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(54) Title: IMAGING SYSTEMS AND METHODS FOR POSITIONING A 3D ULTRASOUND VOLUME IN A DESIRED ORI-
ENTATION
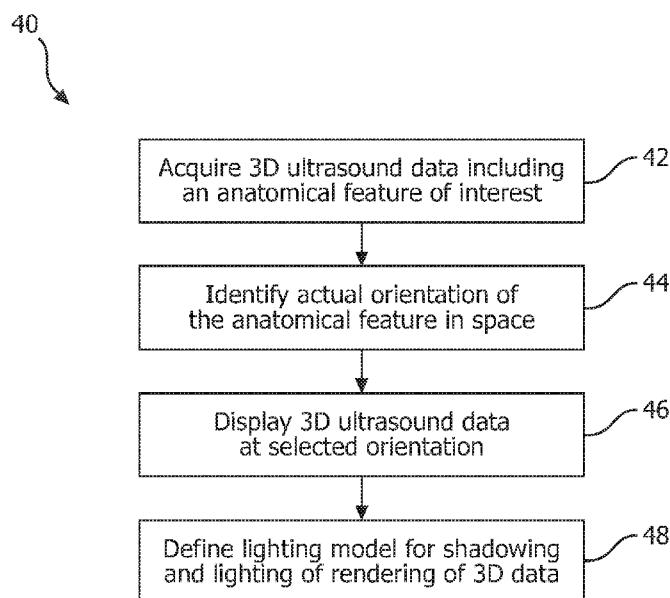
(57) Abstract: Methods and systems are provided
for displaying a 3D ultrasound image volume in a
desired view orientation. A 3D ultrasound image can
be acquired of an anatomical feature in a patient.
The actual orientation of the anatomical feature can
be determined in space. The 3D ultrasound image
including the anatomical feature can be displayed
such that the anatomical feature is positioned in a
selected orientation that is different than the actual
orientation, and in relation to a lighting model for
generating lighting and shadowing on the anatomic-
al feature.

FIG. 2

Declarations under Rule 4.17:

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

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

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Imaging Systems And Methods For Positioning A 3d
Ultrasound Volume In A Desired Orientation

This invention relates to medical diagnostic
ultrasound systems and, in particular, to imaging
systems and methods for displaying a 3D ultrasound
image in a desired view orientation.
With the advent of high resolution 3D renderings
of ultrasound data, diagnostic ultrasound
applications have seen continued improvement with
better 3D imaging and increased capabilities to
identify tissue features not as easily recognized in
traditional 2D scanning procedures. Nevertheless,
the simplicity and efficiency for certain 3D
ultrasound applications still need improvement. For
example, an increasingly important expectation is
being placed on routine obstetrical ultrasound
examinations by mothers that want 3D rendering of
their baby's face. Attempting to generate this image
is necessary from a business standpoint for many
clinicians whose patients will go elsewhere if the
service is not available. Unfortunately, obtaining
good quality 3D renderings of a baby's face can be a
frustrating and time consuming exercise that also
takes away from time that can be spent on ultrasound
diagnostic scans having more clinical value. Thus,
there is need to arrive at the desired imaging result
as quickly as possible and save time for clinically
relevant screening of the fetus for various potential
anomalies. More generally, there is a need for
better methods to display a 3D ultrasound image in a
desired view orientation according to settings that
are optimal for viewing for a certain ultrasound
application. The present invention provides this and
more.

In accordance with the principles of the present invention, methods and systems are provided for displaying a 3D ultrasound image in a desired view orientation. As described further herein, the present invention can include acquiring 3D ultrasound image data comprising an anatomical feature in a patient. In addition, an actual orientation of the anatomical feature can be determined in relation to a transducer probe or other point of interest. For instance, a fetus can be imaged using a 3D ultrasound system and the orientation of the fetus's face can be determined. The present invention further includes displaying the 3D ultrasound image data as a rendering of the anatomical feature such that the anatomical feature is positioned in a selected orientation that is different than the actual orientation. In addition, the anatomical features being rendered can be positioned in spatial relation to a lighting model such that lighting and shadowing regions on the anatomical features are displayed to a user, and in some embodiments, according to a stored setting on an ultrasound system.

