RF pulse is typically chosen so that the intensity of the mark is significantly stronger than any ultrasound echo that might be sensed by transducer 39.

[0042] In some embodiments, when using gated imaging, the modulator outputs an additional signal, which is used for marking the gating signal produced by electrode 46, responsively to the pulses generated by optical sensors 53 and 54. The marked gating signal is subsequently used by the calibration processor to calibrate the time offset between the ECG signal and the ultrasound images and/or position measurements.

[0043] The modulator and induction coil can be viewed collectively as a modulation circuit, which generates ultrasonic marking signals (e.g., RF pulses) based on the outputs of the optical sensors, and marks the ultrasound images using these marking signals. Alternatively to using an induction coil, the modulation circuit may comprise any other suitable mechanism, which produces an ultrasonic marking signal that can be sensed by ultrasound transducer 39. Further alternatively, the currently-acquired image can be marked by electrically adding a voltage pulse to the signals produced by transducer 39. In alternative embodiments, the optical emitter can be driven with an RF signal, such that the pulses generated by optical sensors 53 and 54 are already modulated, thus eliminating the need for modulator 58.

[0044] Typically, the pulse width of the pulses generated by the optical emitters is selected to be sufficiently narrow, so that only a single ultrasound image is marked. Typically, the pulse width is several milliseconds long, significantly shorter than the acquisition time of a single ultrasound image.

[0045] As noted above, calibration processor 57 accepts the sequence of ultrasound images and the sequence of position measurements, which are generally uncorrelated. The calibration processor identifies the ultrasound image in which the calibration mark was embedded, such as by comparing the intensity values in the images to a predetermined threshold.

[0046] The calibration processor also locates, within the sequence of position measurements produced by the positioning subsystem, a position measurement whose coordinates match (e.g., coincide with or are nearest to) the coordinates of the corresponding calibration point. The time difference between the marked ultrasound image and between the position measurement measured at the corresponding calibration point is indicative of the time offset between the sequence of ultrasound images and the sequence of position measurements.

[0047] In some embodiments, the calibration processor calculates the time offset for each of calibration points A and B and averages the result. Alternatively, only a single calibration point may be used. Regardless of the number of calibration points used, the calibration processor may improve the estimation accuracy by rotating wheel 51 several complete rotations and using the generated pulses for averaging a multiplicity of time offset calculations. The calibration processor typically stores the estimated time offset for use during operation of system 20.

[0048] Although the exemplary embodiment of Fig. 4 refers to a mechanical assembly that uses an arm and a rotating wheel, the methods and systems described herein can be used with any other suitable motion assembly that moves catheter 28 via the calibration points.

[0049] The optical emitter, optical sensors, modulator and induction coil can be viewed collectively as an marking circuit, which marks the currently-acquired ultrasound image when the catheter is in one of the calibration points. Alternatively, any other suitable method, assembly or circuit for producing a trigger signal when the catheter reaches a calibration point and for marking the currently-acquired ultrasound image based on such a trigger, can also be used. For example, the trigger can be produced using a magnet and a magnetic sensor, a laser source and an optical sensor, a volume sensor, or any other suitable mechanism.

[0050] Fig. 5 is a signal timing diagram showing an exemplary process of correlating position measurements with ultrasound images, in accordance with an embodiment of the present invention. Electrical pulses 70 and 71 are generated by optical emitters 53 and 54 when catheter 28 reaches calibration points A and B, respectively. Pulses 72 and 73 denote the modulated RF pulses produced by modulator 58 in response to pulses 70 and 71, respectively. A plot 75 shows the video signal of the ultrasound images acquired by transducer 39 of catheter 28. Successive ultrasound images are denoted N-1, N, N+1, ... The video signal of image N is marked with a calibration mark 76 responsively to pulse 72. The mark that corresponds to pulse 73 is not shown for the sake of clarity.

[0051] A measurement sequence 77 denotes the sequence of position measurements produced by positioning processor 36. A position measurement 78 denotes the position measurement whose coordinates match the coordinates of calibration point A. A measurement sequence 79 denotes the sequence of ultrasound images produced by image processor 42. As can be appreciated, the delay between the image acquisition by catheter 28 (plot 75) and between the output of the image processor (sequence 79) may be several image cycles long.

[0052] As explained above, calibration processor 57 estimates the time offset between the marked image (image N) in sequence 79 and between the position measurement measured at calibration point A (measurement 78). This time offset is denoted ΔT in the figure. Although in the present example the offset is measured with respect to the beginning of the marked image, the offset can alternatively be measured with respect to the end of the marked image or to any other suitable reference point in the image.

CALIBRATION METHOD DESCRIPTION

[0053] Fig. 6 is a flow chart that schematically illustrates a method for correlating, position measurements with ultrasound images, in accordance with an embodiment of the present invention. The method begins with assembly 59 moving catheter 28 through the different calibration points, at a catheter scanning step 80.

[0054] When the catheter reaches one of the calibration points, the optical emitter aligns with one of optical sensors 53 and 54. As a result, the optical sensor aligned with the emitter produces a pulse, at a pulse generation step 82. Modulator 58 modulates the pulse generated by the optical sensor, at a modulation step 84. Induction coil 56 marks the video signal of the currently-acquired ultrasound image, at an image marking step 85. The process of steps 80-85 above can be repeated for one or more calibration points and/or for multiple measurements of each calibration point.

[0055] Calibration processor 57 identifies the marked images in the sequence of ultrasound images produced by image processor 42, at an image identification step 86. For each identified marked image, the calibration processor locates the position measurement, whose coordinates match the coordinates of the calibration point in question, at a position measurement identification step 87. The calibration processor calculates the time offset between each marked image and the corresponding position measurement, at a time offset calculation step 88. The calibration processor typically averages the different measured time offsets in order to improve the estimation accuracy. The calculated and averaged time offset is stored and subsequently used for coordinating between the ultrasound images and position measurements during operation of system 20.

[0056] Although the embodiments described herein mainly address calibration of a catheter-based imaging system, the principles of the present invention can also be used for calibrating other types of probes fitted with position sensors and ultrasound transducers, such as endoscopes. Although the embodiments described herein mainly refer to imaging of the heart, the principles of the present invention can also be used for imaging and modeling of other organs.

Claims

1. A calibration apparatus (50), comprising:

    a motion assembly (59), which is arranged to move an imaging probe (28) through a calibration point having known coordinates, the imaging probe including an ultrasound transducer (39) and a position sensor (40) for acquiring concurrently a first sequence of ultrasound images and a second sequence of position measurements;
    a marking circuit (52A, 52B, 53, 54), which is arranged to mark an ultrasound image that is acquired by the ultrasound transducer (39) in the first sequence when the imaging probe (28) is at the calibration point; and
    a processor (57), which is arranged to calibrate a time offset between the first and second sequences by associating the marked ultrasound image in the first sequence with a position measurement in the second sequence whose coordinates match the coordinates of the calibration point;
    characterised in that:

    the marking circuit (52A, 52B, 53, 54) comprises an optical emitter (52A, 52B), which is arranged to emit light, and an optical sensor (53, 54), which is arranged to sense the light and generate an electrical signal responsively to the sensed light when aligned with the optical emitter (52A, 52B), and wherein the optical emitter (52A, 52B) and the optical sensor (53, 54) are attached to the motion assembly (59) so as to align with one another and generate the electrical signal when the imaging probe (28) is at the calibration point, in order to mark the ultrasound image responsively to the electrical signal.

2. The apparatus according to claim 1, wherein the motion assembly (59) comprises a wheel (51) and a movable arm (55A, 55B), wherein a first end of the arm is connected to the wheel (51) and a second end of the arm (55A, 55B) is arranged to be attached to the imaging probe (28), and wherein the wheel (51) is arranged to rotate so as to move the imaging probe (28) through the calibration point.

