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(54) SYSTEMS FOR MEASURING FORCE AND TORQUE ON ULTRASOUND PROBE DURING IMAGING THROUGH STRAIN MEASUREMENT

SYSTEME ZUR MESSUNG VON KRAFT UND DREHMOMENT AUF EINER ULTRASCHALLSONDE WÄHREND DER BILDGEBUNG DURCH DEHNUNGSMESSUNG

SYSTÈMES DE MESURE DE LA FORCE ET DU COUPLE SUR UNE SONDE À ULTRASONS LORS D'UNE IMAGERIE AU MOYEN D'UNE MESURE DE LA CONTRAINTE

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Description

[0001] The present invention generally relates to freehand ultrasound imaging for medical procedures, particularly for prostate biopsy and brachytherapy procedures. The present invention specifically relates to a monitoring and control of consistent force applied through an ultrasound probe to an anatomical object, particularly the prostate.

[0002] Referring to FIG. 1, during a majority of ultrasound-guided biopsy and therapy procedures (e.g., prostate biopsy and brachytherapy), a whole sweep from the anatomy of interest is acquired to reconstruct a three-dimensional ("3D") volume 41 of the anatomy. Specifically, ultrasound imaging is typically carried out freehand style via a handle 32 attached to an ultrasound probe 31 having two-dimensional ("2D") ultrasound transducer(s) (not shown). An electromagnetic or optical position sensor (not shown) is attached to ultrasound probe 31 and a set of 2D B-scans 40 are acquired along with their relative coordinates in a reference coordinate system of an electromagnetic or optical tracker frame 28. The set of 2D images 40 are reconstructed into regular 3D volume 41 for visualization, guidance and analysis.

[0003] During the freehand imaging, the operator presses ultrasound probe 31 against the surface of skin or internal tissue of patient 10 while adjusting a position and an orientation of ultrasound probe 31 to find the desired image plane. During this process, the contact force between ultrasound probe 31 and the skin or tissue of patient 10 deforms the underlying tissue. For example, in transrectal ultrasound ("TRUS") imaging of the prostate, ultrasound probe 31 would be pushed against the rectum wall, which causes a significant deformation in the prostate gland. The amount of deformation correlates with the amount of applied force as well as the tissue composition.

[0004] The reconstructed image volumes 41 may be used for different applications, such as for example, anatomy segmentation 25 and multi-modality image fusion and registration 26. However, volume reconstruction 24 from freehand ultrasound probe 31 is prone to artifacts induced by the ultrasound probe pressure. Specifically, the 2D ultrasound transducer(s) of ultrasound probe 31 are required to be in close contact with the surface of the volume of interest to avoid air gaps that causes shadowing artifact in the acquired images. During a 3D sweep, the tissue being scanned is exposed to variable amount of force and each acquired 2D image 40 is captured from the tissue under different probe pressure. Therefore, the amount of pressure applied to the tissue during image acquisition by the operator may dramatically influence the quality of the acquired images 40 during the freehand style data acquisition 23. As a result, linear slice motion and nonlinear tissue deformations accumulate and produce distracting image artifacts for 3D volume 41.

[0005] Moreover, the variation in tissue geometry caused by varying contact force is the reason why ultrasound images 40 are hard to reproduce. Even if the imaging is performed on the same region of patient 10, the amount of tissue deformation certainly would be different due to changes in the force (probe pressure) and/or the biomechanical properties of the tissues.

[0006] The impact of such deformation and distortion in volume reconstruction 24 is quite dramatic in the context of automatic image segmentation 25, such as, for example, prostate gland segmentation. Furthermore, errors in image segmentation will translate into errors in registration 26 (e.g., magnetic resonance imaging to ultrasound image) and consequently will affect the biopsy and brachytherapy accuracy.

[0007] US 2011152690A1 of Brian W. Anthony et al. "Handheld Force-Controlled Ultrasound Probe", published June 23, 2011, is directed to a handheld ultrasound probe that includes force detection and feedback to permit control and/or characterization of applied forces,

[0008] US 20070167819A1 of Thomas W. Osborn III et al., "Method For In-Vivo Measurement of Biomechanical Properties of Internal Tissues", published July 19, 2007,is directed to a method and device to determine location-dependent biomechanical properties that can include a measurement system in a combined format of a strain gauge type physiological pressure transducer to measure tissue loading stress, and imaging devices such as computed tomography, magnetic resonance imaging or ultrasound imager to measure localized tissue deflection and strain profiles.

[0009] WO2002085214A1 of Jukka Jurvelin et al, "Method and Measuring Device for Examining a Compressible Tissue", published October 31, 2002, is directed to a measuring device for examining a compressible tissue comprising an elongated rigid frame, a measuring arm attached to the frame, preferably comprising a contact surface to be placed against the tissue to be examined, and an ultrasound probe and means for processing signals obtained from the probe.

[0010] WO2003022152A1 of Michael Richard Burcher et al, "Method and Apparatus for Ultrasound Examination", published March 20, 2003, is directed to an ultrasound apparatus and method of ultrasound examination in which contact force between an ultrasound probe and a subject is measured and recorded, allowing deformation to be calculated.

[0011] The present invention provides a force/torque management 27 for monitoring and control of consistent force applied through ultrasound probe 31 to an anatomy of interest of patient 10.

[0012] One form of the present invention is a medical instrument employing an ultrasound probe and a strain sensor. The ultrasound probe includes an ultrasound transducer for acquiring ultrasound images of an anatomical region. The strain sensor is arranged on the ultrasound probe to measure a longitudinal strain applied by the anatomical region on the ultrasound probe as the ultrasound transducer acquires images of the anatomical region. The strain sensor encircles a longitudinal axis of the ultrasound probe and is spaced from the ultrasound transducer relative to the longitudinal axis of the ultrasound probe.

[0013] A second form of the present invention is an ultrasound system employing the aforementioned medical instrument, and a workstation operable to reconstruct an ultrasound volume from the ultrasound images acquired by the ultrasound transducer(s) and responsive to the longitudinal strain measured by the strain sensor, determines an axial force and/or a bending force applied by the anatomical region to the ultrasound probe as the ultrasound transducer acquires ultrasound images of the anatomical region.

[0014] The foregoing forms and other forms of the present invention as well as various features and advantages of the present invention will become further apparent from the following detailed description of various embodiments of the present invention read in conjunction with the accompanying drawings. The detailed description and drawings are merely illustrative of the present invention rather than limiting, the scope of the present invention being defined by the appended claims and equivalents thereof.