In the drawings:

FIGURE 1 illustrates in block diagram form the use of three dimensional ultrasonic imaging to guide or monitor ablation in an embodiment of the present invention.

FIGURE 2 illustrates a workflow in accordance with the present invention for displaying 3D ultrasound data a selected orientation.

FIGURE 3 depicts an example ultrasound procedure for identifying anatomical features in a fetus to determine the actual orientation of the fetus in a mother's womb.

FIGURE 4 illustrates a display of different

selected orientations of anatomical features that can
be stored on an ultrasound system for quick and
reproducible viewing by a user.

Referring to FIG. 1, an ultrasound imaging system
10 constructed in accordance with the principles of the
present invention is shown in block diagram form. In
the ultrasonic diagnostic imaging system of FIG. 1, an
ultrasound probe 12 includes a transducer array 14 for
transmitting ultrasonic waves and receiving echo
information. The transducer array 14, for example, can
include a two dimensional array (as shown) of
transducer elements capable of scanning in both
elevation and azimuth dimensions for 2D and/or 3D
imaging. The transducer array 14 is coupled to a
microbeamformer 16 in the probe 12 which controls
transmission and reception of signals by the transducer
elements in the array. In this example, the
microbeamformer is coupled by the probe cable to a
transmit/receive (T/R) switch 18, which switches
between transmission and reception and protects the
main beamformer 22 from high energy transmit signals.
In some embodiments, the T/R switch 18 and other
elements in the system can be included in the
transducer probe rather than in a separate ultrasound
system base. In some embodiments, the probe 12 can
contain all of the components necessary for outputting
a video signal that can be simply displayed by an
external display. For example, a system may not
include a main beamformer 22, and instead beamforming
may be completed in the probe 12, and the probe can
also include the signal processor 26, the B mode
processor 28, and other electronics for processing
ultrasound signals.

As shown, the transmission of ultrasonic beams
from the transducer array 14 under control of the

microbeamformer 16 is directed by the transmit
controller 20 coupled to the T/R switch 18 and the
beamformer 22, which receives input from the user's
operation of the user interface or control panel 24.
One of the functions controlled by the transmit
controller 20 is the direction in which beams are
steered. Beams may be steered straight ahead from
(orthogonal to) the transducer array, or at different
angles for a wider field of view. In this embodiment,
the partially beamformed signals produced by the
microbeamformer 16 are coupled to a main beamformer 22
where partially beamformed signals from individual
patches of transducer elements are combined into a
fully beamformed signal. Groups of adjacent transducer
elements referred to as "patches" or "subarrays" are
integrally operated by a microbeamformer (µBF) in the
probe 12. Suitable two dimensional arrays are described
in, e.g., U.S. Patent 6,419,633 (Robinson et al.) and
in U.S. Patent 6,368,281 (Solomon et al.)
Microbeamformers are described, e.g., in U.S. Patents
5,997,479 (Savord et al.) and 6,013,032 (Savord), all
of which are incorporated herein by reference.

The beamformed signals are coupled to a signal
processor 26. The signal processor 26 can process the
received echo signals in various ways, such as bandpass
filtering, decimation, I and Q component separation,
and harmonic signal separation. The signal processor 26
may also perform additional signal enhancement such as
speckle reduction, signal compounding, and noise
elimination. The processed signals are coupled to a B
mode processor 28, which can employ amplitude detection
for the imaging of anatomical features, such as a
baby's face in the mother. The signals produced by the
B mode processor are coupled to a 3D image data
processor 30, which is configured to generate 3D image

datasets that can be rendered and processed by the
volume rendering and light model processor 32. As will
be described further herein, the volume rendering and
light model processor 32 can render an imaged

5   anatomical feature such that the anatomical feature is
positioned in a selected orientation that is different
than an actual orientation of the feature in relation
to the transducer probe 12. The volume rendering and
light model processor 32 also can position the

10   orientation of the anatomical feature in spatial
relation to a lighting model such that lighting and
shadowing regions on the anatomical feature are
displayed according to a stored setting on an
ultrasound system. As such, the user interface or

15   control panel 24 can be operated by a user to predefine
the stored setting on the system and thereby generate
the user's desired view of the anatomical feature along
with an optimal lighting arrangement for generating
renderings of the anatomical feature, such as a baby's

20   face.
        The methods of the present invention are carried
out using ultrasound systems as described herein. For
example, the ultrasound systems can operate to perform
any of the following steps: acquire 3D ultrasound image

25   data comprising an anatomical feature in a patient;
determine an actual orientation of the anatomical
feature in space; and/or display the 3D ultrasound
image data as a rendering comprising the anatomical
feature such that the anatomical feature is positioned

30   (1) in a selected orientation that is different than
the actual orientation and (2) in spatial relation to a
lighting model such that lighting and shadowing regions
on the anatomical feature are displayed according to a
stored setting on an ultrasound system.