3. The apparatus according to claim 1, wherein the marking circuit (52A, 52B, 53, 54) comprises a modulation circuit (58), which is arranged to generate an ultrasonic marking signal, which has a frequency that can be sensed by the ultrasound transducer (39), responsively to the electrical signal and to mark the ultrasound image using the ultrasonic marking signal.

4. The apparatus according to claim 3, wherein the modulation circuit (58) comprises an induction coil (56), which is located in a vicinity of the imaging probe (28) and is arranged to induce a Radio Frequency (RF) signal in the ultrasound transducer (39) so as to mark the ultrasound image.

5. The apparatus according to claim 1, wherein the processor (57) is arranged to identify the marked ultrasound image by comparing intensity values of the images in the first sequence to a predetermined threshold.

6. The apparatus according to claim 1, wherein the calibration point comprises two or more different calibration points having known coordinates, wherein the motion assembly (59) is arranged to move the imaging probe (28) through the two or more calibration points, wherein the marking circuit (52A, 52B, 53, 54) is arranged to mark the ultrasound images acquired by the ultrasound transducer (39) when the imaging probe (28) is at the two or more calibration points, and wherein the processor (57) is arranged to calibrate the time offset between the first and second sequences by associating the marked ultrasound images with respective position measurements whose coordinates match the coordinates of the respective calibration points.

7. The apparatus according to claim 1, wherein the motion assembly (59) is arranged to move the imaging probe (28) across the calibration point in at least two instances, and wherein the processor (57) is arranged to measure respective values of the time offset at the at least two instances and to average the measured values.

8. The apparatus according to claim 1, wherein the imaging probe (28) includes an electrode (46) that produces a gating signal for gating the ultrasound images and the position measurements, wherein the marking circuit (52A, 52B, 53, 54) is arranged to mark the gating signal that is produced by the electrode (46) when the imaging probe (28) is at the calibration point, and wherein the processor (57) is arranged to calibrate a time delay between the gating signal and between the first and second sequences using the marked gating signal.

9. The apparatus according to claim 8, wherein the gating signal comprises an electrocardiogram (ECG) signal, and wherein the electrode comprises an intracardiac ECG-sensing electrode.

10. A method for calibration, comprising:

operating an imaging probe (28), which includes a position sensor (40) and an ultrasound transducer (39), so as to acquire concurrently a first sequence of ultrasound images using the ultrasound transducer (39) and a second sequence of position measurements using the position sensor (40);
moving the imaging probe (28) through a calibration point having known coordinates;
marking an ultrasound image that is acquired by the ultrasound transducer (39) in the first sequence when the imaging probe (28) is at the calibration point; and
calibrating a time offset between the first and second sequences by associating the marked ultrasound image in the first sequence with a position measurement in the second sequence whose coordinates match the coordinates of the calibration point;
characterised in that:

marking the ultrasound image comprises positioning an optical emitter (52A, 52B), which emits light, and an optical sensor (53, 54), which senses the light and generates an electrical signal responsively to the sensed light when aligned with the optical emitter (52A, 52B), to align with one another and generate the electrical signal when the imaging probe (28) is at the calibration point, and marking the ultrasound image responsively to the electrical signal.

11. The method according to claim 10, wherein moving the imaging probe (28) comprises attaching the imaging probe (28) to a first end of a movable arm (55A, 55B) whose second end is connected to a wheel (51), and rotating the wheel (51) so as to move the imaging probe through the calibration point.

12. The method according to claim 10, wherein marking the ultrasound image comprises generating an ultrasonic marking signal, which has a frequency that can be sensed by the ultrasound transducer (39), responsively to the electrical signal, and marking the ultrasound image using the ultrasonic marking signal.

13. The method according to claim 12, wherein marking the ultrasound image using the ultrasonic marking signal comprises inducing a Radio Frequency (RF) signal in the ultrasound transducer (39) using an induction coil (56), which is located in a vicinity of the imaging probe (28).

14. The method according to claim 10, wherein calibrating the time offset comprises identifying the marked ultrasound image by comparing intensity values of the images in the first sequence to a predetermined threshold.

15. The method according to claim 10, wherein moving the imaging probe (28) comprises moving the probe (28) through two or more different calibration points having known coordinates, wherein marking the ultrasound image comprises marking the ultrasound images acquired by the ultrasound transducer when the imaging probe (28) is at the two or more calibration points, and wherein calibrating the time offset between the first and second sequences comprises associating the marked ultrasound images with respective position measurements whose coordinates match the coordinates of the respective calibration points.

16. The method according to claim 10, wherein moving the imaging probe (28) comprises crossing the calibration point in at least two instances, and wherein calibrating the time offset comprises measuring values of the time offset at the at least two instances and averaging the measured values.

17. The method according to claim 10, wherein the imaging probe (28) includes an electrode (46) that produces a gating signal for gating the ultrasound images and the position measurements, and comprising marking the gating signal that is produced by the electrode (46) when the imaging probe (28) is at the calibration point, and calibrating a time delay between the gating signal and between the first and second sequences using the marked gating signal.

18. The method according to claim 17, wherein the gating signal comprises an electrocardiogram (ECG) signal, and wherein the electrode (46) comprises an intra-cardiac ECG-sensing electrode.

19. A computer software product for use in a processor-

based calibration apparatus (50), which includes a motion assembly (59) that moves an imaging probe (28), which concurrently acquires a first sequence of ultrasound images using an ultrasound transducer (39) and a second sequence of position measurements using a position sensor (40), through a calibration point having known coordinates, and further includes a marking circuit (52A, 52B, 53, 54), which marks an ultrasound image that is acquired by the ultrasound transducer (39) in the first sequence when the imaging probe (28) is at the calibration point, the product comprising a computer-readable medium, in which program instructions are stored, which instructions, when read by the calibration apparatus, cause the calibration apparatus to calibrate a time offset between the first and second sequences by associating the marked ultrasound image in the first sequence with a position measurement in the second sequence whose coordinates match the coordinates of the calibration point;
characterised in that:

the calibration apparatus calibrates a time offset using the marked ultrasound image produced by the marking circuit (52A, 52B, 53, 54) that comprises an optical emitter (52A, 52B), which is arranged to emit light and an optical sensor (53, 54), which is arranged to sense the light and generate an electrical signal responsively to the sensed light when aligned with the optical emitter (52A, 52B), and wherein the optical emitter (52A, 52B) and the optical sensor (53, 54) are attached to the motion assembly (59) so as to align with one another and generate the electrical signal when the imaging probe (28) is at the calibration point, in order to mark the ultrasound image responsively to the electrical signal.

20. The product according to claim 19, wherein the instructions cause the calibration apparatus to identify the marked ultrasound image by comparing intensity values of the images in the first sequence to a predetermined threshold.

21. The product according to claim 19, wherein the calibration point comprises two or more different calibration points having known coordinates, wherein the motion assembly (59) moves the imaging probe (28) through the two or more calibration points, wherein the marking circuit (52A, 52B, 53, 54) marks the ultrasound images acquired by the ultrasound transducer (39) when the imaging probe (28) is at the two or more calibration points, and wherein the instructions cause the calibration apparatus to calibrate the time offset between the first and second sequences by associating the marked ultrasound images with respective position measurements whose coordinates match the coordinates of the respective calibration points.

22. The product according to claim 19, wherein the motion assembly (59) moves the imaging probe (28) across the calibration point in at least two instances, and wherein the instructions cause the calibration apparatus to measure respective values of the time offset at the at least two instances and to average the measured values.