FIG. 1 illustrates an exemplary embodiment of an ultrasound system in accordance with the present invention.
FIG. 2A illustrates an exemplary embodiment of an ultrasound probe in accordance with the present invention.
FIG. 2B illustrates a cross-sectional view of the ultrasound probe as shown in FIG. 2.
FIG. 3A illustrates exemplary forces generated during a scan of anatomical object by the ultrasound probe shown in FIG. 2A.
FIG. 3B illustrates a cross-sectional view of the ultrasound probe as shown in FIG. 3A.
FIG. 4 illustrates a flowchart representative of an exemplary embodiment of a scanning method in accordance with the present invention.
FIG. 5 illustrates a flowchart representative of an exemplary embodiment of a calibration method in accordance with the present invention.
FIGS. 6A and 6B illustrate exemplary calibration graphs in accordance with the present invention.

[0015] Referring to FIG. 1, an ultrasound system employs a workstation 20 having a computer 21, a monitor 22 and input devices (not shown), a bundle of software/firmware modules 23-27 and a reference tracker 28. For purposes of the present invention, computer 21 is broadly defined herein as any computer structure configured with hardware/circuitry (e.g., processor(s), memory, etc.) for processing 2D ultrasound images 40 to support medical procedures (e.g., prostate biopsy and brachytherapy procedures). To this end, modules 23-27 are programmed and installed on computer 21 to provide various functionality in support of the medical procedures.

[0016] First, an image acquisition module 23 encompasses known method(s) for receiving and storing a data set of 2D ultrasound images 40 from ultrasound probe 31 with each storage of a 2D ultrasound image 40 including a position of that image within the reference coordinate system of tracker 28 (e.g., electromagnetic or optical) via one or more sensors/markers attached to ultrasound probe 31.

[0017] Second, a volume reconstruction module 24 encompasses known method(s) for generating a 3D volume 41 from the relative positions of the 2D ultrasound images 40.

[0018] Third, an image segmentation module 25 encompasses known method(s) for partitioning the 2D ultrasound images 40 prior to reconstruction or for partitioning the 3D volume 41 into a set of disjoint segments according visual properties (e.g., grey level, texture or color) to support an easier analyze of the 3D volume 41.

[0019] Fourth, an image registration module 26 encompasses known method(s) for transforming the data set of 2D ultrasound images 40 and a data set of another imaging modality (e.g., magnetic resonance imaging or computed tomography) into one coordinate system.

[0020] Fifth, strain measurement module 27 encompasses method(s) of the present invention for determining an axial force and a bending force applied by an anatomical region of patient 10 on ultrasound probe 31 during a scanning by ultrasound probe 31 of the anatomical region (e.g., prostrate). To this end, computer 21 receives a measurement by a strain sensor 33 of a longitudinal strain applied by an anatomical region of patient 10 on ultrasound probe 31 during a scanning by ultrasound probe 31 of the anatomical region, and module 27 processes the strain measurement to determine the axial force and the bending force.

[0021] For purposes of the present invention, strain sensor 33 is broadly defined herein as any sensor structurally configured for measuring a longitudinal strain being applied by an object to an instrument, particularly for measuring a longitudinal strain being applied by an anatomical region to ultrasound probe 31 during an ultrasound scan. Also for purposes of the present invention, longitudinal strain is broadly defined herein as any strain parallel to or having a component parallel to a longitudinal axis of ultrasound probe 31.

[0022] In practice, strain sensor 33 may be arranged on ultrasound probe 31 in any manner that facilitates a measurement of a longitudinal strain being applied by an anatomical region to ultrasound probe 31 during an ultrasound scan. For example, strain sensor 33 may be adhered to or integrated with ultrasound probe 31 at or adjacent a proximal end of strain sensor 33. By further example, strain sensor 33 may be installed on a disposable casing that sits tight at or adjacent to a proximal end of ultrasound probe 31.

[0023] Also in practice, strain sensor 33 may employ one (1) or more strain gauges SG of any type (e.g., single axis, three-axial, planar, etc.) arranged on ultrasound probe 31 in manner conducive to a practical measurement of a longitudinal strain being applied by an anatomical region of patient 10 on ultrasound probe 31 during an ultrasound scan. For example, strain gauge(s) may be longitudinally arranged at or adjacent to a proximal end of ultrasound probe 31, particularly in a grid pattern for the employment of two (2) of more strain gauges. Additionally, strain sensor 33 may employ one (1) or more dummy strain gauge(s) for compensation of strain due to variation in temperature.

[0024] The following is a description of exemplary embodiment of strain sensor 33 utilized by module 27, which is followed by a description of exemplary embodiments of a scanning method and of a calibration method of the present invention implemented by module 27.

[0025] FIG. 2A shows medical instrument 30 employing ultrasound probe 31 and a handle 32 attached to proximal end of ultrasound probe 31. Ultrasound probe 31 employs an ultrasound transducer (not shown) for ultrasound imaging an anatomical region of patient 10. The ultrasound transducer is arranged at a distal end of ultrasound probe 31, typically within a dashed circle 35 in dependence upon the orientation of the ultrasound transducer relative the distal end of ultrasound probe 31.

[0026] An embodiment 33a of strain sensor 33 employs four (4) strain gauges SG arranged in a grid pattern on ultrasound probe 31 arranged an equal distant from each other around the periphery of ultrasound probe 31 as shown in FIG. 2B. Strain gauges SG may consist of metallic foil that maximizes the amount of metallic wire or foil subject to strain in the parallel direction of longitudinal axis 34.

[0027] In practice, to measure small changes in resistance, strain gauges SG may be used in a bridge configuration with a voltage excitation source (not shown). Examples of the bridge configuration include, but are not limited to, a quarter-bridge configuration, a half-bridge configuration and a full-bridge configuration.

[0028] Additionally, as shown in FIG. 1, a signal conditioner 36 may be employed in view of the output voltages being relatively small. In one embodiment, signal conditioner 36 may consist of amplifiers to boost the signal level to increase measurement resolution and improve signal-to-noise ratios. Moreover, the strain gauges SG may be located in electrically noisy environments. Therefore, the signal conditioner 36 may also consist of low-pass filters to remove the high-frequency noise prevalent in most environmental settings.

[0029] The output signal(s) from signal gauges SG or alternatively signal conditioner 36 are utilized by module 27 to determine the axial force and the bending force and to display visual representation of the axial force and the bending force on the monitor 22 (e.g., a numeric and/or color coded force map overlaying volume 41). In practice, the output signal(s) from signal gauges SG may be communicated to signal conditioner 36 and/or computer 22 by any known technique and may further be communicated to computer 21 or an additional remote device for storage and display.

[0030] FIG. 3A facilitates an understanding of the axial force and the bending force applied by the anatomical region of ultrasound probe 31 during an ultrasound scan.

