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(54) **SENSOR COORDINATE CALIBRATION IN AN ULTRASOUND SYSTEM**

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(Continued)

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USPC 382/131
See application file for complete search history.

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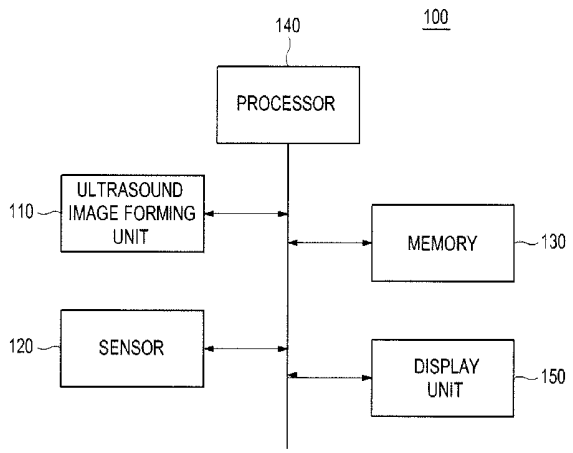
(74) *Attorney, Agent, or Firm* — McDermott Will & Emery LLP

(57) **ABSTRACT**

There is disclosed an embodiment for performing a calibration of a sensor by using an image registration between a three-dimensional ultrasound image and computerized tomography (CT) image. An ultrasound image forming unit includes an ultrasound probe and forms a three-dimensional ultrasound image of a target object. A sensor is coupled to the ultrasound probe. A memory stores a three-dimensional computed tomography (CT) image of the target object and position information on a position between the three-dimensional ultrasound image and the sensor. A processor performs image registration between the three-dimensional CT image and the three-dimensional ultrasound image to form a first transformation function for transforming a position of the sensor to a corresponding position on the three-dimensional CT image and performs calibration of the sensor by applying the position information to the first transformation function.

12 Claims, 5 Drawing Sheets



(51) **Int. Cl.**

A61B 8/08	(2006.01)
A61B 8/00	(2006.01)
A61B 6/03	(2006.01)

(52) **U.S. Cl.**

CPC ***A61B8/4254*** (2013.01); ***A61B 8/4416*** (2013.01); ***A61B 8/483*** (2013.01); ***A61B 8/58*** (2013.01); *A61B 6/03* (2013.01); *G06T 2207/10081* (2013.01); *G06T 2207/10136* (2013.01); *G06T 2207/30056* (2013.01)