Patentansprüche

1. Kalibrierungsvorrichtung (50), die Folgendes umfasst:

eine Bewegungsbaugruppe (59), die ausgelegt ist zum Bewegen einer Bildgebungssonde (28) durch einen Kalibrierungspunkt mit bekannten Koordinaten, wobei die Bildgebungssonde einen Ultraschallwandler (39) und einen Positionssensor (40) zum gleichzeitigen Erfassen einer ersten Sequenz von Ultraschallbildern und einer zweiten Sequenz von Positionsmessungen enthält;
eine Markierungsschaltung (52A, 52B, 53, 54), die ausgelegt ist zum Markieren eines Ultraschallbilds, das durch den Ultraschallwandler (39) in der ersten Sequenz erfasst wird, wenn sich die Bildgebungssonde (28) an dem Kalibrierungspunkt befindet; und
einen Prozessor (57), der ausgelegt ist zum Kalibrieren eines zeitlichen Versatzes zwischen der ersten und zweiten Sequenz durch Assoziieren des markierten Ultraschallbilds in der ersten Sequenz mit einer Positionsmessung in der zweiten Sequenz, deren Koordinaten den Koordinaten des Kalibrierungspunkts entsprechen;
dadurch gekennzeichnet, dass:

die Markierungsschaltung (52A, 52B, 53, 54) einen optischen Emitter (52A, 52B) umfasst, der ausgelegt ist zum Emittieren von Licht, und einen optischen Sensor (53, 54), der ausgelegt ist zum Erfassen des Lichts und Generieren eines elektrischen Signals als Reaktion auf das erfasste Licht, wenn auf den optischen Emitter (52A, 52B) ausgerichtet, und wobei der optische Emitter (52A, 52B) und der optische Sensor (53, 54) an der Bewegungsbaugruppe (59) so angebracht sind, dass sie aufeinander ausgerichtet sind und das elektrische Signal generieren, wenn sich die Bildgebungssonde (28) an dem Kalibrierungspunkt befindet, um das Ultraschallbild als Reaktion auf das elektrische Signal zu markieren.

2. Vorrichtung nach Anspruch 1, wobei die Bewegungsbaugruppe (59) ein Rad (51) und einen beweglichen Arm (55A, 55B) umfasst, wobei ein erstes Ende des Arms mit dem Rad (51) verbunden ist und ein zweites Ende des Arms (55A, 55B) ausgelegt ist, um an der Bildgebungssonde (28) angebracht zu werden, und wobei das Rad (51) ausgelegt ist zum Drehen, um die Bildgebungssonde (28) durch den Kalibrierungspunkt zu bewegen.

3. Vorrichtung nach Anspruch 1, wobei die Markierungsschaltung (52A, 52B, 53, 54) eine Modulationsschaltung (58) umfasst, die ausgelegt ist zum Generieren eines Ultraschallmarkierungssignals, das eine Frequenz aufweist, die von dem Ultraschallwandler (39) erfasst werden kann, als Reaktion auf das elektrische Signal und zum Markieren des Ultraschallbilds unter Verwendung des Ultraschallmarkierungssignals.

4. Vorrichtung nach Anspruch 3, wobei die Modulationsschaltung (58) eine Induktionsspule (56) umfasst, die sich in einer Nähe der Bildgebungssonde (28) befindet und ausgelegt ist zum Induzieren eines Hochfrequenzsignals (HF) in dem Ultraschallwandler (39), um das Ultraschallbild zu markieren.

5. Vorrichtung nach Anspruch 1, wobei der Prozessor (57) ausgelegt ist zum Identifizieren des markierten Ultraschallbilds durch Vergleichen von Intensitätswerten der Bilder in der ersten Sequenz mit einem vorbestimmten Schwellwert.

6. Vorrichtung nach Anspruch 1, wobei der Kalibrierungspunkt zwei oder mehr verschiedene Kalibrierungspunkte mit bekannten Koordinaten umfasst, wobei die Bewegungsbaugruppe (59) ausgelegt ist zum Bewegen der Bildsonde (28) durch die zwei oder mehr Kalibrierungspunkte, wobei die Markierungsschaltung (52A, 52B, 53, 54) ausgelegt ist zum Markieren der von dem Ultraschallwandler (39) erfassten Ultraschallbilder, wenn sich die Bildgebungssonde (28) an den zwei oder mehr Kalibrierungspunkten befindet, und wobei der Prozessor (57) ausgelegt ist zum Kalibrieren des zeitlichen Versatzes zwischen der ersten und zweiten Sequenz durch Assoziieren der markierten Ultraschallbilder mit jeweiligen Positionsmessungen, deren Koordinaten den Koordinaten der jeweiligen Kalibrierungspunkte entsprechen.

7. Vorrichtung nach Anspruch 1, wobei die Bewegungsbaugruppe (59) ausgelegt ist zum Bewegen der Bildgebungssonde (28) durch den Kalibrierungspunkt in mindestens zwei Fällen und wobei der Prozessor (57) ausgelegt ist zum Messen jeweiliger Werte des zeitlichen Versatzes der mindestens zwei Fälle und zum Mitteln der gemessenen Werte.

8. Vorrichtung nach Anspruch 1, wobei die Bildgebungssonde (28) eine Elektrode (46) enthält, die ein Ansteuerungssignal zum Ansteuern der Ultraschallbilder und der Positionsmessungen erzeugt, wobei die Markierungsschaltung (52A, 52B, 53, 54) ausgelegt ist zum Markieren des Ansteuerungssignals, das von der Elektrode (46) erzeugt wird, wenn sich die Bildgebungssonde (28) bei dem Kalibrierungspunkt befindet, wobei der Prozessor (57) ausgelegt ist zum Kalibrieren einer zeitlichen Verzögerung zwischen dem Ansteuerungssignal und zwischen der ersten und zweiten Sequenz unter Verwendung des markierten Ansteuerungssignals.

9. Vorrichtung nach Anspruch 8, wobei das Ansteuerungssignal ein Elektrokardiogrammsignal (EKG) umfasst und wobei die Elektrode eine intrakardiale EKG-Erfassungselektrode umfasst.

10. Verfahren zur Kalibrierung, das Folgendes umfasst:

Betreiben einer Bildgebungssonde (28), die einen Positionssensor (40) und einen Ultraschallwandler (39) enthält, um gleichzeitig eine erste Sequenz von Ultraschallbildern unter Verwendung des Ultraschallwandlers (39) und eine zweite Sequenz von Positionsmessungen unter Verwendung des Positionssensors (40) zu erfassen;

Bewegen der Bildgebungssonde (28) durch einen Kalibrierungspunkt mit bekannten Koordinaten;

Markieren eines Ultraschallbilds, das von dem Ultraschallwandler (39) in der ersten Sequenz erfasst wird, wenn sich die Bildgebungssonde (28) bei dem Kalibrierungspunkt befindet; und

Kalibrieren eines zeitlichen Versatzes zwischen der ersten und zweiten Sequenz durch Assoziieren des markierten Ultraschallbilds in der ersten Sequenz mit einer Positionsmessung in der zweiten Sequenz, deren Koordinaten den Koordinaten des Kalibrierungspunkts entsprechen;

dadurch gekennzeichnet, dass:

das Markieren des Ultraschallbilds das Positionieren eines optischen Emitters (52A, 52B), der Licht emittiert, und eines optischen Sensors (53, 54), der das Licht erfasst und als Reaktion auf das erfasste Licht ein elektrisches Signal generiert, wenn auf den optischen Emitter (52A, 52B) ausgerichtet, umfasst, um aufeinander auszurichten und das elektrische Signal zu generieren, wenn sich die Bildgebungssonde (28) bei dem Kalibrierungspunkt befindet, und Markieren des Ultraschallbilds als Reaktion auf das elektrische Signal.