[0031] Specifically, referring to FIG. 3A, a probe force F_p applied at the distal tip of ultrasound probe 31 to a tissue 50 (e.g., a prostrate) has the same magnitude but opposite direction of a reaction force F_r from tissue 50 to ultrasound probe 31. For purposes of the present invention, reaction force F_r is decomposed into two (2) components: an axial force F_x and a bending force F_y.

[0032] Referring also to FIG. 3B, assuming the measured strain at points SG1, SG2, SG3 and SG4 are ε_1, ε_2, ε_3 and ε_4, respectively, axial force F_x and bending force F_y may be calculated from the following equations [1] and [2]:

$$F_x = -AE\left(\frac{\varepsilon_1 + \varepsilon_2 + \varepsilon_3 + \varepsilon_4}{4}\right) \quad [1]$$

$$F_y = \frac{IE}{2lr_g}\left(\sqrt{(\varepsilon_1 + \varepsilon_x)^2 + (\varepsilon_2 + \varepsilon_x)^2} + \sqrt{(\varepsilon_3 + \varepsilon_x)^2 + (\varepsilon_4 + \varepsilon_x)^2}\right) \quad [2]$$

where, $\varepsilon_x = \frac{F_x}{AE}$ is strain due to axial force F_x, E is module of elasticity of ultrasound probe 31, A is the cross-sectional area of ultrasound probe 31, I is the moment of area of ultrasound probe 31, r_g is the external radius of ultrasound probe 31, and l is the distance from a center each strain gauge SG to the distal tip of ultrasound probe 31. In practice, the longitudinal strain measurement is a voltage as the output of each strain gauge SG or signal conditioner 36 (FIG. 1), which is linearly related to the strain and the location of each strain gauge SG: $\varepsilon_i = k_s v_i$.

[0033] Equations [1] and [2] do not depend on the rotational angle of ultrasound probe 31 around its longitudinal axis 34 since it calculates the total bending force. However, if the angle between the bending force direction and the axis of strain gauge SG1 is θ_a as shown in FIG. 3B, the angle may be calculated from the following equation [3]:

$$\theta_a = \tan^{-1}\left(\frac{\varepsilon_4 - \varepsilon_2}{\varepsilon_1 - \varepsilon_3}\right) \qquad [3]$$

[0034] This angle may be used find the direction of bending force F_y on a cross sectional plane of ultrasound probe 31.

[0035] FIG. 4 illustrates a flowchart 60 representative of a scanning method of the present invention. A stage S61 of flowchart 60 encompasses longitudinal strain measurements by strain sensor 33 (FIG. 1) as previously described herein in connection with FIGS. 2 and 3, and a stage S62 of flowchart 60 encompasses a determination by module 27 (FIG. 1) of axial force F_x and bending force F_y in accordance with a calculation of equations [1] and [2]. The resulting calculations may be displayed on monitor 22 (e.g., a numeric and/or color coded force map overlaying 3D volume 41). Additionally, module 27 may also calculate bending force angle θ_a.

[0036] FIG. 5 illustrates a flowchart 70 representative of a calibration method for the instrument of the invention. A stage S71 of flowchart 70 encompasses strain measurements by strain sensor 33 (FIG. 1) as previously described herein in connection with FIGS. 2 and 3, and a stage S72 of flowchart 70 encompasses a calculation by module 27 of a strain coefficient k_s. For stage S72, the coefficient *AE* in the axial force equation [1] and coefficient $\frac{IE}{2lr_s}$ in bending force equation [2] are determined. For the calibration procedure, it is only required to know the output voltage of each strain gauge for known axial and bending forces. Since the measured voltage is linearly related to the strain, we can relate the coefficient to the measured voltage by adding additional coefficient k_s as shown in respective graphs 80 (FIG. 6A) and 81 (FIG. 6B).

[0037] Referring to FIGS. 1-6B, those having ordinary skill in the art will appreciate numerous benefits of the present invention including, but not limited to, (1) a reduction in motion artifact and image distortion that is caused by uncontrolled variable force exerted by the operator during an ultrasound probe sweep of an anatomy, (2) an improvement in automatic segmentation and inter/intra modality image registration of the ultrasound images, (3) a consistent rescanning across multiple sessions by monitoring and controlling the force and the torque applied through the ultrasound probe, (4) a training tool for radiology trainees by providing live feedback on the exerted hand force to be able to learn the sufficient amount of force and torque to be applied during ultrasound scanning, (5) an estimation of the biomechanical properties of the tissue under ultrasound scanning to accurately construct a Finite Element Model (FEM) of the tissue that may be used for real-time tracking of the tissue deformation, image registration, tissue segmentation, etc., and (6) an estimation of an elasticity of tissue for calculating the stiffness or strain images of soft tissue and to detect cancerous regions which are known to have higher stiffness compared to healthy tissue.

[0038] In practice, computer 21 (FIG. 1) may provide an input mechanism for selectively enabling or disabling module 27 during an ultrasound scan.

Claims

1. A medical instrument, comprising:

an ultrasound probe (31) including an ultrasound transducer for acquiring images (40) of an anatomical region; and
a strain sensor (33) arranged on the ultrasound probe (31) to measure a longitudinal strain applied by the anatomical region to the ultrasound probe (31) as the ultrasound transducer acquires ultrasound images (40) of the anatomical region,

wherein the strain sensor (33) encircles a longitudinal axis of the ultrasound probe (31) and is spaced from the ultrasound transducer relative to the longitudinal axis of the ultrasound probe (31).

2. The medical instrument of claim 1, wherein the strain sensor (33) includes at least one strain gauge (SG) arranged on the ultrasound probe (31).

3. The medical instrument of claim 1, wherein the strain sensor (33) includes
a plurality of strain gauges (SG) arranged in a grid pattern on the ultrasound probe (31).

4. The medical instrument of claim 3, wherein the plurality of strain gauges (SG) are equally spaced within the grid pattern.

5. The medical instrument of claim 1, wherein the strain sensor (33) is arranged adjacent a proximal end of the ultrasound probe (31) and the ultrasound transducer is positioned at a distal end of the ultrasound probe (31).

6. An ultrasound system, comprising:

an ultrasound probe (31) including ultrasound transducer for acquiring images (40) of an anatomical region;
a strain sensor (33) arranged on the ultrasound probe (31) to measure a longitudinal strain applied by the anatomical region to the ultrasound probe (31) as the ultrasound transducer acquires ultrasound images (40) of the anatomical region,
wherein the strain sensor (33) encircles a longitudinal axis of the ultrasound probe (31) and is spaced from the ultrasound transducer relative to the longitudinal axis of the ultrasound probe (31); and
a workstation (20) operable to reconstruct an ultrasound volume (41) from the ultrasound images (40) acquired by the ultrasound transducer,
wherein, responsive to the longitudinal strain measured by the strain sensor (33), the workstation (20) is further operable to determine at least one of an axial force and a bending force applied by the anatomical region to the ultrasound probe (31) as the ultrasound transducer acquires ultrasound images (40) of the anatomical region.

