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(71) **Applicant**: **KONINKLIJKE PHILIPS N.V.** [NL/NL]; High Tech Campus 5, 5656 AE Eindhoven (NL).

(72) **Inventors**: **LU, Huanxiang**; c/o High Tech Campus, Building 5, 5656 AE Eindhoven (NL). **LI, Junbo**; c/o High Tech Campus, Building 5, 5656 AE Eindhoven (NL). **VIGNON, Francois Guy Gerard Marie**; c/o High Tech Campus, Building 5, 5656 AE Eindhoven (NL). **JAIN, Ameet Kumar**; c/o High Tech Campus, Building 5, 5656 AE Eindhoven (NL). **WU, Ying**; c/o High Tech Campus, Building 5, 5656 AE Eindhoven (NL).

(74) **Agents**: **STEFFEN, Thomas** et al.; High Tech Campus Building 5, 5656 AE Eindhoven (NL).

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(54) **Title**: NEEDLE TRAJECTORY PREDICTION FOR TARGET BIOPSY

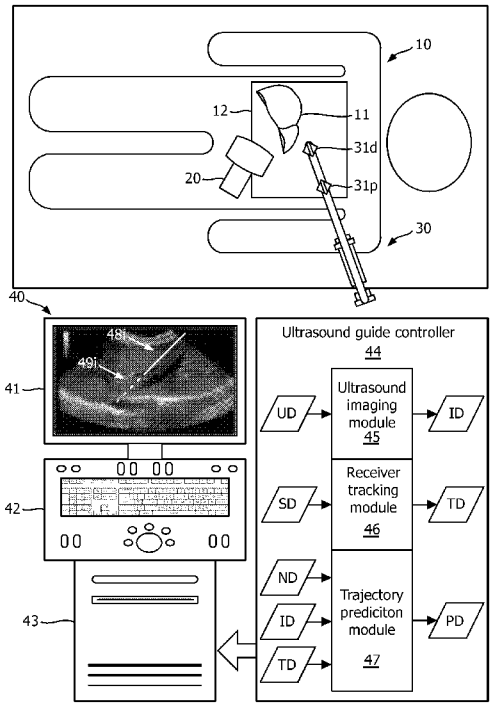

FIG. 1

(57) **Abstract**: A target biopsy system employing an ultrasound probe (20), a target biopsy needle (30) and a ultrasound guide controller (44). In operation, the ultrasound probe (20) projects an ultrasound plane intersecting an anatomical region (e.g. a liver). The target biopsy needle (30) include two or more ultrasound receivers (31) for sensing the ultrasound plane as the target biopsy needle (30) is inserted into the anatomical region. In response to the ultrasound receiver(s) (31) sensing the ultrasound plane, the ultrasound guide controller (44) predicts a biopsy trajectory of the target biopsy needle (30) within the anatomical region relative to the ultrasound plane. The prediction indicates the biopsy trajectory is either within the ultrasound plane (i.e., an in-plane biopsy trajectory) or outside of the ultrasound plane (i.e., an out-of-plane biopsy trajectory).

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NEEDLE TRAJECTORY PREDICTION FOR TARGET BIOPSY

The present invention generally relates to ultrasound-guided target biopsies (e.g., liver biopsy, renal biopsy, etc.). The present invention specifically relates to a prediction of a needle trajectory during a target biopsy procedure.

Ultrasound guidance is widely used for target biopsies to increase the accuracy of the procedure and reduce the potential risk of medical accidents. In such procedures, a needle is inserted into the patient aiming at the biopsy target. In the meanwhile, clinicians usually need to estimate the triggered needle trajectory before firing the biopsy gun in order to know if the needle will puncture through the target tissue. The trajectory is approximately an extension of certain centimeters along the needle shaft estimated from the prior knowledge of the needle parameter. Thus, when the needle is clearly visible in the ultrasound image, it may be relatively easy for the physicians to estimate the trajectory. However, in deep organs (e.g., liver and kidney), needles are usually invisible in the ultrasound image due to their specular nature and unfavorable incidence angles, which results in difficulties in estimating the needle trajectory. Moreover, the needle is not always in the ultrasound image plane during the procedure due to the hand motion of the clinician and breathing motion of the patient, which provides more difficulties in estimating the needle trajectory.