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FIG. 1

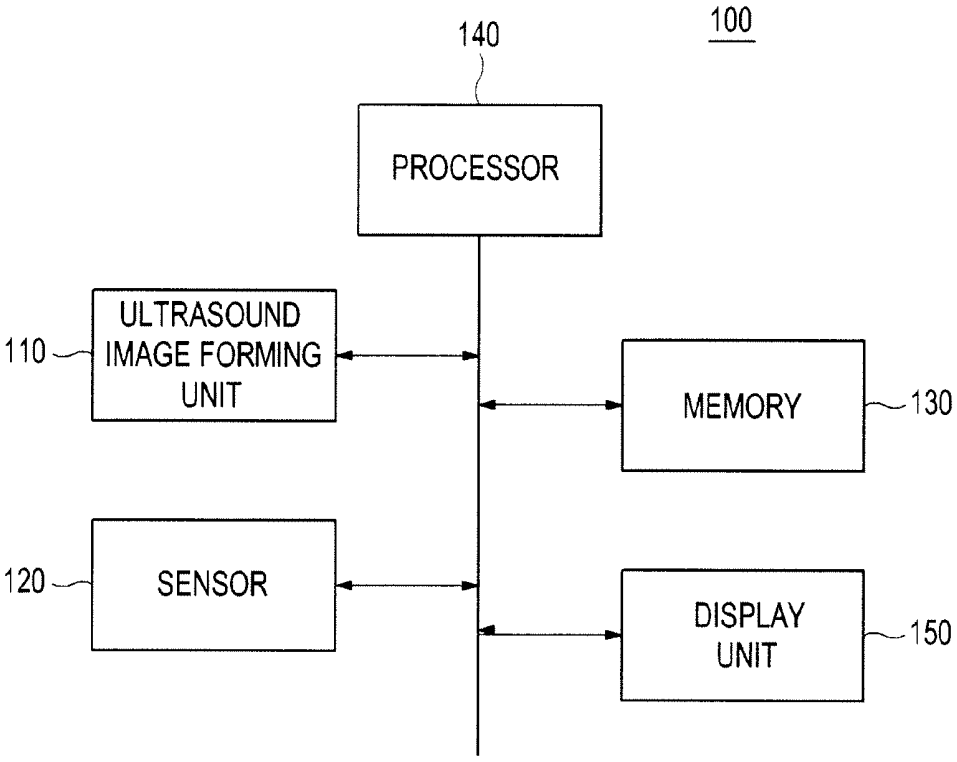

100
140
PROCESSOR
110
ULTRASOUND IMAGE FORMING UNIT
MEMORY
130
120
SENSOR
DISPLAY UNIT
150

FIG. 2

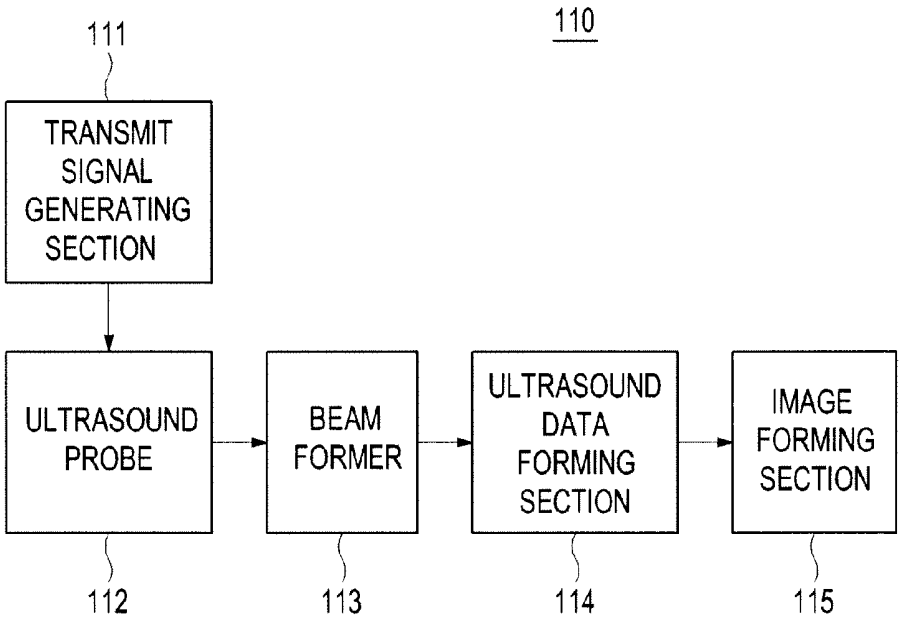

110
111
TRANSMIT SIGNAL GENERATING SECTION
ULTRASOUND PROBE
BEAM FORMER
ULTRASOUND DATA FORMING SECTION
IMAGE FORMING SECTION
112
113
114
115