7. The ultrasound system of claim 6, wherein the strain sensor (33) includes at least one strain gauge (SG) arranged on the ultrasound probe (31).

8. The ultrasound system of claim 7, wherein the strain sensor (33) includes a plurality of strain gauges (SG) arranged in a grid pattern on the ultrasound probe (31).

9. The ultrasound system of claim 8, wherein the plurality of strain gauges (SG) are equally spaced within the grid pattern.

10. The ultrasound system of claim 6, wherein the strain sensor (33) is arranged adjacent a proximal end of the ultrasound probe (31) and the ultrasound transducer is positioned at a distal end of the ultrasound probe (31).

11. The ultrasound system of claim 6, wherein the workstation (20) is further operable to determine the axial force as a function of at least one of an elasticity module of the ultrasound probe (31) and a cross-sectional area of the ultrasound probe (31).

12. The ultrasound system of claim 6, wherein the workstation (20) is further operable to determine the bending force as a function of at least one of an elasticity module of the ultrasound probe (31), an external radius of the ultrasound probe (31), a moment of area of the ultrasound probe (31) and a distance of a center of the strain sensor (33) from a distal tip of the ultrasound probe (31).

13. The ultrasound system of claim 6, wherein the workstation (20) is further operable to display visual representations for at least one of the axial force and the bending force as determined by the workstation (20).

14. The ultrasound system of claim 13, wherein the workstation (20) is further operable to determine an angle between the bending force and a measuring axis of the strain sensor.

Patentansprüche

1. Medizinisches Instrument, das Folgendes umfasst:

eine Ultraschallsonde (31) mit einem Ultraschallwandler zum Erfassen von Bildern (40) einer anatomischen Region; und
einen Dehnungssensor (33), der an der Ultraschallsonde (31) angeordnet ist, um eine Dehnung in Längsrichtung zu messen, die durch die anatomische Region auf die Ultraschallsonde (31) ausgeübt wird, während der Ultraschallwandler Ultraschallbilder (40) der anatomischen Region erfasst,

wobei der Dehnungssensor (33) eine Längsachse der Ultraschallsonde (31) umgibt und von dem Ultraschallwandler in Bezug auf die Längsachse der Ultraschallsonde (31) beabstandet ist.

2. Medizinisches Instrument nach Anspruch 1, wobei der Dehnungssensor (33) mindestens einen Dehnungsmessstreifen (SG) umfasst, der an der Ultraschallsonde (31) angeordnet ist.

3. Medizinisches Instrument nach Anspruch 1, wobei der Dehnungssensor (33) eine Vielzahl von Dehnungsmessstreifen (SG) umfasst, die in einem Gittermuster an der Ultraschallsonde (31) angeordnet sind.

4. Medizinisches Instrument nach Anspruch 3, wobei die Vielzahl von Dehnungsmesstreifen (SG) in dem Gittermuster gleich beabstandet sind.

5. Medizinisches Instrument nach Anspruch 1, wobei der Dehnungssensor (33) angrenzend an ein proximales Ende der Ultraschallsonde (31) angeordnet ist und der Ultraschallwandler an einem distalen Ende der Ultraschallsonde (31) positioniert ist.

6. Ultraschallsystem, das Folgendes umfasst:

eine Ultraschallsonde (31) mit einem Ultraschallwandler zum Erfassen von Bildern (40) einer anatomischen Region;
einen Dehnungssensor (33), der an der Ultraschallsonde (31) angeordnet ist, um eine Dehnung in Längsrichtung zu messen, die durch die anatomische Region auf die Ultraschallsonde (31) ausgeübt wird, während der Ultraschallwandler Ultraschallbilder (40) der anatomischen Region erfasst,
wobei der Dehnungssensor (33) eine Längsachse der Ultraschallsonde (31) umgibt und von dem Ultraschallwandler in Bezug auf die Längsachse der Ultraschallsonde (31) beabstandet ist; und
eine Workstation (20), die betriebsfähig ist, um aus den durch den Ultraschallwandler erfassten Ultraschallbildern (40) ein Ultraschallvolumen (41) zu rekonstruieren,

wobei die Workstation (20) in Reaktion auf die durch den Dehnungssensor (33) gemessene Dehnung in Längsrichtung weiterhin betriebsfähig ist, um mindestens entweder eine Axialkraft oder eine Biegekraft zu ermitteln, die durch die anatomische Region auf die Ultraschallsonde (31) ausgeübt wird, während der Ultraschallwandler Ultraschallbilder (40) der anatomischen Region erfasst.

7. Ultraschallsystem nach Anspruch 6, wobei der Dehnungssensor (33) mindestens einen Dehnungsmessstreifen (SG) umfasst, der an der Ultraschallsonde (31) angeordnet ist.

8. Ultraschallsystem nach Anspruch 7, wobei der Dehnungssensor (33) eine Vielzahl von Dehnungsmessstreifen (SG) umfasst, die in einem Gittermuster an der Ultraschallsonde (31) angeordnet sind.

9. Ultraschallsystem nach Anspruch 8, wobei die Vielzahl von Dehnungsmessstreifen (SG) in dem Gittermuster gleich beabstandet sind.

10. Ultraschallsystem nach Anspruch 6, wobei der Dehnungssensor (33) angrenzend an ein proximales Ende der Ultraschallsonde (31) angeordnet ist und der Ultraschallwandler an einem distalen Ende der Ultraschallsonde (31) positioniert ist.

11. Ultraschallsystem nach Anspruch 6, wobei die Workstation (20) weiterhin betriebsfähig ist, um die Axialkraft als eine Funktion von mindestens entweder einem Elastizitätsmodul der Ultraschallsonde (31) oder einer Querschnittsfläche der Ultraschallsonde (31) zu ermitteln.

12. Ultraschallsystem nach Anspruch 6, wobei die Workstation (20) weiterhin betriebsfähig ist, um die Biegekraft als eine Funktion von mindestens entweder einem Elastizitätsmodul der Ultraschallsonde (31), einem Außenradius der Ultraschallsonde (31), einem Flächenmoment der Ultraschallsonde (31) oder einem Abstand eines Zentrums des Dehnungssensors (33) von einer distalen Spitze der Ultraschallsonde (31) zu ermitteln.