To enhance the visualization of interventional tools in ultrasound image, an ultrasound-based tracking technology has been proposed to track a tip of an interventional tool by embedding small ultrasound receivers near the tip of the interventional tool. The position of the interventional tool is then estimated by processing the signal received by these ultrasound receivers, which is then visualized on the ultrasound image. The present invention enhances such ultrasound-based tracking technology by providing a precise prediction of a three-dimensional ("3D") in-plane biopsy trajectory or a 3D out-of-plane biopsy trajectory on the ultrasound image.

One form of the present invention is a target biopsy system employing an ultrasound probe, a target biopsy needle, two or more ultrasound receivers and an ultrasound guide controller. In operation, the ultrasound probe projects an ultrasound plane intersecting an anatomical region (e.g. an abdominal region, a cranial region, a mammary region, an abdominal region, etc.). The ultrasound receiver(s) sense the

ultrasound plane as the target biopsy needle is inserted into the anatomical region. In response to the ultrasound receiver(s) sensing the ultrasound plane, the ultrasound guide controller predicts a biopsy trajectory of the target biopsy needle within the anatomical region relative to ultrasound plane. The prediction indicates the biopsy trajectory is either within the ultrasound plane (i.e., an in-plane biopsy trajectory) or outside of the ultrasound plane (i.e., an out-of-plane biopsy trajectory).

For purposes of the present invention, the term "ultrasound probe" broadly encompasses any ultrasound probe as known in the art employing one or more ultrasound transducers/transmitters/receivers for projecting an ultrasound plane intersecting the anatomical region. Examples of an ultrasound probe include, but are not limited to, two-dimensional and three-dimensional ultrasound probes with sector, curvilinear or linear geometries.

For purposes of the present invention, the term "target biopsy needle" broadly encompasses any type of biopsy needle as known in the art employing a stylet or the like to thereby cut a tissue sample when the target biopsy needle is inserted into the anatomical region. Examples of a target biopsy needle include, but is not limited to, guillotine-type biopsy needles with a firing or "gun" mechanism used for core biopsy (e.g., a Bio-Cut® or Bard Magnum® biopsy needle).

For purposes of the present invention, terms of the art including, but not limited to, "in-plane", "out-of-plane", "receiver", and "biopsy trajectory" are to be interpreted as known in the art of the present invention and exemplary described herein. More particularly, the term "receiver" is inclusive of a receiver and a transceiver as known in the art.

For purposes of the present invention, the term "ultrasound guide controller" broadly encompasses all structural configurations of an application specific main board or an application specific integrated circuit housed within or linked to a computer or another instruction execution device/system for controlling an application of various inventive principles of the present invention as subsequently described herein. The structural configuration of the ultrasound guide controller may include, but is not limited to, processor(s), computer-usable/computer readable storage medium(s), an operating system, peripheral device controller(s), slot(s) and port(s). Examples of a

computer includes, but is not limited to, a server computer, a client computer, a workstation and a tablet.

A second form of the present invention is the ultrasound guide controller including an ultrasound imaging module, a receiver tracking module and a needle trajectory module. In operation, the ultrasound probe generates an ultrasound image of an anatomical region responsive to ultrasound data from the ultrasound probe representative of the ultrasound plane intersecting an anatomical region. The receiver tracking module tracks a position of each ultrasound receiver relative to the ultrasound image of the anatomical region responsive to sensing data from the ultrasound receivers representative of a sensing of the ultrasound plane as the target biopsy needle is inserted into the anatomical region. The needle trajectory module predicts the biopsy trajectory of the target biopsy needle relative to the ultrasound plane responsive to the tracked positions of the ultrasound receivers relative to the ultrasound image of the anatomical region.

For purposes of the present invention, the term "module" broadly encompasses an application component of the ultrasound guide controller consisting of an electronic circuit or an executable program (e.g., executable software and/firmware).

A third form of the present invention is a target biopsy method involving (1) the ultrasound probe projecting the ultrasound plane intersecting the anatomical region, (2) the ultrasound receivers sensing the ultrasound plane as a target biopsy needle is inserted into the anatomical region, and (3) the ultrasound guide workstation predicting a biopsy trajectory of the target biopsy needle within the anatomical region relative to the ultrasound plane.

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 a target biopsy system in accordance with the present invention.

FIGS. 2-4 illustrate exemplary visualizations of a predicted needle trajectory by the target biopsy system of FIG. 1.