FIG. 3

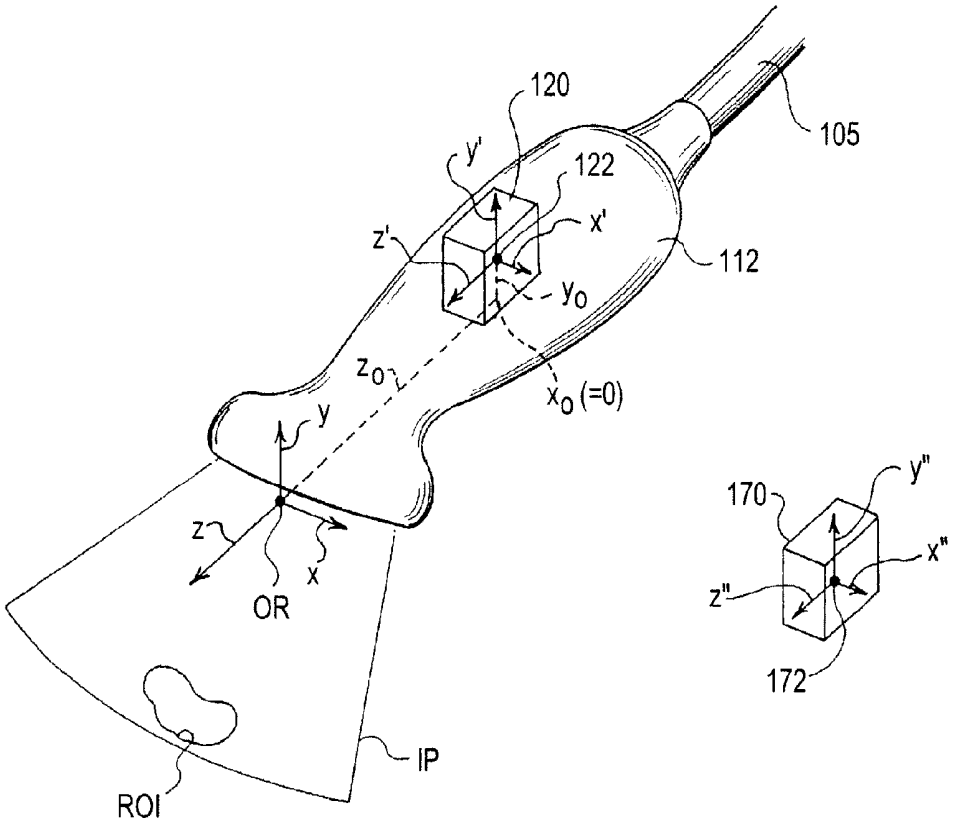


FIG. 4

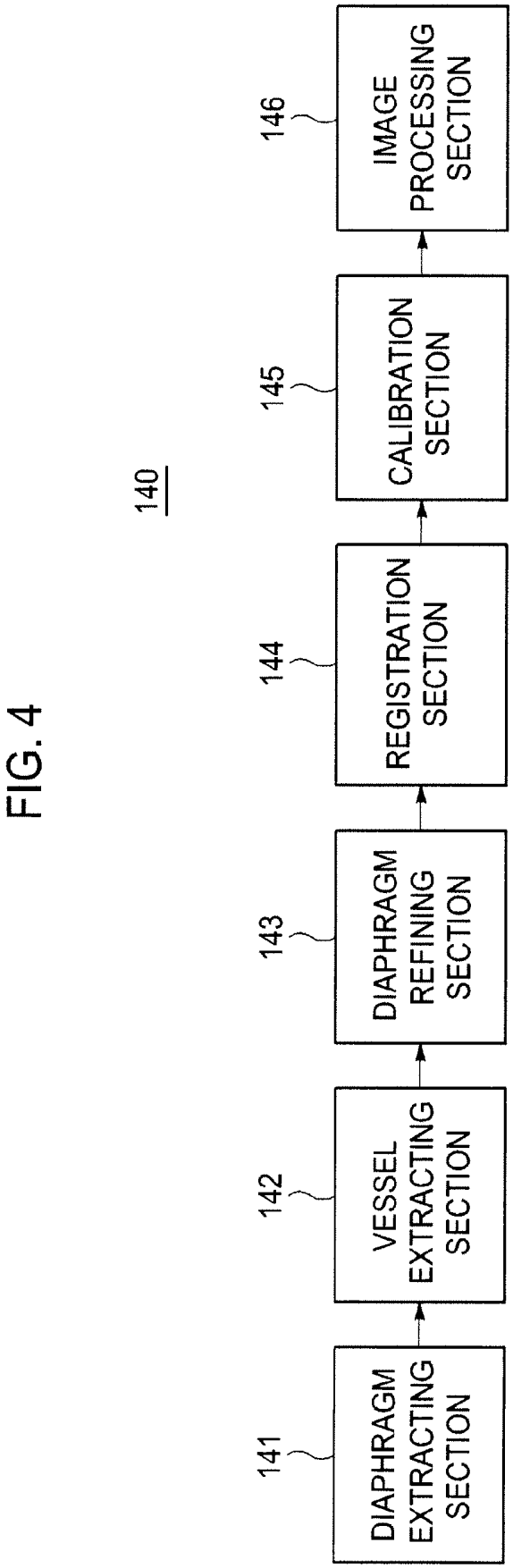
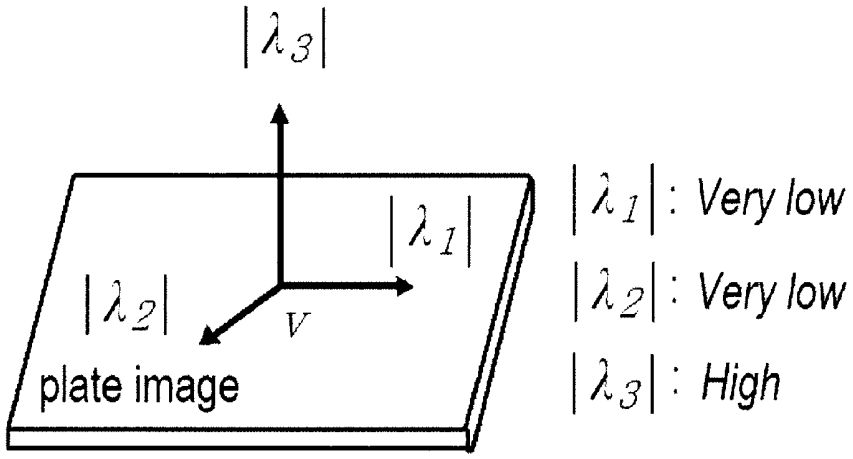

140
141
DIAPHRAGM EXTRACTING SECTION
142
VESSEL EXTRACTING SECTION
143
DIAPHRAGM REFINING SECTION
144
REGISTRATION SECTION
145
CALIBRATION SECTION
146
IMAGE PROCESSING SECTION

FIG. 5



SENSOR COORDINATE CALIBRATION IN AN ULTRASOUND SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority from Korean Patent Application No. 10-2009-0070994 filed on Jul. 31, 2009, the entire subject matter of which is incorporated herein by reference.

TECHNICAL FIELD

The present invention generally relates to ultrasound systems, and more particularly to an ultrasound system and method for performing sensor coordinate calibration through image-based registration between a three-dimensional ultrasound image and a computerized tomography (CT) image.

BACKGROUND

The ultrasound system has become an important and popular diagnostic tool due to its non-invasive and non-destructive nature. Modern high-performance ultrasound imaging diagnostic systems and techniques are commonly used to produce two or three-dimensional images of internal features of patients (target objects).

However, the ultrasound system suffers from inherent shortcomings of an ultrasound image such as a low signal-to-noise ratio and a limited field of view. Thus, the image registration of a CT (or MR) image onto the ultrasound image has been introduced in order to compensate for deficiencies of the ultrasound image. A sensor has been used to perform the image registration of a CT (or MR) image onto the ultrasound image. Researches have been introduced to calibrate the sensor to match coordinates of the CT image and coordinates of the sensor.

Conventionally, after outer markers are attached on a surface of a target object, a CT image and an ultrasound image for the target object with the markers are acquired. Thereafter, the calibration is carried out by using a relationship between coordinates of the markers in the CT and ultrasound image. That is, the outer markers should be attached to the surface of the target objects before obtaining the CT image and the ultrasound image and be maintained in the same position until completing the acquisition of the ultrasound image. Moreover, a sensor must sense the positions of the respective outer markers.

Further, the registration between the coordinate of the CT image and the coordinate of the sensor has been performed by manually inputting inner markers on the CT image. Thus, a user of the ultrasound system had to input the inner markers, which causes the registration between the coordinate of the CT image and the coordinate of the sensor to be wrong.

SUMMARY

An embodiment for forming a plurality of three-dimensional ultrasound images is disclosed herein. In one embodiment, by way of non-limiting example, an ultrasound system, comprises: an ultrasound image forming unit including a ultrasound probe and being configured to form a three-dimensional ultrasound image of a target object; a sensor coupled to the ultrasound probe; a memory configured to store a three-dimensional computed tomography (CT) image of the target object and position information on a position between the three-dimensional ultrasound image and the sensor; and a processor configured to perform image registration between the three-dimensional CT image and the three-dimensional ultrasound image to thereby form a first transformation function for transforming a position of the sensor to a corresponding position on the three-dimensional CT image and perform calibration of the sensor by applying the position information to the first transformation function.