13. Ultraschallsystem nach Anspruch 6, wobei die Workstation (20) weiterhin betriebsfähig ist, um visuellen Darstellungen für mindestens entweder die Axialkraft oder die Biegekraft anzuzeigen, wie sie durch die Workstation (20) ermittelt wurde.

14. Ultraschallsystem nach Anspruch 13, wobei die Workstation (20) weiterhin betriebsfähig ist, um einen Winkel zwischen der Biegekraft und einer Messachse des Dehnungssensors zu ermitteln.

Revendications

1. Instrument médical, comprenant :

une sonde à ultrasons (31) comportant un transducteur à ultrasons permettant d'acquérir des images (40) d'une région anatomique; et
un capteur de contrainte (33) agencé sur la sonde à ultrasons (31) et permettant de mesurer une contrainte longitudinale exercée par la région anatomique sur la sonde à ultrasons (31) lorsque le transducteur à ultrasons acquiert des images à ultrasons (40) de la région anatomique,

dans lequel le capteur de contrainte (33) entoure un axe longitudinal de la sonde à ultrasons (31) et est espacé du transducteur à ultrasons par rapport à l'axe longitudinal de la sonde à ultrasons (31).

2. Instrument médical selon la revendication 1, dans lequel le capteur de contrainte (33) comporte au moins une jauge de contrainte (SG) agencée sur la sonde à ultrasons (31).

3. Instrument médical selon la revendication 1, dans lequel le capteur de contrainte (33) comporte une pluralité de jauges de contrainte (SG) agencées selon un motif de grille sur la sonde à ultrasons (31).

4. Instrument médical selon la revendication 3, dans lequel la pluralité de jauges de contrainte (SG) sont espacées de manière égale à l'intérieur du motif de grille.

5. Instrument médical selon la revendication 1, dans lequel le capteur de contrainte (33) est agencé de manière adjacente à une extrémité proximale de la sonde à ultrasons (31) et le transducteur à ultrasons est placé à une extrémité distale de la sonde à ultrasons (31).

6. Système à ultrasons, comprenant :

une sonde à ultrasons (31) comportant un transducteur à ultrasons permettant d'acquérir des images (40) d'une région anatomique;
un capteur de contrainte (33) agencé sur la sonde à ultrasons (31) et permettant de mesurer une contrainte longitudinale exercée par la région anatomique sur la sonde à ultrasons (31) lorsque le transducteur à ultrasons acquiert des images à ultrasons (40) de la région anatomique,
dans lequel le capteur de contrainte (33) entoure un axe longitudinal de la sonde à ultrasons (31) et est espacé du transducteur à ultrasons par rapport à l'axe longitudinal de la sonde à ultrasons (31) ; et
un poste de travail (20) utilisable pour reconstituer un volume à ultrasons (41) à partir des images à ultrasons (40) acquises par le transducteur à ultrasons,

dans lequel, en réponse à la contrainte longitudinale mesurée par le capteur de contrainte (33), le poste de travail (20) est utilisable en outre pour déterminer au moins soit une force axiale, soit une force de flexion exercée par la région anatomique sur la sonde à ultrasons (31) lorsque le transducteur à ultrasons acquiert des images à ultrasons (40) de la région anatomique.

7. Système à ultrasons selon la revendication 6, dans lequel le capteur de contrainte (33) comporte au moins une jauge de contrainte (SG) agencée sur la sonde à ultrasons (31).

8. Système à ultrasons selon la revendication 7, dans lequel le capteur de contrainte (33) comporte une pluralité de jauges de contrainte (SG) agencées selon un motif de grille sur la sonde à ultrasons (31).

9. Système à ultrasons selon la revendication 8, dans lequel la pluralité de jauges de contrainte (SG) sont espacées de manière égale à l'intérieur du motif de grille.

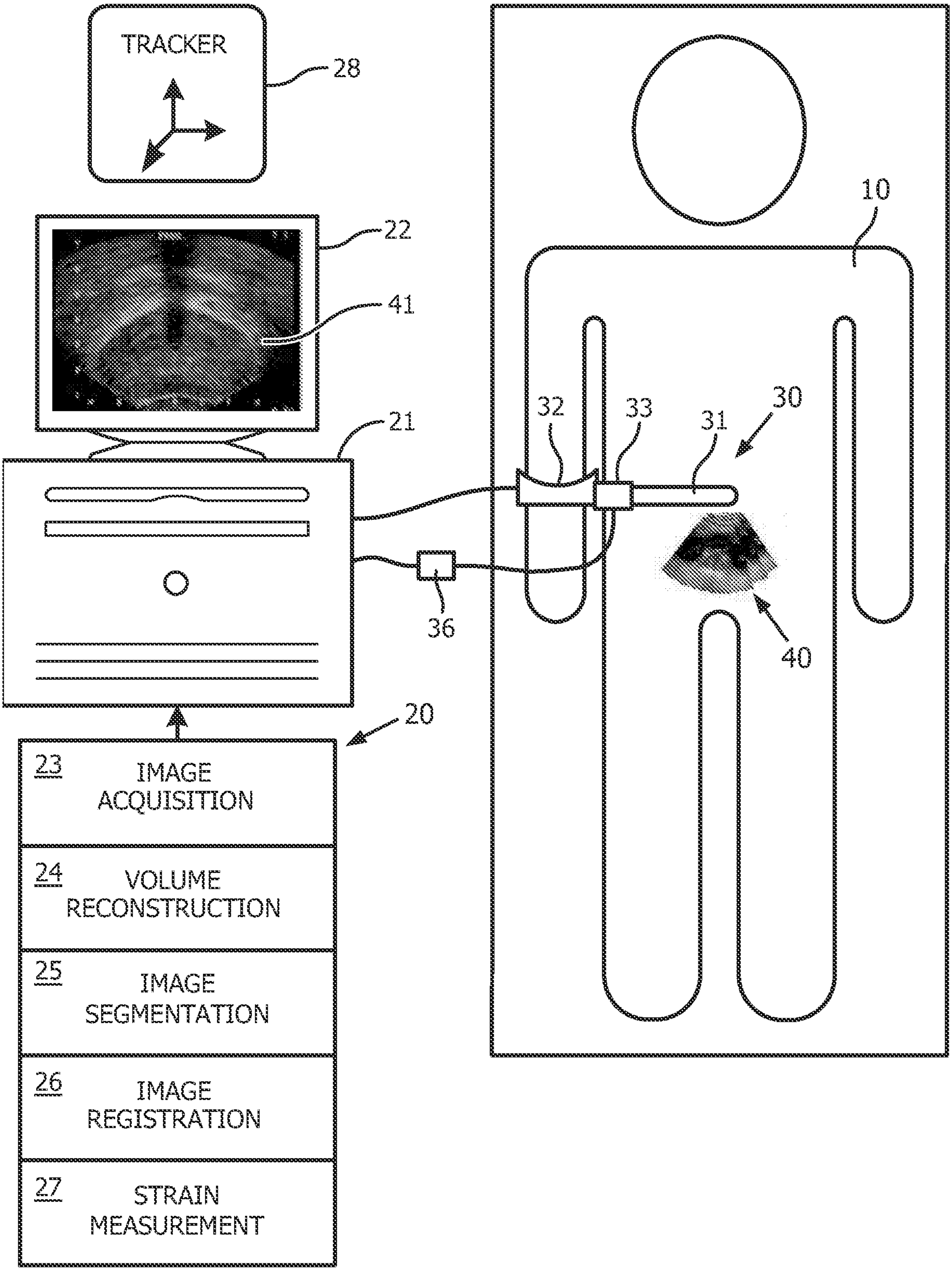
10. Système à ultrasons selon la revendication 6, dans lequel le capteur de contrainte (33) est agencé de manière adjacente à une extrémité proximale de la sonde à ultrasons (31) et le transducteur à ultrasons est placé à une extrémité distale de la sonde à ultrasons (31).