11. Verfahren nach Anspruch 10, wobei das Bewegen der Bildgebungssonde (28) das Anbringen der Bildgebungssonde (28) an einem ersten Ende eines beweglichen Arms (55A, 55B) umfasst, dessen zweites Ende mit einem Rad (51) verbunden ist, und das Drehen des Rads (51), um die Bildgebungssonde durch den Kalibrierungspunkt zu bewegen.

12. Verfahren nach Anspruch 10, wobei das Markieren des Ultraschallbilds das Generieren eines Ultraschallmarkierungssignals umfasst, das eine Frequenz aufweist, die von dem Ultraschallwandler (39) erfasst werden kann, als Reaktion auf das elektrische Signal, und Markieren des Ultraschallbilds unter Verwendung des Ultraschallmarkierungssignals.

13. Verfahren nach Anspruch 12, wobei das Markieren des Ultraschallbilds unter Verwendung des Ultraschallmarkierungssignals das Induzieren eines Hochfrequenzsignals (HF) in dem Ultraschallwandler (39) unter Verwendung einer Induktionsspule (56) umfasst, die sich in einer Nähe der Bildgebungssonde (28) befindet.

14. Verfahren nach Anspruch 10, wobei das Kalibrieren des zeitlichen Versatzes das Identifizieren des markierten Ultraschallbilds durch Vergleichen von Intensitätswerten der Bilder in der ersten Sequenz mit einem vorbestimmten Schwellwert umfasst.

15. Verfahren nach Anspruch 10, wobei das Bewegen der Bildgebungssonde (28) das Bewegen der Sonde (28) durch zwei oder mehr verschiedene Kalibrierungspunkte mit bekannten Koordinaten umfasst, wobei das Markieren des Ultraschallbilds das Markieren der von dem Ultraschallwandler erfassten Ultraschallbilder, wenn sich die Bildgebungssonde (28) an den zwei oder mehr Kalibrierungspunkten befindet, umfasst und wobei das Kalibrieren des zeitlichen Versatzes zwischen der ersten und zweiten Sequenz das Assoziieren der markierten Ultraschallbilder mit jeweiligen Positionsmessungen umfasst, deren Koordinaten den Koordinaten der jeweiligen Kalibrierungspunkte entsprechen.

16. Verfahren nach Anspruch 10, wobei das Bewegen der Bildgebungssonde (28) das Kreuzen des Kalibrierungspunkts in mindestens zwei Fällen umfasst und wobei das Kalibrieren des zeitlichen Versatzes das Messen von Werten des zeitlichen Versatzes der mindestens zwei Fälle und Mitteln der gemessenen Werte umfasst.

17. Verfahren nach Anspruch 10, wobei die Bildgebungssonde (28) eine Elektrode (46) enthält, die ein Ansteuerungssignal zum Ansteuern der Ultraschallbilder und der Positionsmessungen erzeugt, und umfassend das Markieren des Ansteuerungssignals, das von der Elektrode (46) erzeugt wird, wenn die Bildgebungssonde (28) sich bei dem Kalibrierungspunkt befindet, und Kalibrieren einer zeitlichen Verzögerung zwischen dem Ansteuerungssignal und zwischen der ersten und zweiten Sequenz unter Verwendung des markierten Ansteuerungssignals.

18. Verfahren nach Anspruch 17, wobei das Ansteuerungssignal ein Elektrokardiogrammsignal (EKG) umfasst und wobei die Elektrode (46) eine intrakardiale EKG-Erfassungselektrode umfasst.

19. Computersoftwareprodukt zur Verwendung in einer prozessorbasierten Kalibrierungsvorrichtung (50), die eine Bewegungsbaugruppe (59) enthält, die eine Bildgebungssonde (28), die gleichzeitig eine erste Sequenz von Ultraschallbildern unter Verwendung eines Ultraschallwandlers (39) und eine zweite Sequenz von Positionsmessungen unter Verwendung eines Positionssensors (40) erfasst, durch einen Kalibrierungspunkt mit bekannten Koordinaten bewegt und weiterhin eine Markierungsschaltung (52A, 52B, 53, 54) enthält, die ein Ultraschallbild markiert, das von dem Ultraschallwandler (39) in der ersten Sequenz erfasst wird, wenn sich die Bildgebungssonde (28) an dem Kalibrierungspunkt befindet, wobei das Produkt ein computerlesbares Medium umfasst, in dem Programmanweisungen gespeichert sind, wobei die Anweisungen beim Lesen durch die Kalibrierungsvorrichtung bewirken, dass die Kalibrierungsvorrichtung einen zeitlichen Versatz zwischen der ersten und zweiten Sequenz kalibriert durch Assoziieren des markierten Ultraschallbilds in der ersten Sequenz mit einer Positionsmessung in der zweiten Sequenz, deren Koordinaten den Koordinaten des Kalibrierungspunkts entsprechen;
dadurch gekennzeichnet, dass:

die Kalibrierungsvorrichtung einen zeitlichen Versatz kalibriert unter Verwendung des markierten Ultraschallbilds, das von der Markierungsschaltung (52A, 52B, 53, 54) erzeugt wird, die einen optischen Emitter (52A, 52B), der ausgelegt ist zum Emittieren von Licht, und einen optischen Sensor (53, 54), der ausgelegt ist zum Erfassen des Lichts und Generieren eines elektrischen Signals als Reaktion auf das erfasste Licht umfasst, wenn auf den optischen Emitter (52A, 52B) ausgerichtet, und wobei der optische Emitter (52A, 52B) und der optische Sensor (53, 54) so an der Bewegungsbaugruppe (59) angebracht sind, dass sie aufeinander ausgerichtet sind und das elektrische Signal generieren, wenn sich die Bildgebungssonde (28) bei dem Kalibrierungspunkt befindet, um das Ultraschallbild als Reaktion auf das elektrische Signal zu markieren.

20. Produkt nach Anspruch 19, wobei die Anweisungen bewirken, dass die Kalibrierungsvorrichtung das markierte Ultraschallbild identifiziert durch Vergleichen von Intensitätswerten der Bilder in der ersten Sequenz mit einem vorbestimmten Schwellwert.

21. Produkt nach Anspruch 19, wobei der Kalibrierungspunkt zwei oder mehr verschiedene Kalibrierungspunkte mit bekannten Koordinaten umfasst, wobei die Bewegungsbaugruppe (59) die Bildgebungssonde (28) durch die zwei oder mehr Kalibrierungspunkte bewegt, wobei die Markierungsschaltung (52A, 52B, 53, 54) die von dem Ultraschallwandler (39) erfassten Ultraschallbilder markiert, wenn sich die Bildgebungssonde (28) an den zwei oder mehr Kalibrierungspunkten befindet, und wobei die Anweisungen bewirken, dass die Kalibrierungsvorrichtung den zeitlichen Versatz zwischen der ersten und zweiten Sequenz kalibriert durch Assoziieren der markierten Ultraschallbilder mit jeweiligen Positionsmessungen, deren Koordinaten den Koordinaten der jeweiligen Kalibrierungspunkte entsprechen.

22. Produkt nach Anspruch 19, wobei die Bewegungsbaugruppe (59) die Bildgebungssonde (28) in mindestens zwei Fällen über den Kalibrierungspunkt bewegt und wobei die Anweisungen bewirken, dass die Kalibrierungsvorrichtung jeweilige Werte des zeitlichen Versatzes in den mindestens zwei Fällen misst und die gemessenen Werte mittelt.