In another embodiment, a method of performing a calibration of a sensor, comprises: a) obtaining a three-dimensional ultrasound image of a target object obtained by the ultrasound system and a three-dimensional CT image; b) calculating a position information on a position between the three-dimensional ultrasound image and the sensor; c) performing registration between the three-dimensional ultrasound image and the three-dimensional CT image to obtain a first transformation function for transforming a position of the sensor to a corresponding position on the three-dimensional CT image; and d) performing calibration of the sensor by applying the position information to the first transformation function.

The Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used in determining the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram showing an illustrative embodiment of an ultrasound system.

FIG. **2** is a block diagram showing an illustrative embodiment of an ultrasound image forming unit.

FIG. **3** is an illustrative embodiment of an ultrasound probe.

FIG. **4** is a block diagram showing an illustrative embodiment of a processor.

FIG. **5** is a schematic diagram showing an example of eigenvalues in the Hessian matrix.

DETAILED DESCRIPTION

A detailed description may be provided with reference to the accompanying drawings. One of ordinary skill in the art may realize that the following description is illustrative only and is not in any way limiting. Other embodiments of the present invention may readily suggest themselves to such skilled persons having the benefit of this disclosure.

FIG. **1** is a block diagram showing an illustrative embodiment of an ultrasound system which embodies the methods of the present invention. The ultrasound system **100** may include an ultrasound image forming unit **110**, a sensor **120**, a memory **130**, a processor **140** and a display unit **150**.

The ultrasound image forming unit **110** may be configured to transmit ultrasound signals to a target object (not shown) and receive ultrasound echo signals reflected from the target object. The ultrasound image forming unit **110** may be further configured to form a three-dimensional ultrasound image of the target object based on the received ultrasound echo signals.

FIG. **2** is a block diagram showing an illustrative embodiment of an ultrasound image forming unit **110**. The ultrasound image forming unit **110** may include a transmit (Tx) signal generating section **111**, an ultrasound probe **112** including a plurality of transducer elements (not shown), a beam former **113**, an ultrasound data forming section **114** and an image forming section **115**.

The Tx signal generating section **111** may generate Tx signals according to an image mode set in the ultrasound system **100**. The image mode may include a brightness (B) mode, a Doppler (D) mode, a color flow mode, etc. In one exemplary embodiment, the B mode may be set in the ultrasound system **100** to obtain a B mode ultrasound image.

The ultrasound probe **112** may receive the Tx signals from the Tx signal generating section **111** and generate ultrasound signals, which may travel into the target object. The ultrasound probe **112** may further receive ultrasound echo signals reflected from the target object and convert them into electrical receive signals. In such a case, the electrical receive signals may be analog signals. The ultrasound probe **112** may be a three-dimensional probe, a two-dimensional probe, a one-dimensional probe or the like.

FIG. **3** is an illustrative embodiment of an ultrasound probe **112**. At least one transducer element (not shown) of the ultrasound probe **112** generates an image plane IP, which is used to scan a region of interest ROI. The image plane IP may be one of slice planes of the three-dimensional ultrasound image. The sensor **120** is attached to the housing of the ultrasound probe **112** to determine the position and orientation of the image plane IP. The ultrasound system **100** coupled with the ultrasound probe **112** via the probe cable **105** can use the data generated by the sensor **120** to determine the position and orientation of the sensor **120** and/or the image plane IP, as described below.

In this preferred embodiment, the sensor **120** is a magnetic sensor that monitors the free-hand movement of the ultrasound probe **112** in six degrees of freedom with respect to a transducer element **170**. As shown in FIG. **3**, the sensor **120** and the transducer element **170** each define an origin (**122**, **172**, respectively) defined by three orthogonal axes (X', Y', Z' and X", Y", Z", respectively). The sensor **120** monitors the translation of the origin **122** with respect to the origin **172** of the transducer element **170** to determine position and monitor the rotation of the X', Y', Z' axes with respect to the X", Y", Z" axes of the transducer element **170** to determine orientation.

The position and orientation of the sensor **120** can be used to determine the position and orientation of the image plane IP. As shown in FIG. **3**, the image plane IP defines an origin OR defined by three orthogonal axes X, Y, Z, which are preferably aligned with the origin of a center acoustic line generated by the ultrasound probe **112**. The position of the origin **122** and the orientation of axes X', Y', Z' of the sensor **120** may not precisely coincide with the position of the origin OR and the orientation of the axes X, Y, Z of the image plane IP. For example, in FIG. **3**, the origin OR of the image plane IP is offset from the origin **122** of the sensor **120** by a distance z_0 along the Z-direction and a distance of y_0 along the Y-direction. In FIG. **3**, there is no offset along the X-direction nor is there a rotational offset in the orientation of the axes. Accordingly, the position and orientation of the sensor **120** do not directly describe the position and orientation of the image plane IP.

To determine the position an orientation of the image plane IP from the position and orientation of the sensor **120**, sensor calibration data is used to transform the position and orientation of the sensor **120** to the position and orientation of the image plane IP. For simplicity, the term "position and orientation" is used to broadly refer to position and/or orientation. Accordingly, if the sensor **120** has the same orientation as the image plane IP, then the position and orientation calibration data may not contain any orientation calibration data. Similarly, as shown in FIG. **3**, the sensor **120** may not have a positional offset with respect to one or more axes of the image plane IP.