35   FIGURE 2 is a flow chart showing the workflow 40

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of an implementation of the present invention. This
workflow 40 begins with a step 42 that includes
acquiring 3D ultrasound image data that includes at
least a portion of an anatomical feature of interest.

5   For example, as described further herein, a 3D
ultrasound imaging system can be used to collect images
of a fetus in a mother. The anatomical features of
interest might include, but are not limited to, the
nose, chin, eyes and/or skull of the fetus. In some

10   embodiments, an anatomical feature of interest might
include at least a portion of a patient's organ, such
as a heart, kidney or liver.

       In step 44, an ultrasound system can be used to
process the 3D ultrasound data such that an actual

15   orientation of the anatomical feature (e.g., a baby's
face) can be determined and, optionally, displayed to a
user on a screen. This step includes known techniques
for performing 3D ultrasound imaging in which the probe
transmits and receives echo data from the patient to

20   show a 2D or 3D image of the patient's anatomy on a
display. In some embodiments, automated detection of
the orientation of the anatomical feature can be
accomplished using structural modeling and anatomical
landmark identification. In certain embodiments, the

25   present invention can include identifying the actual
orientation by applying structural models to define a
surface orientation of the anatomical feature and/or
identifying anatomical landmarks in the anatomical
feature.

30   In one aspect, the method for determining the
actual orientation of the anatomical feature (e.g., a
fetus' face) follows the methods described in Cuignet
et al., 2013 IEEE Symposium on Biomedical Imaging,
pages 768-771, which is incorporated herein by

35   reference. The method of determining actual

orientation can include, for example, identifying anatomical features of a fetus that are echogenic independently of the probe position: the skull, the midsagittal plane and the orbits of the eyes. The skull can be detected and segmented using a shape model and a template deformation algorithm. An initial anatomical frame of reference can thus be defined. Then, the detection of both the midsagittal plane and orbits of the eyes allows to remove orientation ambiguities and eventually to refine this frame of reference.

Other features may also be detected and used to determine actual orientation. For example, the face and other landmarks can be detected. As shown in FIG. 3, an ultrasound image plane 50 corresponding to the sagittal plane can be acquired by traditional scanning of the mother 52 with an ultrasound probe 54. The forehead 56, the nose 58 and the chin 60 of the fetus can be identified using, e.g., learning-based algorithms or other models. In some embodiments, other structures such as the hypothalamus, the nasal bone end, the palatine bones, and/or the cheekbone can be identified and used to determine the fetal orientation. Upon identification of the relative positions of the various anatomical features of the fetus, the actual orientation of the fetus can be determined and, in some embodiments, displayed to the user. With respect to a fetal face, for example, the present invention further includes automated sculpting away of ultrasound data representing tissue that is not part of the facial tissue. This can be accomplished by different techniques, such as by application of the same structural model that can be applied to orient the fetal head.

As provided herein, the present invention in-part provides a quick and easy technique to display

anatomical features at a desired orientation without
time-consuming interaction by the sonographer during a
scan. For example, instead of displaying the image of
an anatomical feature in the actual orientation with
5   respect to the probe, Step 46 of the workflow 40
includes displaying the 3D ultrasound data including
the anatomical feature at a selected orientation that
is different than the actual orientation. For example,
a sonographer may image a fetus such that the fetus's
10   face is actually oriented directly looking at the
transducer probe. However, for better viewing of
features of the fetus's face the sonographer may desire
that the image be displayed at a different selected
orientation in which the fetus's face is at an angle to
15   the transducer probe. Moreover, as shown in Step 48, a
lighting model can be used to add shadowing and/or
lighting aspects to the 3D rendered ultrasound data
displayed to the sonographer. In some embodiments, the
lighting model can include one or more lights that are
20   positioned in 3D space with respect to the rendered 3D
volume of the anatomical feature, e.g., the fetus. The
lights in the lighting model can be manually positioned
by the user or they can be included in a standard set
of positions that provide the optimal lighting and
25   shadowing for a particular orientation of the 3D
rendered ultrasound volume. In certain embodiments,
relative intensities of the lighting and shadowing can
be tuned by the user after displaying the 3D ultrasound
image data. Furthermore, the selected orientation of
30   the anatomical features as well as the lighting models
can be saved on the system for later use and reference.
        As described herein, the present invention
includes displaying 3D ultrasound image data as a
rendering that includes an anatomical feature of
35   interest. In certain embodiments, the anatomical