Revendications

1. Appareil d'étalonnage (50), comprenant :

un ensemble générateur de mouvement (59) qui est conçu pour déplacer une sonde de formation d'image (28) en la faisant passer par un point d'étalonnage ayant des coordonnées connues, la sonde de formation d'image comprenant un transducteur à ultrasons (39) et un capteur de position (40) pour acquérir simultanément une première séquence d'images ultrasonores et une seconde séquence de mesures de position ;
un circuit de marquage (52A, 52B, 53, 54) qui est conçu pour marquer une image ultrasonore acquise par le transducteur à ultrasons (39) dans la première séquence lorsque la sonde de formation d'image (28) se situe au point d'étalonnage ; et
un processeur (57) qui est conçu pour étalonner un décalage temporel entre les première et seconde séquences en associant l'image ultrasonore marquée dans la première séquence à une mesure de position dans la seconde séquence, dont les coordonnées correspondent aux coordonnées du point d'étalonnage ;
caractérisé en ce que :

le circuit de marquage (52A, 52B, 53, 54) comprend un émetteur optique (52A, 52B) qui est conçu pour émettre de la lumière et un capteur optique (53, 54) qui est conçu pour détecter la lumière et générer un signal électrique en réponse à la lumière détectée lorsqu'il est aligné avec l'émetteur optique (52A, 52B), et dans lequel l'émetteur optique (52A, 52B) et le capteur optique (53, 54) sont fixés à l'ensemble générateur de déplacement (59) de manière à ce qu'ils s'alignent l'un avec l'autre et à générer le signal électrique lorsque la sonde de formation d'image (28) se situe au point d'étalonnage, afin de marquer l'image ultrasonore en réponse au signal électrique.

2. Appareil selon la revendication 1, dans lequel l'ensemble générateur de mouvement (59) comprend une roue (51) et un bras mobile (55A, 55B), dans lequel une première extrémité du bras est reliée à la roue (51) et une seconde extrémité du bras (55A, 55B) est conçue pour être fixée à la sonde de formation d'image (28), et dans lequel la roue (51) est conçue pour tourner de manière à déplacer la sonde de formation d'image (28) en la faisant passer par le point d'étalonnage.

3. Appareil selon la revendication 1, dans lequel le circuit de marquage (52A, 52B, 53, 54) comprend un circuit de modulation (58) qui est conçu pour générer un signal de marquage ultrasonore qui possède une fréquence pouvant être détectée par le transducteur à ultrasons (39) en réponse au signal électrique et pour marquer l'image ultrasonore au moyen du signal de marquage ultrasonore.

4. Appareil selon la revendication 3, dans lequel le circuit de modulation (58) comprend une bobine d'induction (56) qui est située au voisinage de la sonde de formation d'image (28) et est conçu pour induire un signal radiofréquence (RF) dans le transducteur à ultrasons (39) de manière à marquer l'image ultrasonore.

5. Appareil selon la revendication 1, dans lequel le processeur (57) est conçu pour identifier l'image ultrasonore marquée en comparant des valeurs d'intensité des images de la première séquence à un seuil prédéterminé.

6. Appareil selon la revendication 1, dans lequel le point d'étalonnage comprend deux points d'étalonnage différents ou plus ayant des coordonnées connues, dans lequel l'ensemble générateur de déplacement

(59) est conçu pour déplacer la sonde de formation d'image (28) en la faisant passer par les deux points d'étalonnage ou plus, dans lequel le circuit de marquage (52A, 52B, 53, 54) est conçu pour marquer les images ultrasonores acquises par le transducteur à ultrasons (39) lorsque la sonde de formation d'image (28) se situe aux deux points d'étalonnage ou plus, et dans lequel le processeur (57) est conçu pour étalonner le décalage temporel entre les première et seconde séquences en associant les images ultrasonores marquées à des mesures de position respectives dont les coordonnées correspondent aux coordonnées des points d'étalonnage respectifs.

7. Appareil selon la revendication 1, dans lequel l'ensemble générateur de déplacement (59) est conçu pour déplacer la sonde de formation d'image (28) en la faisant passer par le point d'étalonnage dans au moins deux cas, et dans lequel le processeur (57) est conçu pour mesurer des valeurs respectives du décalage temporel dans les au moins deux cas et pour moyenner les valeurs mesurées.

8. Appareil selon la revendication 1, dans lequel la sonde de formation d'image (28) comprend une électrode (46) qui produit un signal de déblocage pour débloquer les images ultrasonores et les mesures de position, dans lequel le circuit de marquage (52A, 52B, 53, 54) est conçu pour marquer le signal de déblocage qui est produit par l'électrode (46) lorsque la sonde de formation d'image (28) se situe au point d'étalonnage, et dans lequel le processeur (57) est conçu pour étalonner un temps de retard entre le signal de déblocage et entre les première et seconde séquences au moyen du signal de déblocage marqué.

9. Appareil selon la revendication 8, dans lequel le signal de déblocage comprend un signal d'électrocardiogramme (ECG) et dans lequel l'électrode comprend une électrode intracardiaque de détection d'ECG.

10. Procédé d'étalonnage, consistant à :

faire fonctionner une sonde de formation d'image (28) qui comprend un capteur de position (40) et un transducteur à ultrasons (39), de manière à acquérir simultanément une première séquence d'images ultrasonores en utilisant le transducteur à ultrasons (39) et une seconde séquence de mesures de position au moyen du capteur de position (40) ;
déplacer la sonde de formation d'image (28) en la faisant passer par un point d'étalonnage ayant des coordonnées connues ;
marquer une image ultrasonore qui est acquise par le transducteur à ultrasons (39) dans la première séquence lorsque la sonde de formation d'image (28) se situe au point d'étalonnage ; et
étalonner un premier décalage temporel entre les première et seconde séquences en associant l'image ultrasonore marquée dans la première séquence à une position de mesure dans la seconde séquence dont les coordonnées correspondent aux coordonnées du point d'étalonnage ;
caractérisé en ce que :

le marquage de l'image ultrasonore consiste à positionner un émetteur optique (52A, 52B) qui émet de la lumière et un capteur optique (53, 54) qui détecte la lumière et génère un signal électrique en réponse à la lumière détectée lorsqu'il est aligné avec l'émetteur optique (52A, 52B), de manière à ce qu'ils s'alignent l'un avec l'autre et à générer le signal électrique lorsque la sonde de formation d'image (28) est au point d'étalonnage, et à marquer l'image ultrasonore en réponse au signal électrique.

11. Procédé selon la revendication 10, dans lequel le déplacement de la sonde de formation d'image (28) consiste à fixer la sonde de formation d'image (28) à une première extrémité d'un bras mobile (55A, 55B) dont la seconde extrémité est reliée à une roue (51), et à faire tourner la roue (51) de manière à déplacer la sonde de formation d'image en la faisant passer par le point d'étalonnage.

12. Procédé selon la revendication 10, dans lequel le marquage de l'image ultrasonore consiste à générer un signal de marquage ultrasonore qui possède une fréquence pouvant être détectée par le transducteur à ultrasons (39) en réponse au signal électrique et à marquer l'image ultrasonore au moyen du signal de marquage ultrasonore.

13. Procédé selon la revendication 12, dans lequel le marquage de l'image ultrasonore à l'aide du signal de marquage ultrasonore consiste à induire un signal radiofréquence (RF) dans le transducteur à ultrasons (39) au moyen d'une bobine d'induction (56) qui est située au voisinage de la sonde de formation d'image (28).

14. Procédé selon la revendication 10, dans lequel l'étalonnage du décalage temporel consiste à identifier l'image ultrasonore marquée en comparant des valeurs d'intensité des images de la première séquence à un seuil prédéterminé.