There are a number of ways of defining the image plane/sensor offset. One method of calibrating at least some types of sensors use three orthogonal linear dimension offsets in X, Y, Z and three rotation angles about each of these axes. Other methods include using a position transformation matrix or quaternions, which are described in the user manual for the mini Bird™ and the Flock of Bird™ systems by Ascension Technology Corp.

As described above, the ultrasound probes with position and orientation sensors are typically used only with ultrasound systems that contain the calibration data for the probe/sensor pair. Conventionally, the probe/sensor pair is calibrated, and the calibration data is stored in the ultrasound system **100**, which will be used in conjunction with the probe/sensor pair. If the probe/sensor pair is to be used with a different ultrasound system, then the probe/sensor pair typically needs to be re-calibrated on that different ultrasound system. Since sonographers are often unable or unwilling to perform probe/sensor pair calibration, probe/sensor pairs are often used only with the ultrasound system for which the probe/sensor pair was initially calibrated.

Referring back to FIG. **2**, the beam former **113** may convert the electrical receive signals outputted from the ultrasound probe **112** into digital signals. The beam former **113** may further apply delays to the digital signals in consideration of the distances between the transducer elements and focal points to thereby output receive-focused signals.

The ultrasound data forming section **114** may form a plurality of ultrasound data by using the receive-focused signals. In one embodiment, the plurality of ultrasound data may be radio frequency (RF) data or IQ data. The image forming section **115** may form the three-dimensional ultrasound image of the target object based on the ultrasound data.

Referring back to FIG. **1**, the sensor **120** may be mounted on one side of the ultrasound probe **112**. In one embodiment, by way of non-limiting examples, the sensor **120** may be built in the ultrasound probe **112** to be away from the plurality of transducer elements (not shown) by a predetermined distance. Alternatively, the sensor **120** may be externally mounted on the ultrasound probe **112** to be away from the plurality of transducer elements. The sensor **120** may include a three-dimensional sensor, which can detect a three-dimensional position and an angle of the ultrasound probe **112**.

The memory **130** may store a three-dimensional CT image of the target object. In one embodiment, by way of non-limiting examples, the three-dimensional CT image may be a three-dimensional CT image of a liver in which a diaphragm and a blood vessel are extracted. The memory **130** may store information on a position between the three-dimensional ultrasound image and the sensor **120** (hereinafter, referred to as "position information"). The position information may include information on a distance between the transducer elements (not shown) and the sensor **120**. In one embodiment, by way of non-limiting examples, the memory **120** may include at least one of a random access memory (RAM), a hard disk drive or the like.

The processor **140** may be configured to perform registration between the three-dimensional CT image and the three-dimensional ultrasound image, thereby forming a transformation function (T_{probe}) for representing the ultrasound probe **112** on the three-dimensional CT image. Furthermore, the processor **140** may perform calibration of the sensor **120** to match coordinates of the three-dimensional CT image (not shown) and coordinates of the sensor **120** based on the position information and the transformation function.

FIG. **4** is a block diagram showing an illustrative embodiment of the processor **140**. The processor **140** may include a

diaphragm extracting section **141**, a vessel extracting section **142**, a diaphragm refining section **143**, a registration section **144**, a calibration section **145** and an image processing section **146**.

The diaphragm extracting section **141** may be configured to extract a diaphragm from the three-dimensional ultrasound image formed in the ultrasound image forming unit **110**. In one embodiment, the diaphragm extracting section **141** may perform a Hessian matrix based flatness test upon the three-dimensional ultrasound image to extract the diaphragm. The diaphragm may be considered as a curved surface in the three-dimensional ultrasound image. Thus, regions in which a voxel intensity change in a normal direction at a surface is greater than a voxel intensity change in a horizontal direction at the surface may be extracted as the diaphragm. FIG. **5** is a schematic diagram showing an example of eigenvalues λ_1, λ_2 and λ_3 in the Hessian matrix.

Hereinafter, an operation of the diaphragm extracting section **141** will be described in detail. The diaphragm extracting section **141** may be configured to select voxels having a relatively high flatness value. The flatness $\mu(v)$ may be defined as the following equation (1).

$$\mu(v)=\phi_1(v)\phi_2(v)\phi_3(v)/\phi_{3_{max}}(v) \quad (1)$$

wherein $\phi_1(v)$, $\phi_2(v)$ and $\phi_3(v)$ in the equation (1) may be represented as the following equation (2).

$$\phi_1(v)=\left(1-\frac{\lambda_1(v)}{\lambda_3(v)}\right)^2,\ \phi_2(v)=\left(1-\frac{\lambda_2(v)}{\lambda_3(v)}\right)^2,\ \phi_3(v)=\sum_i \lambda_i(v)^2 \quad (2)$$

wherein λ_1, λ_2 and λ_3 denote eigenvalues of the Hessian matrix at voxel v. The flatness $\mu(v)$ may be normalized to have values ranging from 0-1. A flatness map may be formed based on the flatness values obtained from all of the voxels according to the equations (1) and (2). Thereafter, the voxels having a relatively high flatness value are selected. In one embodiment, the voxels having the flatness over 0.1 may be selected.

The diaphragm extracting section **141** may be further configured to perform the morphological opening upon the selected voxels to remove small clutters therefrom. The morphological opening may be carried out by sequentially performing erosion and dilation. That is, a predetermined number of the voxels are removed in the edges of the area in which the voxels exist, and thus, the area becomes contracted (erosion). In this manner, it becomes possible to remove small clutters. Thereafter, the edges of the area are expanded by the predetermined number of the voxels (dilation). These erosion and dilation may be performed by one or more voxels.