11. Système à ultrasons selon la revendication 6, dans lequel le poste de travail (20) est utilisable en outre pour déterminer la force axiale en fonction au moins soit d'un module d'élasticité de la sonde à ultrasons (31), soit d'une aire de section transversale de la sonde à ultrasons (31).

12. Système à ultrasons selon la revendication 6, dans lequel le poste de travail (20) est utilisable en outre pour déterminer la force de flexion en fonction au moins soit d'un module d'élasticité de la sonde à ultrasons (31), soit d'un rayon externe de la sonde à ultrasons (31), soit d'un moment d'inertie de la sonde à ultrasons (31), soit d'une distance entre le centre du capteur de contrainte (33) et l'extrémité distale de la sonde à ultrasons (31).

13. Système à ultrasons selon la revendication 6, dans lequel le poste de travail (20) est utilisable en outre pour afficher des représentations visuelles au moins soit de la force axiale, soit de la force de flexion déterminée par le poste de travail (20).

14. Système à ultrasons selon la revendication 13, dans lequel le poste de travail (20) est utilisable en outre pour déterminer un angle entre la force de flexion et un axe de mesure du capteur de contrainte.


TRACKER
28
22
41
21
20
23 IMAGE ACQUISITION
24 VOLUME RECONSTRUCTION
25 IMAGE SEGMENTATION
26 IMAGE REGISTRATION
27 STRAIN MEASUREMENT
10
32
33
31
30
36
40