feature is positioned in a selected orientation that is
different than the actual orientation, e.g. by the
volume rendering and lighting model processor in FIG.
1. The anatomical feature can also be positioned in
spatial relation to a lighting model such that lighting
and shadowing regions on the anatomical feature are
displayed according to a stored setting on an
ultrasound system. In some embodiments, the stored
setting for the positioning and lighting model details
can be generated by a user selecting the selected
orientation from a plurality of displayed orientation
views. In addition, the stored setting can be
configured to be used for a plurality of sequential
ultrasound scans. For instance, the same selected
orientation can be used for sequential patient scans
such that each baby face ultrasound image has the same
orientation and same lighting model for different
patients. This aspect can improve throughput, for
example, with scanning procedures such that a
sonographer does not have to spend time orienting the
rendering and lighting. Instead, the system of the
present invention has a stored setting, which can be
selected by a user, that initiates these steps
automatically.

      FIG. 4 illustrates an embodiment of the present
invention in which an ultrasound system includes three
stored settings that show selecte6d orientations of the
baby's face rendered in 3D and having different
lighting models to highlight certain features of the
baby's face. The display 62, for example, includes
three thumbnail images 64 that show real-time
renderings of the 3D ultrasound image data acquired of
a baby's face. Each of the selected orientations 66 of
the baby's face can be displayed to a user and the user
can select the desired orientation among the three.

After selection, e.g., using a touchscreen input, mouse or other input device, the selected orientation of interest can be displayed in a fuller view 68 to the user. The image of the baby's face can be simply saved and printed or provided electronically to a mother. The stored settings on the system may be provided by default on an ultrasound system. Alternatively, a sonographer or other clinician can manually define the selected orientations and store those settings on the system for later use, e.g., as shown in FIG. 4. It is noted that the present invention can also be applied for viewing other tissue structures in a fetus, such as a hand or foot. In another example, a heart could be imaged similar to the fetus as described herein. A heart model could be used to identify the orientation of the heart, and a selected orientation could be used to show the heart at a different orientation than the actual orientation shown in the acquired 3D ultrasound data. The selected orientations could be designed such that a specific chamber of the heart is always displayed in a certain orientation, and in addition with lighting and shadowing to better view specific tissue areas of the heart for better diagnostic capabilities.

It will be understood that the examples and embodiments described herein are for illustrative purposes and that various modifications or changes in light thereof may be suggested to persons skilled in the art and are included within the spirit and purview of this application and scope of the appended claims. Moreover, different combinations of embodiments described herein are possible, and such combinations are considered part of the present invention. In addition, all features discussed in connection with any one embodiment herein can be readily adapted for use in

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other embodiments herein. The use of different terms or reference numerals for similar features in different embodiments does not necessarily imply differences other than those which may be expressly set forth. Accordingly, the present invention is intended to be described solely by reference to the appended claims, and not limited to the preferred embodiments disclosed herein.

WHAT IS CLAIMED IS:

1.   A method for displaying a 3D ultrasound
image in a desired view orientation, the method
comprising:
    acquiring 3D ultrasound image data comprising an
anatomical feature in a patient;
    determining an actual orientation of the
anatomical feature in relation to a transducer probe;
and
    displaying the 3D ultrasound image data as a
rendering comprising the anatomical feature such that
the anatomical feature is positioned (1) in a
selected orientation that is different than the
actual orientation and (2) in spatial relation to a
lighting model such that lighting and shadowing
regions on the anatomical feature are displayed
according to a stored setting on an ultrasound
system.