15. Procédé selon la revendication 10, dans lequel le déplacement de la sonde de formation d'image (28) consiste à déplacer la sonde (28) en la faisant passer par deux points d'étalonnage différents ou plus ayant des coordonnées connues, dans lequel le marquage de l'image ultrasonore consiste à marquer les images ultrasonores acquises par le transducteur à ultrasons lorsque la sonde de formation d'image (28) se situe aux deux points d'étalonnage ou plus, et dans lequel l'étalonnage du décalage temporel entre les première et seconde séquences consiste à associer les images ultrasonores marquées à des mesures de position respectives dont les coordonnées correspondent aux coordonnées des points d'étalonnage respectifs.

16. Procédé selon la revendication 10, dans lequel le déplacement de la sonde de formation d'image (28) consiste à passer par le point d'étalonnage dans au moins deux cas, et dans lequel l'étalonnage du décalage temporel consiste à mesurer des valeurs du décalage temporel dans les au moins deux cas et à moyenner les valeurs mesurées.

17. Procédé selon la revendication 10, dans lequel la sonde de formation d'image (28) comprend une électrode (46) qui produit un signal de déblocage pour débloquer les images ultrasonores et les mesures de position, et consistant à marquer le signal de déblocage qui est produit par l'électrode (46) lorsque la sonde de formation d'image (28) se situe au point d'étalonnage, et à étalonner un temps de retard entre le signal de déblocage et entre les première et seconde séquences au moyen du signal de déblocage marqué.

18. Procédé selon la revendication 17, dans lequel le signal de déblocage comprend un signal d'électrocardiogramme (ECG) et dans lequel l'électrode (46) comprend une électrode intracardiaque de détection d'ECG.

19. Produit à base de logiciel informatique destiné à être utilisé dans un appareil d'étalonnage (50) à base de processeur, qui comprend un ensemble générateur de déplacement (59) déplaçant une sonde de formation d'image (28) qui acquiert simultanément une première séquence d'images ultrasonores au moyen d'un transducteur à ultrasons (39) et une seconde séquence de mesures de position au moyen d'un capteur de position (40), en la faisant passer par un point d'étalonnage ayant des coordonnées connues, et qui comprend en outre un circuit de marquage (52A, 52B, 53, 54) qui marque une image ultrasonore acquise par le transducteur à ultrasons (39) dans la première séquence lorsque la sonde de formation d'image (28) se situe au point d'étalonnage, le produit comprenant un support lisible par ordinateur sur lequel sont stockées des instructions, lesquelles instructions, lorsqu'elles sont lues par l'appareil d'étalonnage ont pour effet que l'appareil d'étalonnage étalonne un décalage temporel entre les première et seconde séquences en associant l'image ultrasonore marquée dans la première séquence à une mesure de position dans la seconde séquence, dont les coordonnées correspondent aux coordonnées du point d'étalonnage ;
caractérisé en ce que :

l'appareil d'étalonnage étalonne un décalage temporel au moyen de l'image ultrasonore marquée produite par le circuit de marquage (52A, 52B, 53, 54) qui comprend un émetteur optique (52A, 52B) conçu pour émettre de la lumière et un capteur optique (53, 54) conçu pour détecter la lumière et générer un signal électrique en réponse à la lumière détectée lorsqu'il est aligné avec l'émetteur optique (52A, 52B), et dans lequel l'émetteur optique (52A, 52B) et le capteur optique (53, 54) sont fixés à l'ensemble générateur de déplacement (59) de manière à ce qu'ils s'alignent l'un avec l'autre et à générer le signal électrique lorsque la sonde de formation d'image (28) se situe au point d'étalonnage, afin de marquer l'image ultrasonore en réponse au signal électrique.

20. Produit selon la revendication 19, dans lequel les instructions ont pour effet que l'appareil d'étalonnage identifie l'image ultrasonore marquée en comparant des valeurs d'intensité des images de la première séquence à un seuil prédéterminé.

21. Produit selon la revendication 19, dans lequel le point d'étalonnage comprend deux points d'étalonnage différents ou plus ayant des coordonnées connues, dans lequel l'ensemble générateur de déplacement (59) déplace la sonde de formation d'image (28) en la faisant passer par les deux points d'étalonnage ou plus, dans lequel le circuit de marquage (52A, 52B, 53, 54) marque les images ultrasonores acquises par le transducteur à ultrasons (39) lorsque la sonde de formation d'image (28) se situe aux deux points d'étalonnage ou plus, et dans lequel les instructions ont pour effet que l'appareil d'étalonnage étalonne le décalage temporel entre les première et seconde séquences en associant les images ultrasonores marquées à des mesures de position respectives dont les coordonnées correspondent aux coordonnées des points d'étalonnage respectifs.

22. Produit selon la revendication 19, dans lequel l'ensemble de déplacement (59) déplace la sonde de formation d'image (28) en la faisant passer par le point d'étalonnage dans au moins deux cas, et dans lequel les instructions ont pour effet que l'appareil d'étalonnage mesure des valeurs respectives du décalage temporel dans les au moins deux cas et calcule la moyenne des valeurs mesurées.