The diaphragm is the largest surface in the three-dimensional ultrasound image. The largest surface may be selected among candidate surfaces obtained by the intensity-based connected component analysis (CCA) for the voxels and the selected surface may be regarded as the diaphragm in the three-dimensional ultrasound image. The voxel-based CCA is one of the methods of grouping regions in which voxel values exist. For example, the number of voxels connected to each of the voxels through a connectivity test by referring to values of voxels neighboring the corresponding voxel (e.g., 26 voxels) may be computed. The voxels, of which connected voxels are greater than the predetermined number, are selected as candidate groups. Since the diaphragm is the widest curved surface in the ROI, the candidate group having the most connected voxels may be selected as the diaphragm. The surface of the diaphragm may be smoothened.

The vessel extracting section **142** may be configured to perform vessel extraction upon the three-dimensional ultrasound image. The vessel extracting section **142** may be configured to perform the vessel extraction through ROI masking, vessel segmentation and classification.

To avoid mis-extraction of the vessels due to mirroring artifacts, the ROI masking may be applied to the three-dimensional ultrasound image by modeling the diaphragm as a polynomial curved surface. For example, the ROI masking may be used to model the diaphragm as the polynomial curved surface by using the least means square. However, if all of the lower portions of the modeled polynomial curved surface are eliminated, then meaningful vessel information may be lost at a portion of regions due to an error of the polynomial curved surface. To avoid losing the vessel information, the lower portion of the modeled polynomial curved surface may be eliminated with a marginal distance. For example, the marginal distance may be set to about 10 voxels at a lower portion of the ROI mask.

Subsequently, the vessel extracting section **142** may be further configured to segment a vessel region and a non-vessel region. To exclude non-vessel high intensity regions such as the diaphragm and vessel walls, a low intensity bound value having a less reference bound value in the ROI masked three-dimensional ultrasound image may be set as a reference bound value. Thereafter, voxels with a higher intensity value than the reference bound value may be removed. The remaining regions may be binarized by using an adaptive threshold value. Then, the binarized segments may be labeled as vessel candidates.

Next, the vessel extracting section **142** may be further configured to remove non-vessel-type clutters from the binarization image to form real vessel regions from the vessel candidates. In one embodiment, the vessel classification may include a size test, which evaluates the quality of fit to a cylindrical tube, for filtering out tiny background clutters, a structure-based vessel test for removing non-vessel type clutters, i.e., an initial vessel test, a gradient magnitude analysis, and a final vessel test for precisely removing the clutters. Although some clutters are not removed through the structure-based vessel test, an initial threshold may be marginally set so that all vessels may be included. For example, a threshold value of the initial vessel test may be set to 0.6. At the final vessel test, clutters, which may be formed by small shading artifacts having low gradient magnitudes, may be precisely removed by considering variation of voxel values, i.e., gradient magnitudes, to thereby extract vessel data. In one embodiment, a threshold of the final vessel test may be set to 0.4.

The diaphragm refining section **143** may be configured to refine the diaphragm region by removing the clutters with the extracted vessel regions. The clutters are mainly placed near the vessel walls. For example, the vessel walls of inferior vena cava (IVC) are more likely to be connected to the diaphragm and cause clutters. These clutters may degrade the accuracy of the feature based registration, and thus, it may be necessary to refine the diaphragm region. To refine the diaphragm, the vessel regions are extracted according to the vessel extraction mentioned above, the extracted vessel regions may be dilated, and then the dilated vessel regions may be subtracted from the initially extracted diaphragm region to estimate vessel walls. The estimated vessel walls may be removed from the diaphragm region. Finally, the diaphragm region may be extracted by applying CCA and the size test.

The registration section **144** may be configured to perform the image registration between the three-dimensional ultrasound and CT image. The registration section **144** may extract sample points from the vessel regions and the diaphragm

region, respectively, among the features extracted from the three-dimensional ultrasound image. Also, after the vessel regions and the diaphragm region are extracted from the CT image, the registration section **144** may extract sample points from the vessel and the diaphragm region, respectively. The image registration between the three-dimensional ultrasound and CT image may be performed based on the extracted sample points to thereby form the transformation function (T_{probe}) between the three-dimensional CT image and the three-dimensional ultrasound image. The transformation function (T_{probe}) may be given by a matrix and used to transform a position of the ultrasound probe **112** to a corresponding position on the three-dimensional CT image.

The calibration section **145** may perform the calibration of the sensor **120** based on the transformation matrix (T_{probe}) from the registration section **144** and the position information stored in the memory **130**. More particularly, the calibration section **145** may form a transformation matrix (T_{sensor}) between the sensor **120** and the three-dimensional ultrasound image, i.e., a transformation matrix representing a position of the sensor **120** with respect to the three dimensional ultrasound image. The transformation matrix (T_{sensor}) may be given by a matrix. The transformation matrix (T_{sensor}) may be defined as the following equation (3).

$$T_{sensor} = \begin{vmatrix} r11 & r12 & r13 & x \\ r21 & r22 & r23 & y \\ r31 & r32 & r33 & z \\ 0 & 0 & 0 & 1 \end{vmatrix} \quad (3)$$

$$r11 = \cos\theta y * \cos\theta z + \sin\theta x * \sin\theta y * \sin\theta z$$

$$r12 = \sin\theta z * \cos\theta y - \sin\theta x * \sin\theta y * \cos\theta z$$

$$r13 = \cos\theta x * \sin\theta y,\ r21 = \sin\theta z * \cos\theta x$$

$$r22 = \cos\theta z * \sin\theta x,\ r23 = \sin\theta x$$

$$r31 = \sin\theta z * \sin\theta x * \cos\theta y - \cos\theta z * \sin\theta y$$

$$r32 = -\cos\theta z * \sin\theta x * \cos\theta y - \sin\theta z * \sin\theta y$$

$$r33 = \cos\theta x * \cos\theta y$$

wherein, x denotes coordinate of a lateral direction of the sensor **120**, y denotes coordinate of an elevation direction of the sensor **120**, z denotes an axial direction of the sensor **120**, θ_x denotes an angle of the sensor **120** from the x-axis, θ_y denotes an angle of the sensor **120** from the y-axis, and θ_z denotes an angle of the sensor **120** from the z-axis. The elevation direction may be a swing direction of the transducer elements, the axial direction may be a scan line direction from the transducer elements and the lateral direction may be a longitudinal direction of the transducer elements.