2.   The method of claim 1, wherein the stored
setting is generated by a user selecting the selected
orientation from a plurality of displayed orientation
views.

3.   The method of claim 2, wherein the stored
setting is configured to be used for a plurality of
sequential ultrasound scans.

4.   The method of claim 1, wherein the stored
setting is selected by a user.

5.   The method of claim 1, wherein identifying
the actual orientation comprises applying structural
models to define a surface orientation of the

anatomical feature, identifying anatomical landmarks in the anatomical feature, or a combination thereof.

6.   The method of claim 1, wherein relative intensities of the lighting and shadowing can be tuned by the user after displaying the 3D ultrasound image data.

7.   The method of claim 6, comprising saving the displayed selected orientation of the 3D ultrasound image on the ultrasound system.

8.   The method of claim 1, wherein the anatomical feature comprises at least a portion of a face, hand, and/or foot of a fetus.

9.   A system for displaying a 3D ultrasound image volume in a desired view orientation, the system comprising instructions thereon, which when executed, cause the system to:
    acquire 3D ultrasound image data comprising an anatomical feature in a patient;
    determine an actual orientation of the anatomical feature in space; and
    display the 3D ultrasound image data as a rendering comprising the anatomical feature such that the anatomical feature is positioned (1) in a selected orientation that is different than the actual orientation and (2) in spatial relation to a lighting model such that lighting and shadowing regions on the anatomical feature are displayed according to a stored setting on an ultrasound system.

10.   The system of claim 9, wherein the system

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is configured to display the selected orientation
according to a user selection of the setting.

11. The system of claim 9, wherein the setting
comprises a plurality of orientation views that are
displayed to a user for selection.

12. The system of claim 9, wherein the selected
orientation is pre-selected before the acquiring of
the 3D ultrasound image data.

13. The system of claim 11, wherein the
selected orientation is pre-selected by a user.

14. The system of claim 9, wherein identifying
the actual orientation comprises applying structural
models to define a surface orientation of the
anatomical feature, identifying anatomical landmarks
in the anatomical feature, or a combination thereof.

15. The system of claim 9, wherein the
instructions, which when executed, further cause the
system to select a lighting model to provide shading
and lighting of a rendering of the 3D ultrasound
image data.

16. The system of claim 9, wherein the
anatomical feature comprises at least a portion of a
face of fetus.

17. The system of claim 16, wherein the system
is configured to remove at least some of the
ultrasound data representing tissue that is not
facial tissue of the face of the fetus.