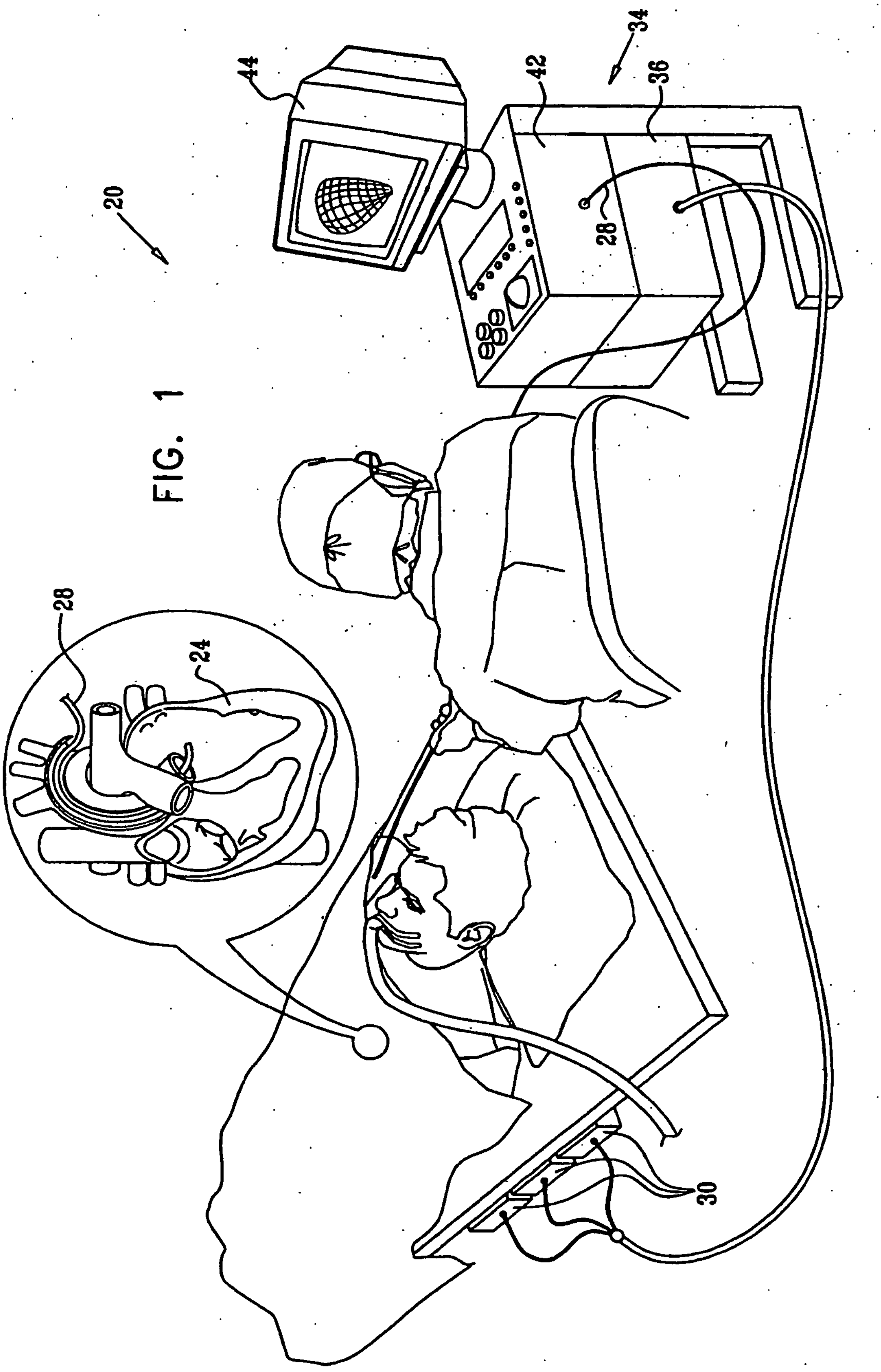


FIG. 1

FIG. 2

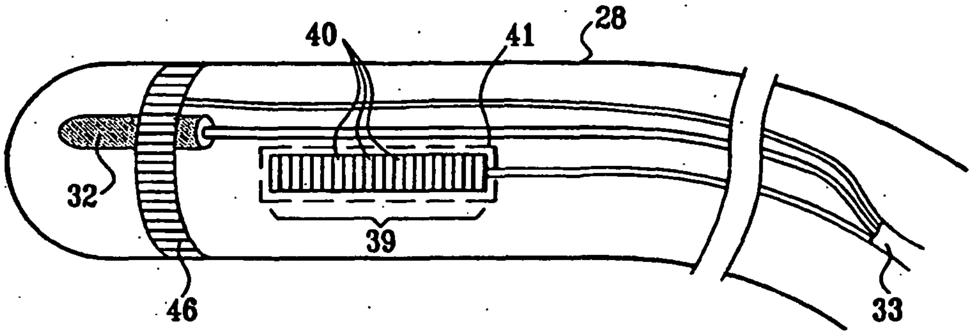
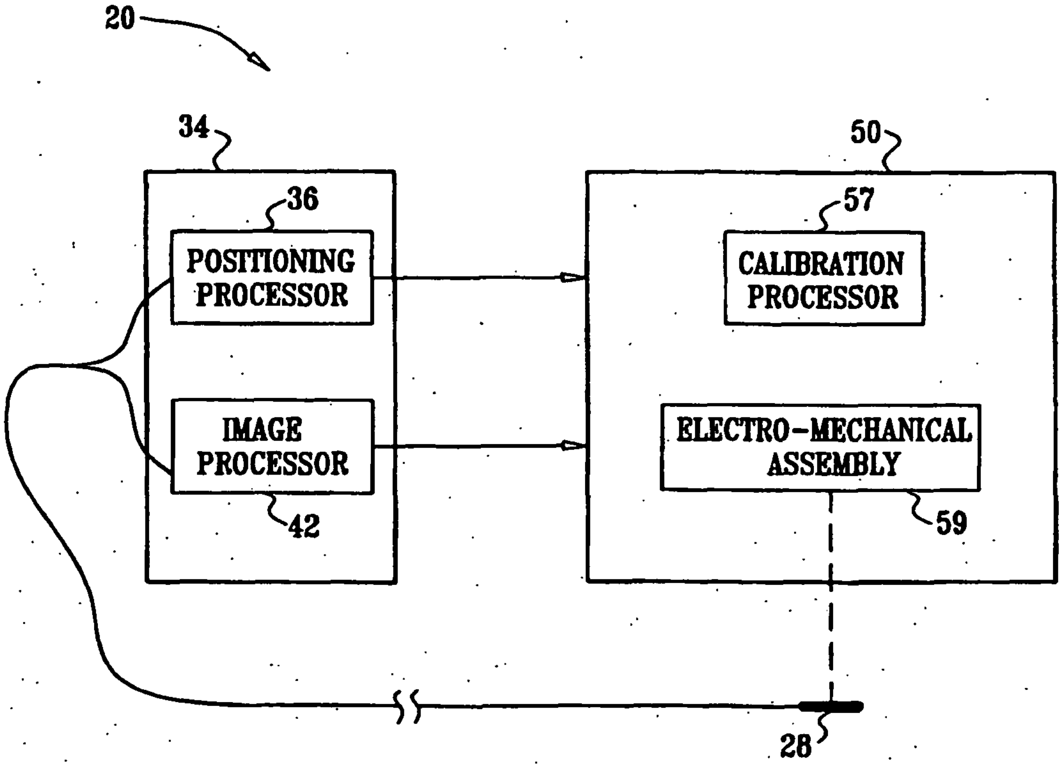