The calibration section **145** may perform the calibration based on the transformation matrix (T_{probe}) and the transformation matrix (T_{sensor}). The robe, calibration section **145** may form a transformation matrix (T) representing the position of the sensor **120** on the three-dimensional CT image. In one embodiment, the calibration section **145** may form the transformation matrix (T) through matrix multiplication of the transformation matrix (T_{probe}) and the transformation matrix (T_{sensor}).

The image processing section **146** may apply the transformation matrix (T) to the three-dimensional CT image to thereby form a two-dimensional CT image according to a two-dimensional ultrasound image.

Referring back to FIG. **1**, the display unit **150** may display the two-dimensional CT image, which is provided from the processor **140**. Furthermore, the display unit **150** may display the three-dimensional ultrasound image and the three-dimensional CT image.

Any reference in this specification to "one embodiment," "an embodiment," "example embodiment," "illustrative embodiment," etc. means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. The appearances of such phrases in various places in the specification are not necessarily all referring to the same embodiment. Further, when a particular feature, structure or characteristic is described in connection with any embodiment, it is submitted that it is within the purview of one skilled in the art to affect such feature, structure or characteristic in connection with other ones of the embodiments.

Although embodiments have been described with reference to a number of illustrative embodiments thereof, it should be understood that numerous other modifications and embodiments can be devised by those skilled in the art that will fall within the spirit and scope of the principles of this disclosure. More particularly, numerous variations and modifications are possible in the component parts and/or arrangements of the subject combination arrangement within the scope of the disclosure, the drawings and the appended claims. In addition to variations and modifications in the component parts and/or arrangements, alternative uses will also be apparent to those skilled in the art.

What is claimed is:

1. An ultrasound system, comprising:

an ultrasound image forming unit including an ultrasound probe and being configured to form a three-dimensional ultrasound image of a target object;

a sensor coupled to the ultrasound probe;

a memory configured to store a three-dimensional computed tomography (CT) image of the target object and position information on a position between the three-dimensional ultrasound image and the sensor; and

a processor configured to extract a same anatomic region from the three-dimensional ultrasound image and the three-dimensional CT image, perform image registration between the three-dimensional CT image and the three-dimensional ultrasound image based on the same anatomic region to thereby form a first transformation function for transforming a position on the three-dimensional CT image to a corresponding position on the three-dimensional ultrasound image, form a second transformation function between the three-dimensional ultrasound image and the sensor based on the position information and perform calibration of the sensor to match coordinates of the CT image and coordinates of the sensor based on the first transformation function and the second transformation function.

2. The ultrasound system of claim **1**, wherein the target object includes a liver.

3. The ultrasound system of claim **1**, wherein the processor comprises:

a diaphragm extracting section configured to extract a diaphragm region from candidate surfaces obtained by using an intensity-based connected component analysis (CCA);

a vessel extracting section configured to extract vessel regions by removing non-vessel-type clutters from vessel candidates obtained by removing voxels of the three-dimensional ultrasound image having intensity value greater than a reference bound value;

a registration section configured to extract sample points from the diaphragm region and the vessel regions and perform the image registration between the three-dimensional ultrasound image and CT image based on the extracted sample points to thereby form the first transformation function; and

a calibration section configured to perform calibration of the sensor.

4. The ultrasound system of claim **3**, wherein the diaphragm extracting section is further configured to:

obtain flatness values from voxels of the three-dimensional ultrasound image;

select voxels having a flatness value greater than a reference value;

remove a predetermined number of the voxels in edges of an area in which voxel values exist;

expanding the edges by the predetermined number of the voxels;

obtain the candidate surfaces from the voxels by the CCA; and

select a widest surface among the candidate surfaces to extract the diaphragm region.

5. The ultrasound system of claim **3**, wherein the vessel extracting section is further configured to:

model the diaphragm region to a polynomial curved surface in the three-dimensional ultrasound image to form a region of interest (ROI) mask;

perform ROI masking by applying the ROI mask to the three-dimensional ultrasound image;

form the vessel candidates by removing voxels having the intensity value greater than the reference bound value from the ROI masked three-dimensional ultrasound image;

and extract the vessel regions by sequentially performing a size test, a structure-based vessel test, a gradient magnitude analysis, and a final vessel test for removing the non-vessel-type clutters from the vessel candidates.

6. The ultrasound system of claim **3**, wherein the calibration section is further configured to:

multiply the first transformation function by the second transformation function to form a third transformation function for representing the position of the sensor on the three-dimensional CT image; and

perform calibration of the sensor based on the third transformation function.