To facilitate an understanding of the present invention, exemplary embodiments of the present invention will be provided herein directed to an ultrasound guided target biopsy procedure for a liver 11 of a patient 10 as shown in FIG. 1. From the description of the exemplary embodiments of the present invention, those having ordinary skill in the art will appreciate how to make and use the present invention for any type of ultrasound-guided target biopsy procedure (e.g., prostate, kidney, breast etc.) involving various types of ultrasound probes and target biopsy needles.

For purposes of the present invention, terms of the art including, but not limited to, "firing mechanism", "co-axial introducer" and "tracked position" are to be interpreted as known in the art of the present invention and exemplary described herein.

Referring to FIG. 1, the ultrasound-guided target biopsy procedure involves an ultrasound probe 20 and a target biopsy needle 30 for extracting tissue from liver 11 of patient 10 as known in the art.

Ultrasound probe 20 employs one or more ultrasound transducers, transmitters receivers and/or transceivers for projecting an ultrasound plane intersecting an abdominal region 12 (e.g., ultrasound plane 21 as shown in FIG. 2). Examples of ultrasound probe 20 include, but are not limited to, two-dimensional and three-dimensional ultrasound probes with sector, curvilinear or linear geometries.

Target biopsy needle 30 employs a stylet or the like to thereby cut a tissue sample of liver 11 when needle 30 is inserted into abdominal region 12. Examples of target biopsy needle 30 include, but is not limited to, guillotine-type biopsy needles with an automatic/semi-automatic firing or "gun" mechanism used for core biopsy (e.g., a Bio-Cut® or Bard Magnum® biopsy needle). When included, a fire mechanism is operated to project target biopsy needle along a biopsy trajectory of target biopsy needle within abdominal region 12.

The present invention attaches two or more ultrasound receivers 31 (i.e., a receiver or a transceiver) for sensing the ultrasound plane as target biopsy needle 30 is being inserted within abdominal region 12 of patient 10. As known in the art, a degree of sensing the ultrasound plane is a function of a distance between an ultrasound receiver 31 and the ultrasound plane.

In practice, ultrasound receivers 31 are spatially arranged on biopsy needle 30 suitable for facilitating a distinctive sensing of the ultrasound plane by each ultrasound receiver 31. In one embodiment, as shown in FIG. 1, distal ultrasound receiver 31d is attached to/embedded within target biopsy needle 30 adjacent a tip of target biopsy needle 30 and a proximal ultrasound receiver 31p is attached to/embedded within target biopsy needle 30 is a middle of shaft of target biopsy needle 30. In an alternative embodiment, target biopsy needle 30 includes a coaxial introducer through which target biopsy needle 30 into abdominal region 12 with receivers 31 being attached to/embedded within the coaxial introducer.

The ultrasound-guided target biopsy procedure involves an ultrasound guide machine 40 employing a monitor 41, an interface platform 42, a workstation 43 and a ultrasound guide controller 44 installed within workstation 43. While not shown, in practice, ultrasound probe 20 and ultrasound receivers 31 are connected/coupled to workstation 43 in any manner as known in the art.

Ultrasound guide controller 44 includes and/or is accessible by an operating system (not shown) as known in the art for controlling various graphical user interfaces, data and images on monitor 41 as directed by a workstation operator (e.g., a doctor, technician, etc.) via a keyboard, buttons, dials, joysticks, etc. of interface platform 42, and for storing/reading data as programmed and/or directed by the workstation operator of interface platform 42.

Ultrasound guide controller 44 further executes application modules including an ultrasound imaging module 45, a receiver tracking module 46, and a trajectory prediction module 47 for implementing an ultrasound guided target biopsy procedure of liver 11 in accordance with the present invention.

Specifically, ultrasound imaging module 45 is structurally configured to receive ultrasound data *UD* from ultrasound probe 20 representative of the ultrasound plane intersecting abdominal region 12 of patient 11, and to execute a known process for generating a planar ultrasound image of abdominal region 12 for display by monitor 41 as shown.

Receiver tracking module 46 is structurally configured to sense data *SD* from ultrasound receivers 31 representative of a sensing of the ultrasound plane as the target biopsy needle 30 is inserted into abdominal region 12 of patient 11, and to execute a

known process for tracking a position of each ultrasound receiver 31 relative to the ultrasound plane intersecting abdominal region 12. For each ultrasound receiver 31, the tracked position indicates whether the particular ultrasound receiver 31 is within the ultrasound plane (i.e., in-plane) or outside of the ultrasound plane (i.e., out-of-plane). More particularly, the sensing of the ultrasound plane of the particular ultrasound receiver 31 will indicate a three-dimensional ("3D") position of each ultrasound receiver 31 in terms of height, width and depth whereby in-plane has zero (0) depth and out-of-plane has a non-zero depth.