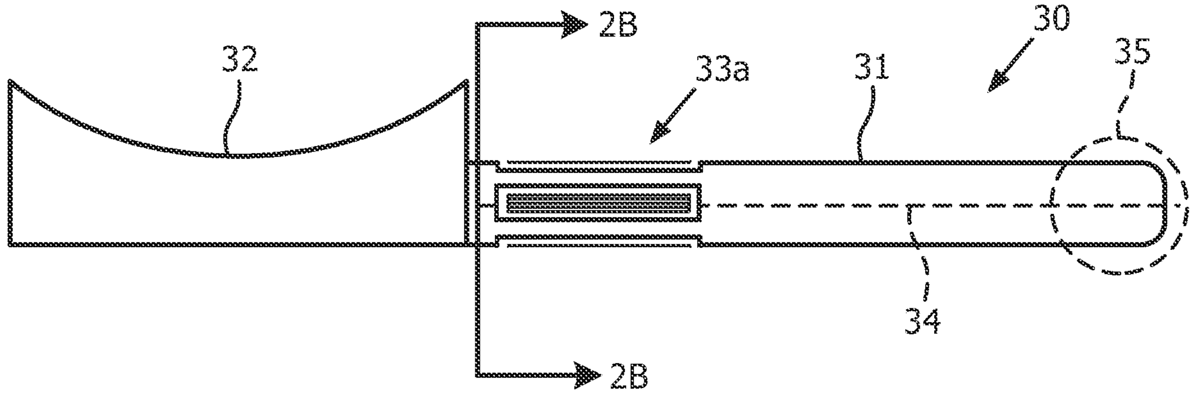


FIG. 2A

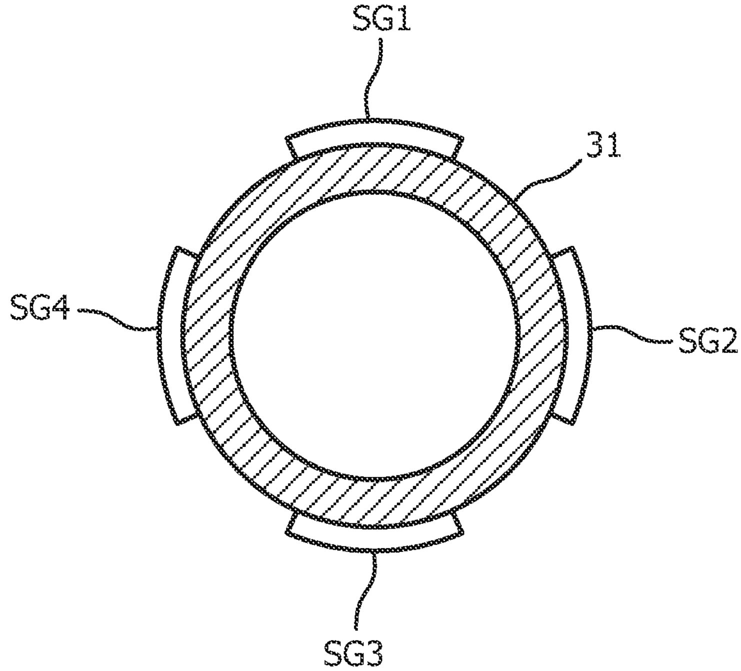


FIG. 2A

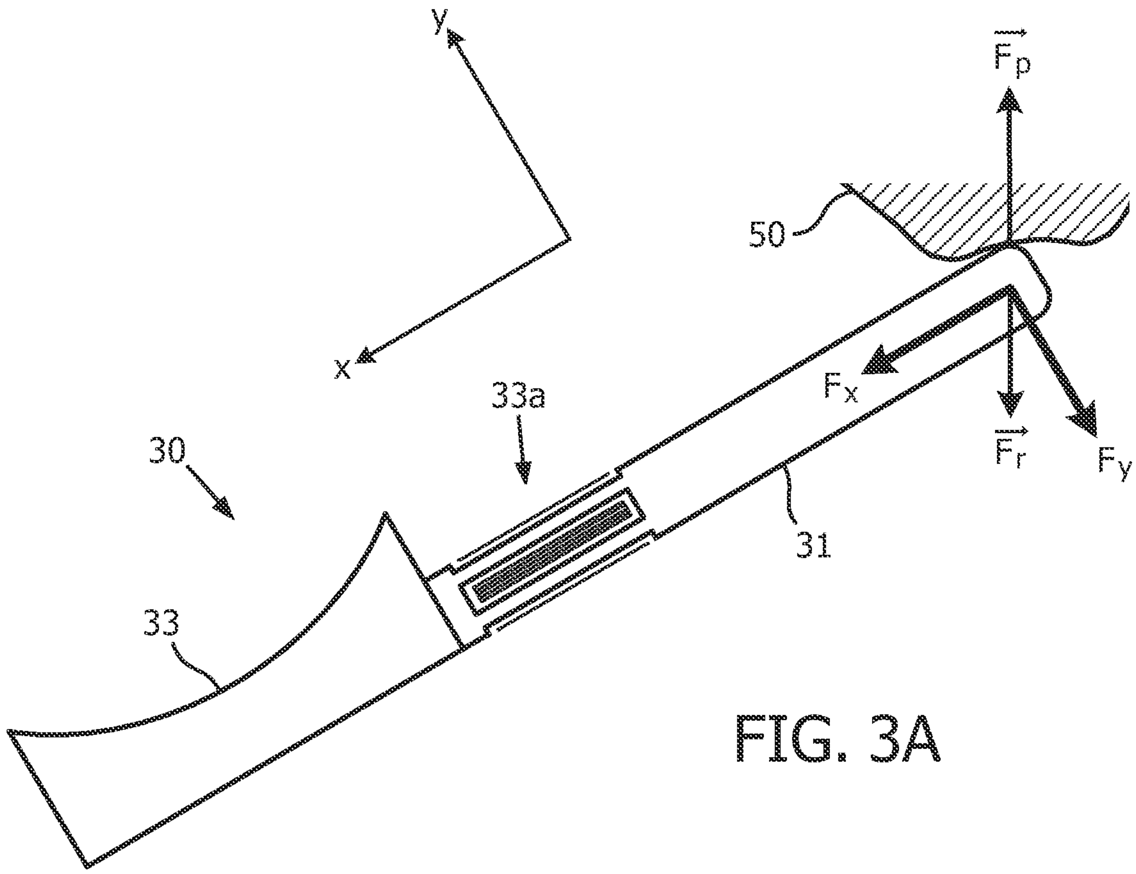

y
x
$\vec{F_p}$
50
33a
F_x
$\vec{F_r}$
F_y
30
31
33

FIG. 3A

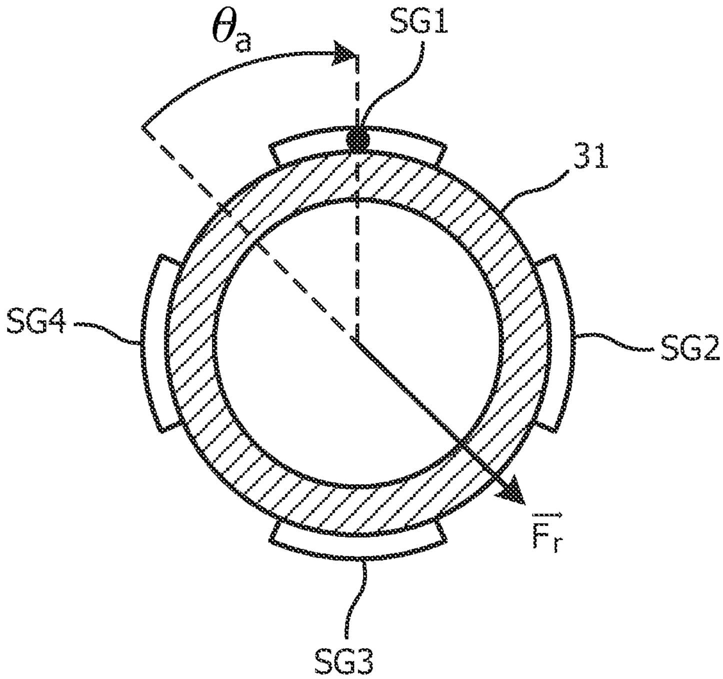

θ_a
SG1
31
SG4
SG2
$\vec{F_r}$
SG3

FIG. 3C

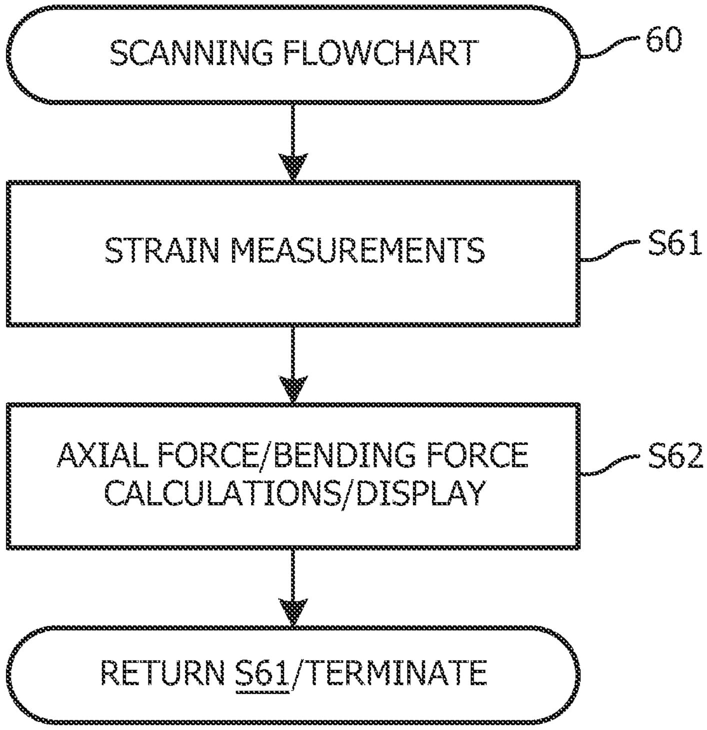

SCANNING FLOWCHART
60
STRAIN MEASUREMENTS
S61
AXIAL FORCE/BENDING FORCE CALCULATIONS/DISPLAY
S62
RETURN S61/TERMINATE

FIG. 4

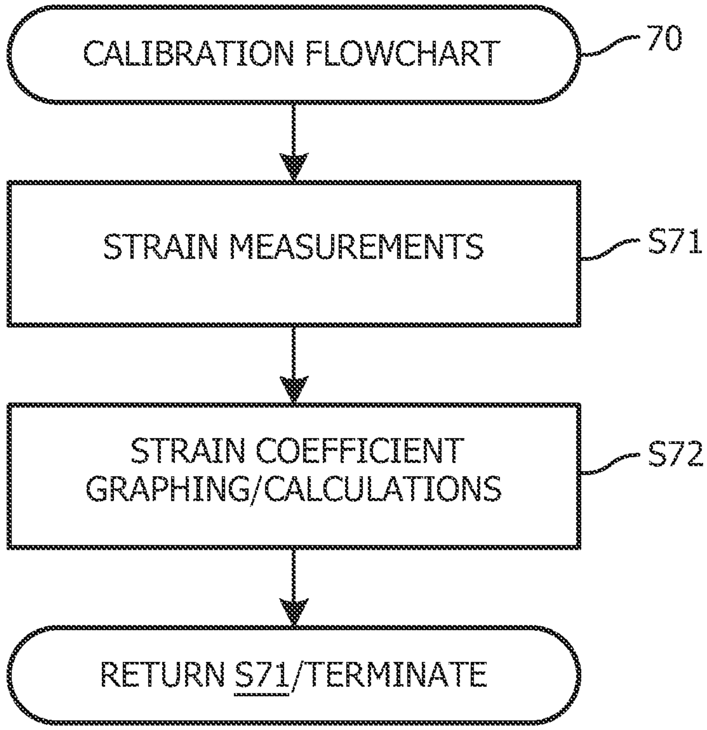

CALIBRATION FLOWCHART
70
STRAIN MEASUREMENTS
S71
STRAIN COEFFICIENT GRAPHING/CALCULATIONS
S72
RETURN S71/TERMINATE

FIG. 5

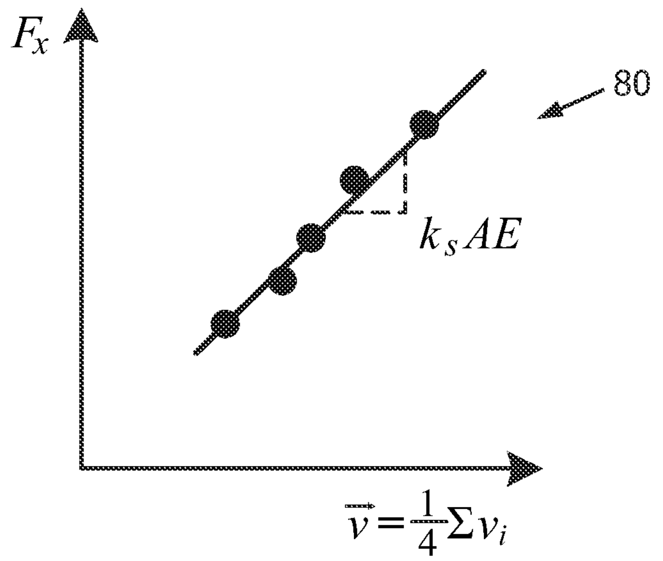

F_x
80
$k_s AE$
$\vec{v} = \frac{1}{4}\Sigma v_i$

FIG. 6A

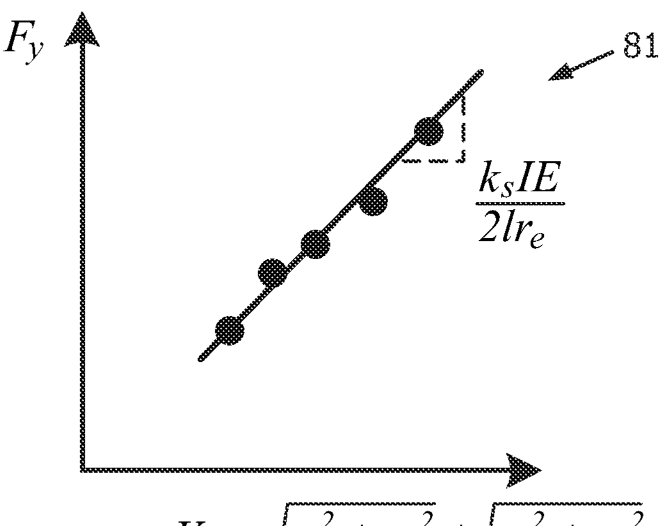

F_y
81
$\frac{k_s IE}{2lr_e}$
$Vy = \sqrt{v_1^2 + v_2^2} + \sqrt{v_3^2 + v_4^2}$

FIG. 6B

REFERENCES CITED IN THE DESCRIPTION

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- WO 2003022152 A1, Michael Richard Burcher **[0010]**

patsnap

专利名称(译)	通过应变测量在成像期间测量超声探头上的力和扭矩的系统		
公开(公告)号	EP2978378B1	公开(公告)日	2017-03-08