7. A method of calibrating an ultrasound system having an ultrasound probe and a sensor, comprising:

a) obtaining a three-dimensional ultrasound image of a target object and a three-dimensional CT image of the target object;

b) calculating a position information on a position between the three-dimensional ultrasound image and the sensor;

c) extracting a same anatomic region from the three-dimensional ultrasound image and the three-dimensional CT image;

d) performing registration between the three-dimensional ultrasound image and the three-dimensional CT image based on the same anatomic region to obtain a first transformation function for transforming a position on the three-dimensional CT image to a corresponding position on the three-dimensional ultrasound image;

e) forming a second transformation function between the three-dimensional ultrasound image and the sensor based on the position information; and

f) performing calibration of the sensor to match coordinates of the CT image and coordinates of the sensor based on the first transformation function and the second transformation function.

8. The method of claim **7**, wherein the target object is a liver.

9. The method of claim **7**, wherein the step c) comprises:

c1) extracting a diaphragm region from candidate surfaces obtained by using an intensity-based connected component analysis (CCA);

c2) extracting vessel regions by removing non-vessel-type clutters from vessel candidates obtained by removing voxels of the three-dimensional ultrasound image having intensity value greater than a reference bound value; and

c3) extracting sample points from the diaphragm region and the vessel regions,

wherein the step d) includes performing the image registration between the three-dimensional ultrasound image and CT image based on the extracted sample points to form the first transformation function.

10. The method of claim **9**, wherein the step c1) comprises:

obtaining flatness from voxels of the three-dimensional ultrasound image;

selecting voxels having a flatness greater than a reference value;

removing a predetermined number of the voxels in edges of an area in which voxel values exist, expanding the edges by the predetermined number of the voxels;

obtaining the candidate surfaces from the voxels by the intensity-based connected component analysis (CCA); and

selecting a widest surface among the candidate surfaces to extract the diaphragm region.

11. The method of claim **9**, wherein the step c2) comprises:

modeling the diaphragm region to a polynomial curved surface in the three-dimensional ultrasound image to form a region of interest (ROI) mask;

performing ROI masking by applying the ROI mask to the three-dimensional ultrasound image;

forming vessel candidates by removing voxels having an intensity value greater than a reference bound value from the ROI masked three-dimensional ultrasound image; and

extracting the vessel regions by sequentially performing a size test, a structure-based vessel test, a gradient magnitude analysis, and a final vessel test for removing the non-vessel-type clutters from the vessel candidates.

12. The method of claim **7**, wherein the step f) comprises:

f1) multiplying the first transformation function by the second transformation function to form a third transformation function for representing the position of the sensor on the three-dimensional CT image; and

f2) performing calibration of the sensor based on the third transformation function.

* * * * *

专利名称(译)	超声系统中的传感器坐标校准		
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[标]申请(专利权)人(译)	HYUN董GYU RA JONG BEOM LEE DUHGOON 南优贤		
申请(专利权)人(译)	HYUN董GYU RA JONG BEOM LEE DUHGOON 南优贤		
当前申请(专利权)人(译)	三星MEDISON CO.，LTD.		
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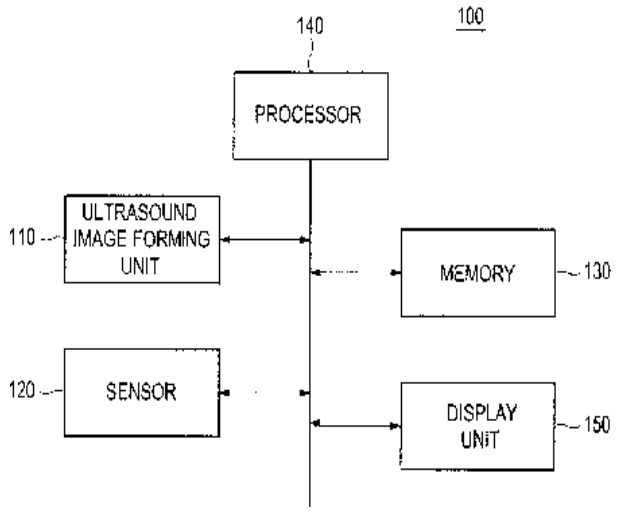
IPC分类号	G06T7/00 A61B6/00 A61B8/00 A61B8/08 A61B6/03		
CPC分类号	G06T7/0028 A61B6/5247 A61B8/0833 A61B8/4254 A61B8/4416 A61B8/483 A61B8/58 A61B6/03 G06T2207/10081 G06T2207/10136 G06T2207/30056 G01S15/899 G06T7/33 G06T7/11 G06T7/337 A61B6/032 A61B8/0891 A61B8/4444 A61B8/461 A61B8/469 A61B8/488 A61B8/5207 A61B8/5223 A61B8/5261 G06T11/00 G06T2207/10028 G06T2207/20221 G06T2207/30101		
代理机构(译)	MCDERMOTT WILL & EMERY LLP		
优先权	1020090070994 2009-07-31 KR		
其他公开文献	US20110026796A1		
外部链接	Espacenet USPTO		

摘要(译)

公开了一种用于通过使用三维超声图像和计算机断层摄影（CT）图像之间的图像配准来执行传感器的校准的实施例。超声图像形成单元包括超声探头并形成目标对象的三维超声图像。传感器耦合到超声探头。存储器存储目标对象的三维计算机断层摄影（CT）图像和关于三维超声图像与传感器之间的位置的位置信息。处理器在三维CT图像和三维超声图像之间执行图像配准，以形成第一变换功能，用于将传感器的位置变换到三维CT图像上的对应位置，并通过以下方式执行传感器的校准：将位置信息应用于第一变换函数。


100
140
PROCESSOR
110
ULTRASOUND IMAGE FORMING UNIT
MEMORY
130
120
SENSOR
DISPLAY UNIT
150