Trajectory prediction module 47 is structurally configured to receive needle data *ND*, pre-operatively or intra-operatively, representative of a dimension/configuration profile of target biopsy needle 30 whereby parameters of needle 30 are known for determining an orientation of needle 30 relative to the ultrasound plane intersecting abdominal region 12 including, but not limited to, (1) a length of needle 30 prior to and subsequent to a firing of needle 30 and (2) an attachment point of each ultrasound receiver 31.

Trajectory prediction module 47 is further structurally configured to receive image data *ID* from ultrasound imaging module 45 representative of the planar ultrasound image of abdominal region 12 being displayed, and tracking data *TD* from receiver tracking module 46 representative of the tracked positions of ultrasound receivers 31 relative to the ultrasound plane intersecting abdominal region 12. In response thereto, trajectory prediction module 47 is further structurally configured to receive to predict a biopsy trajectory of target biopsy needle 30 relative to the ultrasound plane by executing a process of the present invention including:

(1) determining an orientation of a virtual version of an unfired needle 30 relative to the planar ultrasound image derived from a length of a virtual positioning of a segment of needle 30 between ultrasound receivers 31 relative to the planar ultrasound image as a function of the tracked positions of ultrasound receivers 31 ("orientation determination"); and

(2) determining a tip extension of a virtual version of a fired needle 30 previously oriented relative to the planar ultrasound image derived from a length of a virtual positioning of a fired stylet of needle 30 ("firing determination").

The orientation determination facilitates a generation by trajectory prediction module 47 of a needle overlay on the planar ultrasound image, and the firing determination facilitates a generation by trajectory prediction module 47 of a biopsy trajectory overlay on the planar ultrasound image. For example, as shown in FIG. 1, monitor 41 is displaying an in-plane needle overlay 48i and an in-plane biopsy trajectory overlay 49i when both ultrasound receivers 31 are in-plane of the ultrasound plane intersecting abdominal region 12.

In practice, the overlays may have any shape and/or any color indicative of an in-plane or out-of-plane sensing of needle 30 and the biopsy trajectory. For example, FIGS. 2-4 shows a sequence of needle 30 being transitioned from out-of-plane to in-plane relative to an ultrasound plane 21.

Specifically, FIG. 2 illustrates an initial insertion of needle 30 within abdominal region 12 (not shown) whereby both ultrasound receivers 31 are out-of-plane and an orientation of needle 30 is non-parallel to ultrasound plane 21. For this initial insertion, a needle overlay 48o of a white solid triangular shape based from a proximal end to distal end and a biopsy trajectory overlay 49o of a white dashed triangular shape based from an unfired needle tip to a fired needle tip illustrates both ultrasound receivers 31 are out-of-plane and that a fired needle tip would be out-of-plane.

FIG. 3 illustrates a further insertion of needle 30 within abdominal region 12 (not shown) whereby the distal ultrasound receiver 31 is in-plane, the proximal ultrasound receiver 31 is out-of-plane, and an orientation of needle 30 is non-parallel to ultrasound plane 21. For this further insertion, needle overlay 48o and biopsy trajectory overlay 49o illustrates the distal ultrasound receiver 31 is in-plane and the fired needle tip would be out-of-plane opposite needle 30.

FIG. 4 illustrates a rotation of ultrasound probe 20 relative to the insertion of needle 30 within abdominal region 12 (not shown) whereby both ultrasound receivers 31 are in-plane and therefore needle 30 in-plane to ultrasound plane 21. For this probe

rotation, needle overlay 48i is a white line and biopsy trajectory overlay 49i is a dashed line illustrating the in-plane needle 30.

For the example of FIGS. 2-4, needle overlay 48o and biopsy trajectory overlay 49o may be colored red to indicate an out-of-plane needle 30, and needle overlay 48i is and biopsy trajectory overlay 49i may be colored green to indicate an in-plane needle 30.

Referring back to FIG. 1, trajectory prediction module 47 provides prediction data *PD* to the appropriate display module(s) of ultrasound guide controller 44 for display of the overlays on the ultrasound image. Additionally, prediction data *PD* may include a numerical readout of a distance of each ultrasound receiver 31 from the ultrasound plane and an angular orientation of needle 30 relative to the ultrasound plane to facilitate an operator of machine 40 in re-positioning ultrasound probe 20 and/or re-inserting needle 30.