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FIG. 1

40

Acquire 3D ultrasound data including
an anatomical feature of interest   42

Identify actual orientation of
the anatomical feature in space   44

Display 3D ultrasound data
at selected orientation   46

Define lighting model for shadowing
and lighting of rendering of 3D data   48
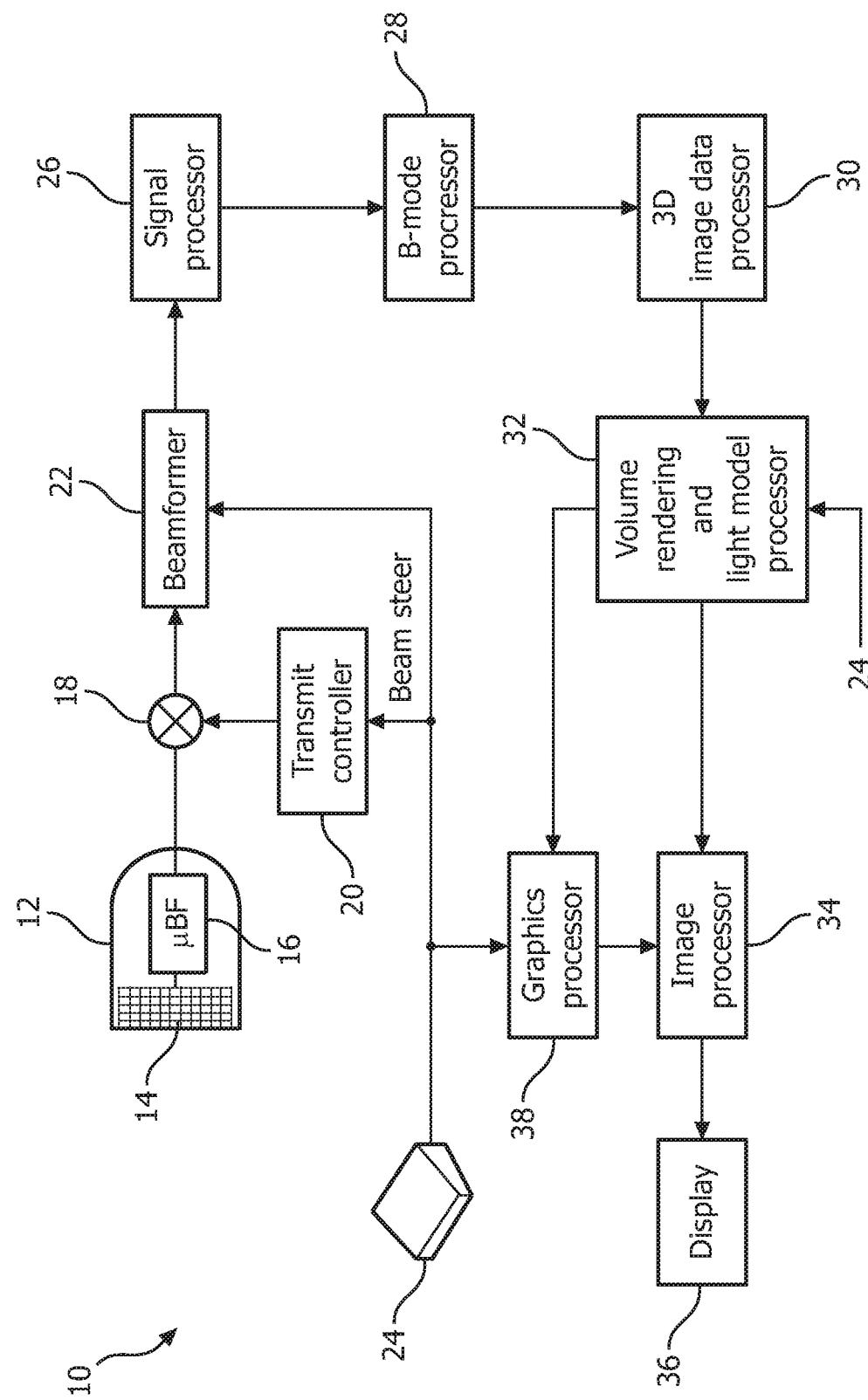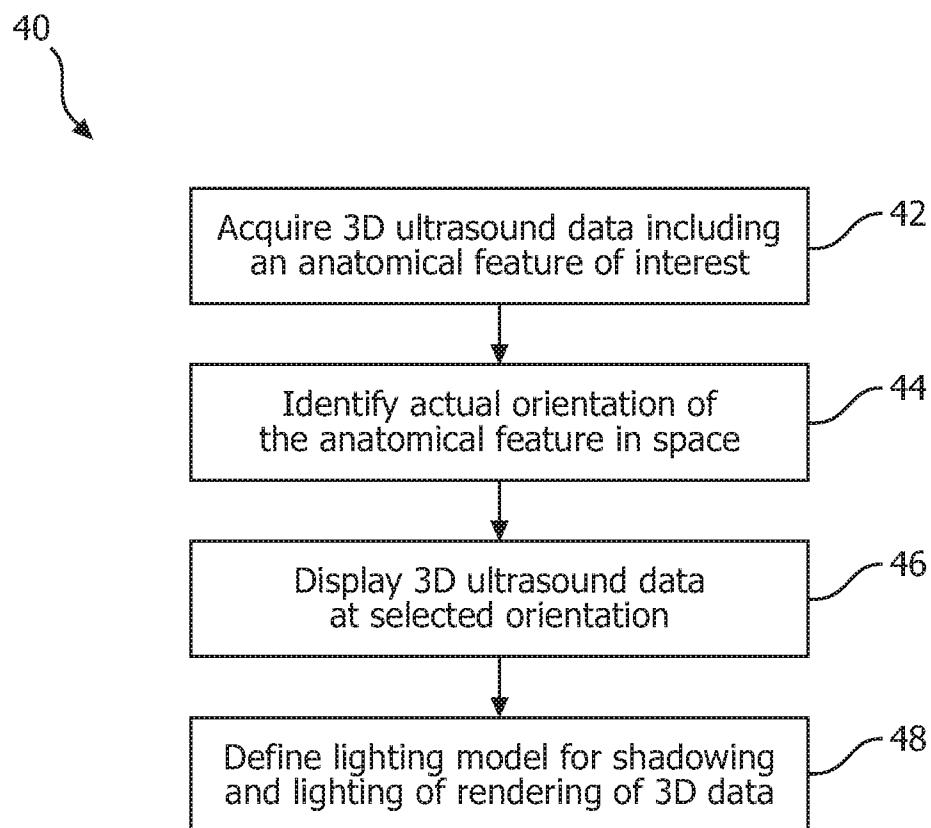
FIG. 2
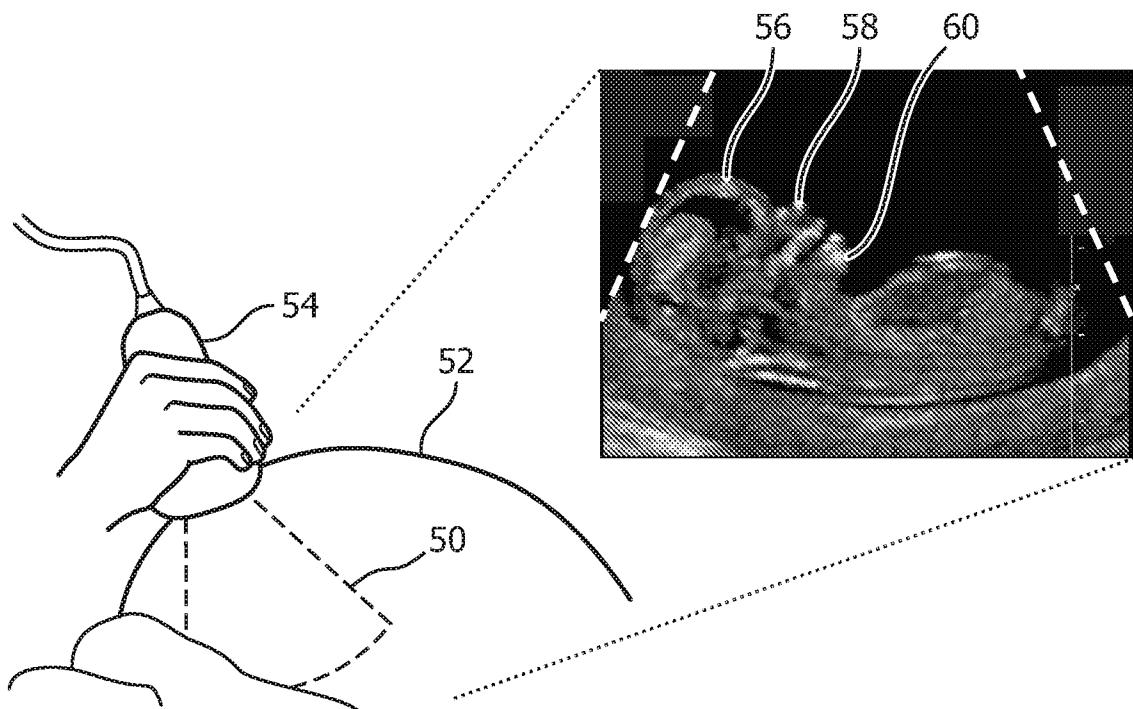
FIG. 3

FIG.4

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. A61B8/00   A61B8/08   G06T15/50
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A61B G06T

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/125016 A1 (LAZEBNIK ROEE [US] ET AL) 26 May 2011 (2011-05-26)	1,5-9, 14-17
Y	paragraph [0020] - paragraph [0057]; figures 1-4 paragraph [0074] -----	2-4, 10-13
Y	US 2014/081141 A1 (NISHIHARA KURAMITSU [JP] ET AL) 20 March 2014 (2014-03-20) paragraph [0051] - paragraph [0053] -----	2-4, 10-13
A	US 2013/072797 A1 (LEE KWANG-HEE [KR]) 21 March 2013 (2013-03-21) paragraph [0062] - paragraph [0098]; figures 1-11 -----	1-17

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

* Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 August 2015	11/08/2015

Name and mailing address of the ISA/	Authorized officer
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Form PCT/ISA/210 (second sheet) (April 2005)

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