申请号	EP2014717874	申请日	2014-03-27
[标]申请(专利权)人(译)	皇家飞利浦电子股份有限公司		
申请(专利权)人(译)	皇家飞利浦N.V.		
当前申请(专利权)人(译)	皇家飞利浦N.V.		
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发明人	TAHMASEBI MARAGHOOSH, AMIR MOHAMMAD SHARIFI, MAHMOUDREZA STANTON, DOUGLAS ALLEN		
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其他公开文献	EP2978378A1		
外部链接	Espacenet		

摘要(译)

超声系统采用超声探头（31），应变传感器（33）和工作站（20）。超声探头（31）包括用于采集解剖区域的超声图像（40）的超声换能器。应变传感器（33）布置在超声探头（31）上，以在超声换能器获取解剖区域的超声图像（40）时测量由解剖区域施加到超声探头（31）的纵向应变。应变传感器（33）环绕超声探头（31）的纵向轴线并且相对于超声探头（31）的纵向轴线与超声换能器间隔开。工作站（20）从超声换能器获取的超声图像（40）重建超声体积（41），并且响应于由应变传感器（33）测量的纵向应变，确定由其施加的轴向力和/或弯曲力。当超声换能器获取解剖区域的超声图像（40）时，超声探头（31）的解剖区域。


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(54) SYSTEMS FOR MEASURING FORCE AND TORQUE ON ULTRASOUND PROBE DURING IMAGING THROUGH STRAIN MEASUREMENT
SYSTEME ZUR MESSUNG VON KRAFT UND DREHMOMENT AUF EINER ULTRASCHALLSONDE WÄHREND DER BILDGEBUNG DURCH DEHNUNGSMESSUNG
SYSTÈMES DE MESURE DE LA FORCE ET DU COUPLE SUR UNE SONDE À ULTRASONS LORS D'UNE IMAGERIE AU MOYEN D'UNE MESURE DE LA CONTRAINTE

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