Referring to FIGS. 1-4, from the description of the exemplary embodiments of the present invention, those having ordinary skill in the art will appreciate numerous benefits of an intervention system and method of the present invention including, but not limited to, (1) application for various ultrasound-guided target biopsy procedures (e.g., liver biopsy, renal biopsy, etc.), particularly procedures whereby the biopsy needle is not clearly visible during the procedure, and (2) enhanced training for doctors in performing target biopsies.

Furthermore, as one having ordinary skill in the art will appreciate in view of the teachings provided herein, features, elements, components, etc. described in the present disclosure/specification and/or depicted in the FIGS. 1-4 may be implemented in various combinations of electronic components/circuitry, hardware, executable software and executable firmware, particularly as application modules of a controller as described herein, and provide functions which may be combined in a single element or multiple elements. For example, the functions of the various features, elements, components, etc. shown/illustrated/depicted in the FIGS. 1-4 can be provided through the use of dedicated hardware as well as hardware capable of executing software in association with appropriate software. When provided by a processor, the functions can be provided by a single dedicated processor, by a single shared processor, or by a plurality of individual processors, some of which can be shared and/or multiplexed.

Moreover, explicit use of the term "processor" should not be construed to refer exclusively to hardware capable of executing software, and can implicitly include, without limitation, digital signal processor ("DSP") hardware, memory (e.g., read only memory ("ROM") for storing software, random access memory ("RAM"), non-volatile storage, etc.) and virtually any means and/or machine (including hardware, software, firmware, circuitry, combinations thereof, etc.) which is capable of (and/or configurable) to perform and/or control a process.

Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass both structural and functional equivalents thereof. Additionally, it is intended that such equivalents include both currently known equivalents as well as equivalents developed in the future (e.g., any elements developed that can perform the same or substantially similar function, regardless of structure). Thus, for example, it will be appreciated by one having ordinary skill in the art in view of the teachings provided herein that any block diagrams presented herein can represent conceptual views of illustrative system components and/or circuitry embodying the principles of the invention. Similarly, one having ordinary skill in the art should appreciate in view of the teachings provided herein that any flow charts, flow diagrams and the like can represent various processes which can be substantially represented in computer readable storage media and so executed by a computer, processor or other device with processing capabilities, whether or not such computer or processor is explicitly shown.

Furthermore, exemplary embodiments of the present invention can take the form of a computer program product or application module accessible from a computer-usable and/or computer-readable storage medium providing program code and/or instructions for use by or in connection with, e.g., a computer or any instruction execution system. In accordance with the present disclosure, a computer-usable or computer readable storage medium can be any apparatus that can, e.g., include, store, communicate, propagate or transport the program for use by or in connection with the instruction execution system, apparatus or device. Such exemplary medium can be, e.g., an electronic, magnetic, optical, electromagnetic, infrared or semiconductor system (or apparatus or device) or a propagation medium. Examples of a computer-readable medium include, e.g., a semiconductor or solid state memory, magnetic tape, a

removable computer diskette, a random access memory (RAM), a read-only memory (ROM), flash (drive), a rigid magnetic disk and an optical disk. Current examples of optical disks include compact disk – read only memory (CD-ROM), compact disk – read/write (CD-R/W) and DVD. Further, it should be understood that any new computer-readable medium which may hereafter be developed should also be considered as computer-readable medium as may be used or referred to in accordance with exemplary embodiments of the present invention and disclosure.

Having described preferred and exemplary embodiments of novel and inventive system and method for predicting a needle trajectory for target biopsy, (which embodiments are intended to be illustrative and not limiting), it is noted that modifications and variations can be made by persons having ordinary skill in the art in light of the teachings provided herein, including the FIGS 1-4. It is therefore to be understood that changes can be made in/to the preferred and exemplary embodiments of the present disclosure which are within the scope of the embodiments disclosed herein.

Moreover, it is contemplated that corresponding and/or related systems incorporating and/or implementing the device or such as may be used/implemented in a device in accordance with the present disclosure are also contemplated and considered to be within the scope of the present invention. Further, corresponding and/or related method for manufacturing and/or using a device and/or system in accordance with the present disclosure are also contemplated and considered to be within the scope of the present invention.