40
41
28
32
39
46
33

FIG. 3


20
34
36
POSITIONING PROCESSOR
IMAGE PROCESSOR
42
50
57
CALIBRATION PROCESSOR
ELECTRO-MECHANICAL ASSEMBLY
59
28

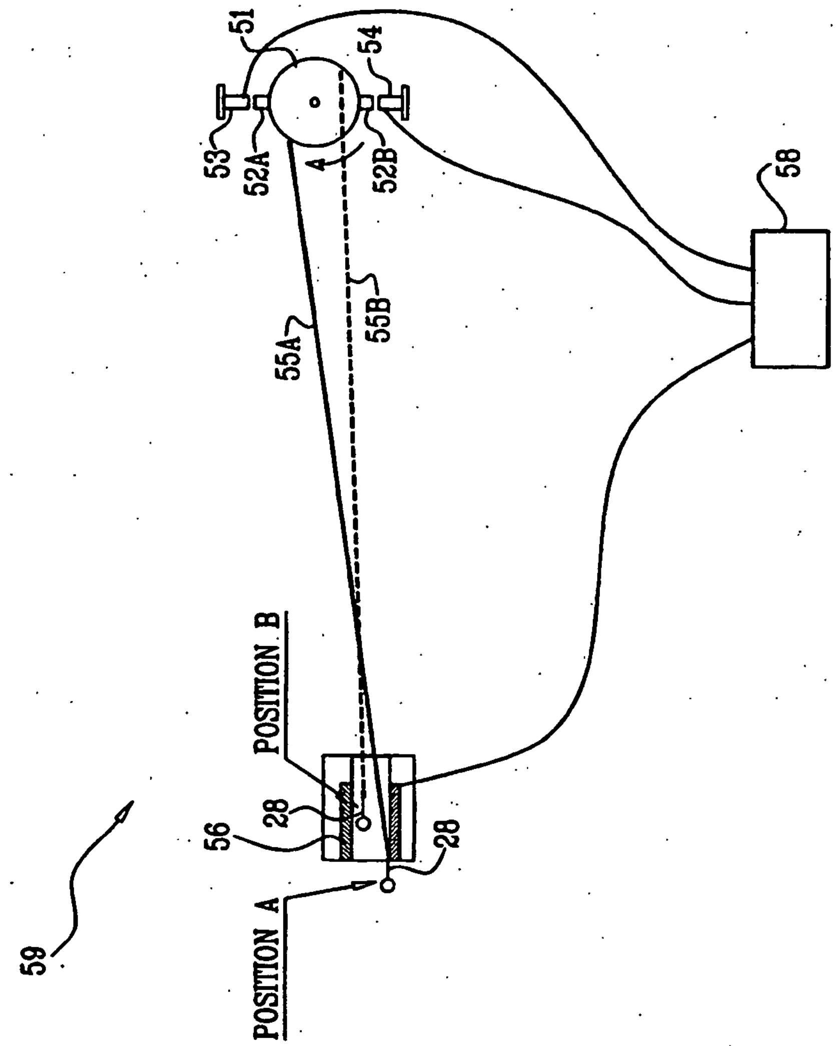


FIG. 4

FIG. 5

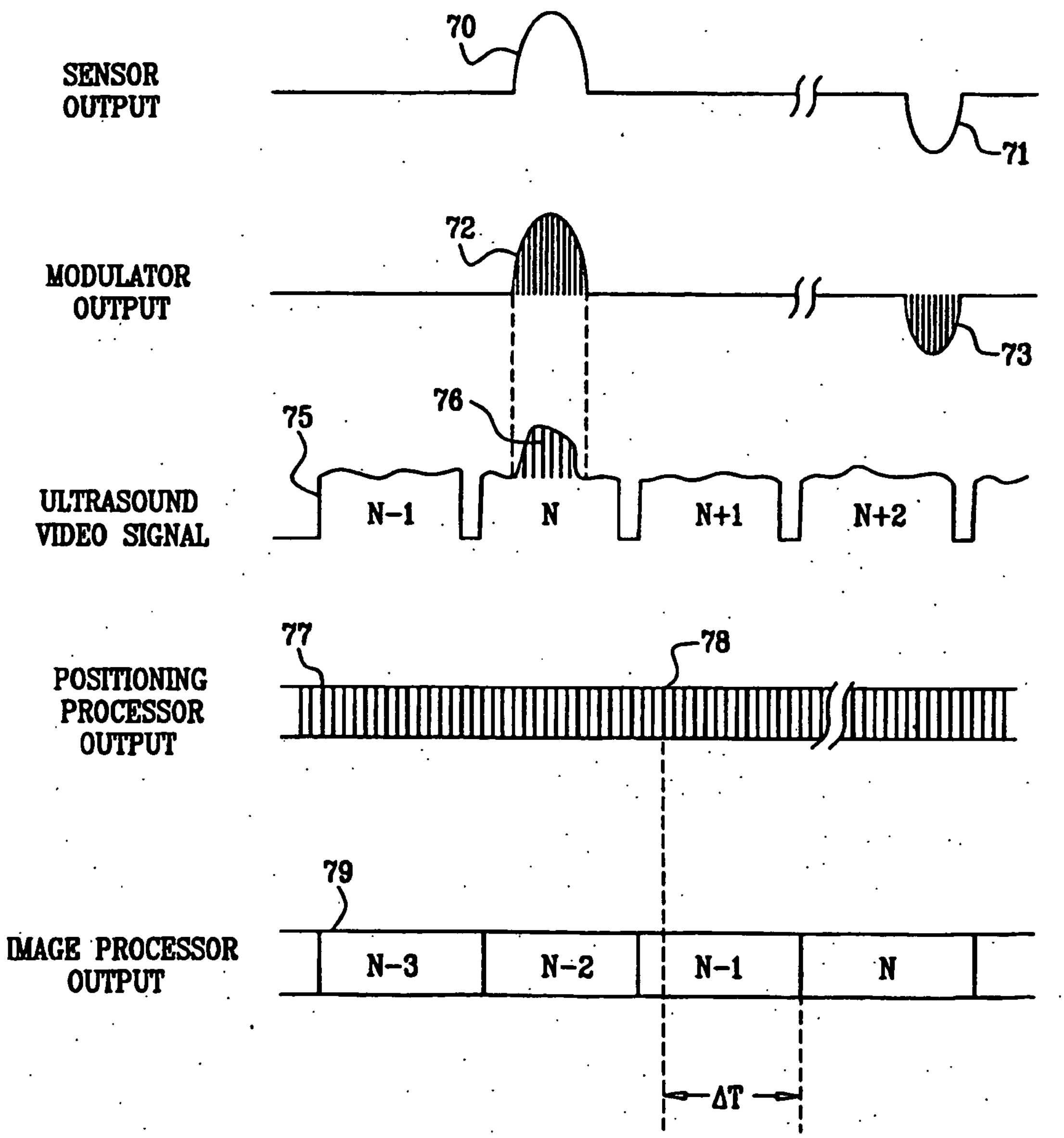
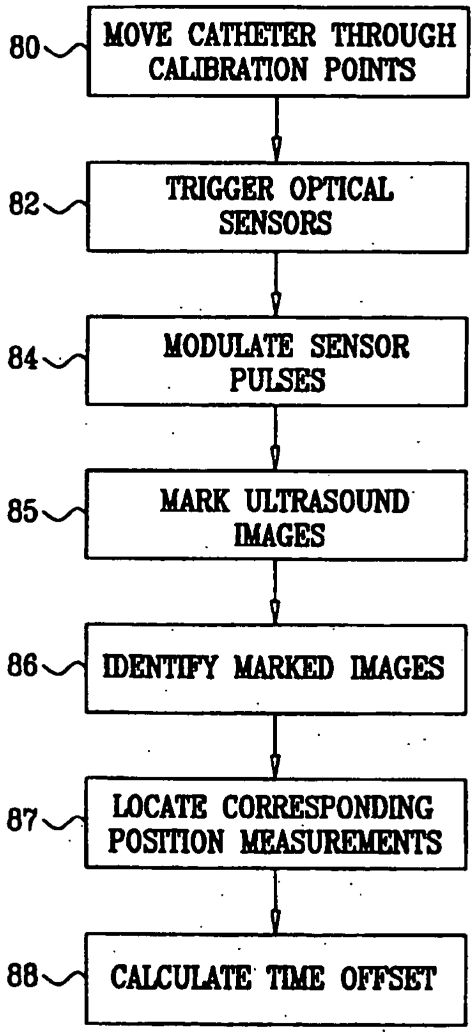

SENSOR
OUTPUT
70
71
MODULATOR
OUTPUT
72
73
ULTRASOUND
VIDEO SIGNAL
75
76
N-1
N
N+1
N+2
POSITIONING
PROCESSOR
OUTPUT
77
78
IMAGE PROCESSOR
OUTPUT
79
N-3
N-2
N-1
N
ΔT

FIG. 6


80
MOVE CATHETER THROUGH CALIBRATION POINTS
82
TRIGGER OPTICAL SENSORS
84
MODULATE SENSOR PULSES
85
MARK ULTRASOUND IMAGES
86
IDENTIFY MARKED IMAGES
87
LOCATE CORRESPONDING POSITION MEASUREMENTS
88
CALCULATE TIME OFFSET

REFERENCES CITED IN THE DESCRIPTION

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Non-patent literature cited in the description

- **Prager.** *Stradx: real-time acquisition and visualisation of freehand ultrasound* **[0006]**

专利名称(译)	超声图像与门控位置测量的相关性		
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[标]申请(专利权)人(译)	韦伯斯特生物官能公司		
申请(专利权)人(译)	生物传感韦伯斯特，INC.		
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优先权	11/669620 2007-01-31 US		
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外部链接	Espacenet		

摘要(译)

校准装置（50）包括运动组件（59），其被布置成使成像探针（28）移动通过具有已知坐标的校准点。成像探头包括超声换能器（39）和位置传感器，用于同时获取第一序列的超声图像和第二序列的位置测量。该装置还包括标记电路，该标记电路被布置成当成像探针处于校准点时标记由超声换能器以第一序列获取的超声图像。处理器被布置成通过将第一序列中的标记的超声图像与第二序列中的位置测量相关联来校准第一和第二序列之间的时间偏移，第二序列的坐标与校准点的坐标匹配。