Claims

1. A target biopsy system, comprising:

an ultrasound probe (20) operable to project an ultrasound plane intersecting an anatomical region;

a target biopsy needle (30);

at least two ultrasound receivers (31) in a known arrangement relative to the target biopsy needle (30), each ultrasound receiver (31) being operable to sense the ultrasound plane as the target biopsy needle (30) is inserted into the anatomical region; and

an ultrasound guide controller (44) operable in communication with the ultrasound probe (20) and the at least two ultrasound receivers (31) to predict a biopsy trajectory of the target biopsy needle (30) within the anatomical region relative to the ultrasound plane responsive to a sensing of the ultrasound plane by the at least two ultrasound receivers (31).

2. The target biopsy system of claim 1, wherein the target biopsy needle (30) includes the at least two ultrasound receivers (31).

3. The target biopsy system of claim 1, wherein the target biopsy needle (30) includes a firing mechanism operable to project the target biopsy needle (30) along the predicted biopsy trajectory of the target biopsy needle (30) within the anatomical region.

4. The target biopsy system of claim 1, wherein the target biopsy needle (30) includes a coaxial introducer operable to introduce the target biopsy needle into the anatomical region.

5. The target biopsy system of clam 1,

wherein a distal ultrasound receiver (31) of the at least two ultrasound receivers (31) is adjacent a tip of the target biopsy needle (30); and

wherein each additional ultrasound receiver (31) of the at least two ultrasound receiver (31) are spatially arranged on the target biopsy needle (30).

6. The target biopsy system of claim 1, wherein the ultrasound guide controller (44) predicts the biopsy trajectory as an in-plane biopsy trajectory responsive to the sensing of the ultrasound plane indicating the at least two ultrasound receivers (31) being within the ultrasound plane.

7. The target biopsy system of claim 6, wherein the ultrasound guide controller (44) predicts the biopsy trajectory as an out-of-plane biopsy trajectory responsive to the sensing of the ultrasound plane indicating at least one of the at least two ultrasound receivers (31) being outside the ultrasound plane.

8. The target biopsy system of claim 1, further comprising:

a monitor (41) operable in communication with the ultrasound guide controller (44) to display the planar ultrasound image; and

wherein the ultrasound guide controller (44) is operable to control a display of a biopsy trajectory overlay on a planar ultrasound image of the anatomical region displayed by the monitor (41), the biopsy trajectory overlay being derived from a prediction of the biopsy trajectory of the target biopsy needle (30) within the anatomical region relative to the ultrasound plane.

9. The target biopsy system of claim 8, wherein the ultrasound guide controller (44) controls the display of the biopsy trajectory overlay as an in-plane biopsy trajectory responsive to the at least two ultrasound receivers (31) being within the ultrasound plane.

10. The target biopsy system of claim 8, wherein the ultrasound guide controller (44) controls the display of the biopsy trajectory overlay as an out-of-plane biopsy trajectory responsive to at least one of the at least two ultrasound receivers (31) being outside the ultrasound plane.

11. The target biopsy system of claim 8, further comprising:

an interface platform (42) operable in communication with the ultrasound guide controller (44) to control the display of the planar ultrasound image by the monitor (41).

12. The target biopsy system of claim 1, wherein the ultrasound guide controller (44) includes:

an ultrasound imaging module (45) operable in communication with the ultrasound probe (20) to generate a planar ultrasound image of an anatomical region responsive to ultrasound data representative of an ultrasound plane intersecting an anatomical region;

a receiver tracking module (46) operable in communication with the at least two ultrasound receivers (31) to a track position of each ultrasound receiver (31) relative to the ultrasound plane responsive to sensing data representative of a sensing of the ultrasound plane as the target biopsy needle (30) is inserted into the anatomical region; and

a trajectory prediction module (47) operable in communication with the ultrasound imaging module (45) and the receiver tracking module (46) to predict the biopsy trajectory of the target biopsy needle (30) relative to the ultrasound plane responsive to the tracked positions of the at least two ultrasound receivers (31) relative to the planar ultrasound image of the anatomical region.

13. A ultrasound guide controller (44) of a target biopsy utilizing an ultrasound probe (20) and a target biopsy needle (30) and at least two ultrasound receivers (31), the ultrasound guide controller (44) comprising:

an ultrasound imaging module (45) operable in communication with the ultrasound probe (20) to generate a planar ultrasound image of an anatomical region responsive to ultrasound data representative of an ultrasound plane intersecting an anatomical region;

a receiver tracking module (46) operable in communication with the at least two ultrasound receivers (31) to track a position of each ultrasound receiver (31) relative to the ultrasound plane responsive to sensing data representative of a sensing of the

ultrasound plane as the target biopsy needle (30) is inserted into the anatomical region; and

a trajectory prediction module (47) operable in communication with the ultrasound imaging module (45) and the receiver tracking module (46) to predict a biopsy trajectory of the target biopsy needle (30) relative to the ultrasound plane responsive to the tracked positions of the at least two ultrasound receivers (31) relative to the planar ultrasound image of the anatomical region.

14. The ultrasound guide controller (44) of claim 13, wherein the trajectory prediction module (47) predicts the biopsy trajectory as an in-plane biopsy trajectory responsive to the tracked positions of the at least two ultrasound receivers (31) indicating the at least two ultrasound receivers (31) being within the ultrasound plane.

15. The ultrasound guide controller (44) of claim 13, wherein the trajectory prediction module (47) predicts the biopsy trajectory as an out-of-plane biopsy trajectory responsive to the tracked positions of the at least two ultrasound receivers (31) indicating at least one of the at least two ultrasound receivers (31) being outside the ultrasound plane.

16. A target biopsy method, comprising:

an ultrasound probe (20) projecting an ultrasound plane intersecting an anatomical region;

at least two ultrasound receivers (31) sensing the ultrasound plane as a target biopsy needle (30) is inserted into the anatomical region; and

an ultrasound guide controller (44) predicting a biopsy trajectory of the target biopsy needle (30) within the anatomical region relative to the ultrasound plane.

17. The target biopsy method of claim 16, wherein the ultrasound guide controller (44) predicts the biopsy trajectory an in-plane biopsy trajectory responsive to the sensing of the ultrasound plane indicating the at least two ultrasound receivers (31) being within the ultrasound plane.

18. The target biopsy method of claim 16, wherein the ultrasound guide controller (44) controls a display of a biopsy trajectory overlay as an out-of-plane biopsy trajectory responsive to the sensing of the ultrasound plane indicating at least one of the at least two ultrasound receivers (31) being outside the ultrasound plane.

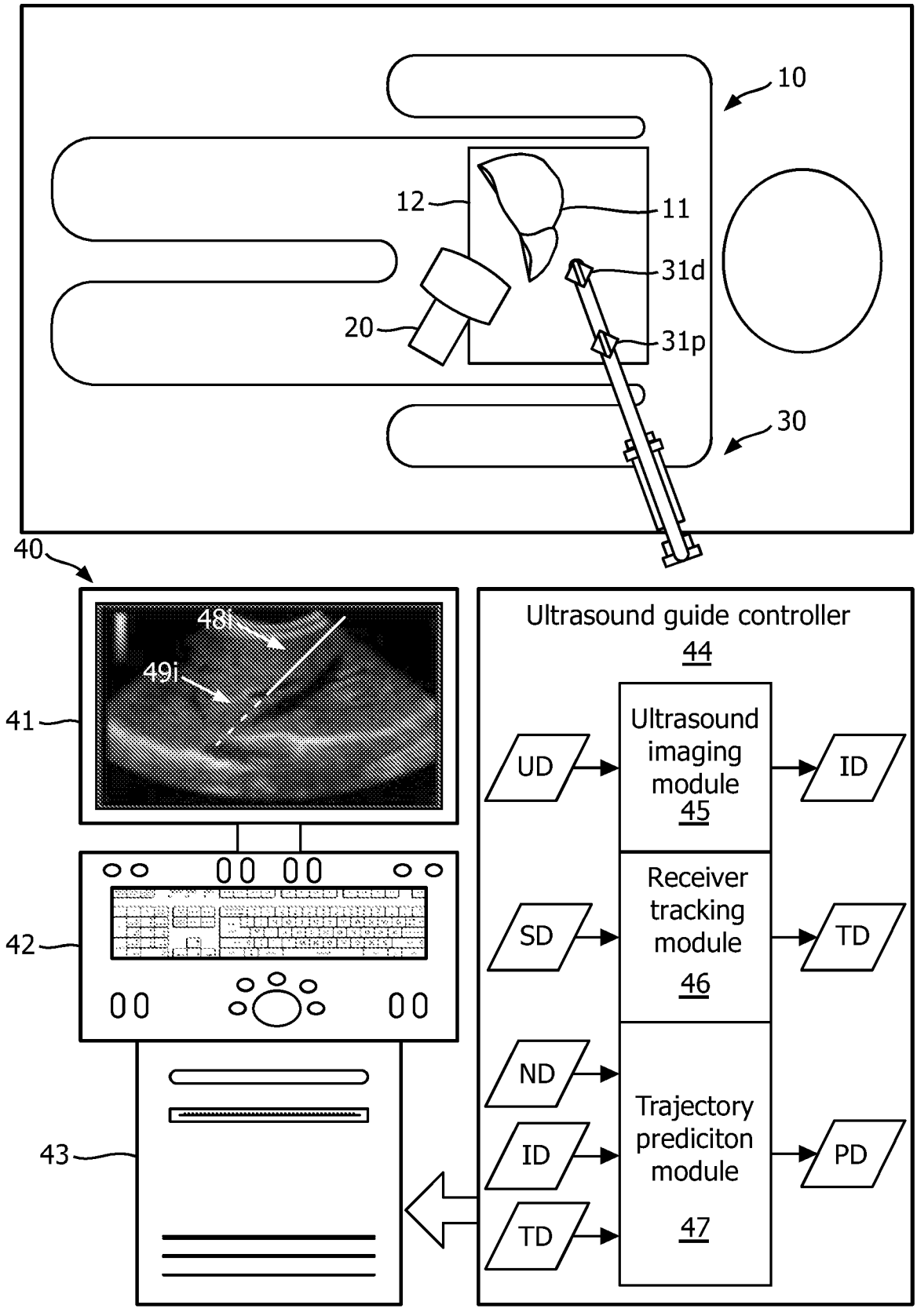
19. The target biopsy method of claim 16, further comprising:

the ultrasound guide controller (44) controls a display of a biopsy trajectory overlay on a planar ultrasound image of the anatomical region derived from the prediction of the biopsy trajectory of the target biopsy needle (30) within the anatomical region relative to the ultrasound plane.

20. The target biopsy method of claim 16,

wherein a distal ultrasound receiver (31) of the at least two ultrasound receivers (31) is adjacent a tip of the target biopsy needle (30); and

wherein each additional ultrasound receiver (31) of the at least two ultrasound receiver (31) are spatially arranged relative to the target biopsy needle (30).


10
12
11
31d
20
31p
30
40
48i
49i
41
42
43
Ultrasound guide controller
44
UD
Ultrasound imaging module
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ID
SD
Receiver tracking module
46
TD
ND
ID
TD
Trajectory prediciton module
47
PD

FIG. 1

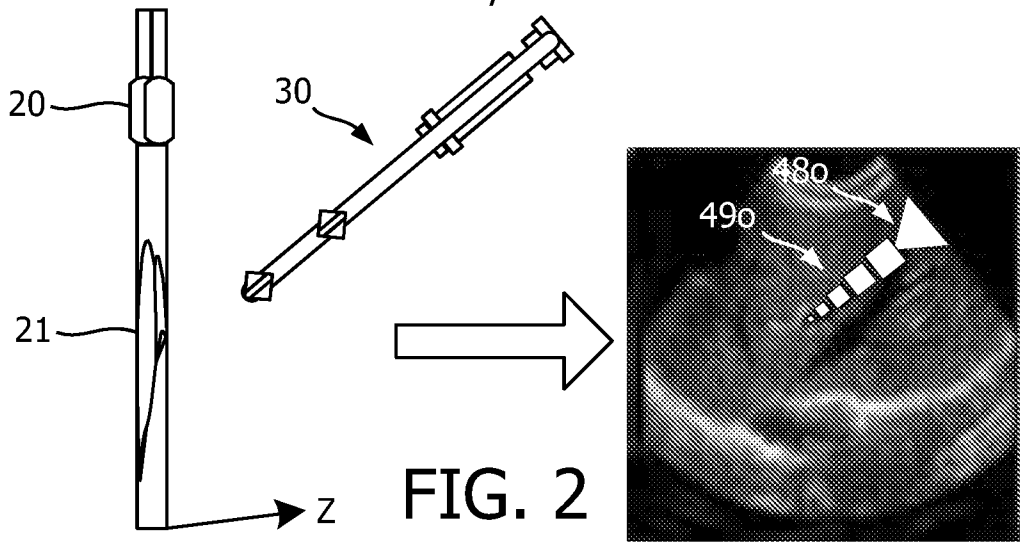

FIG. 2

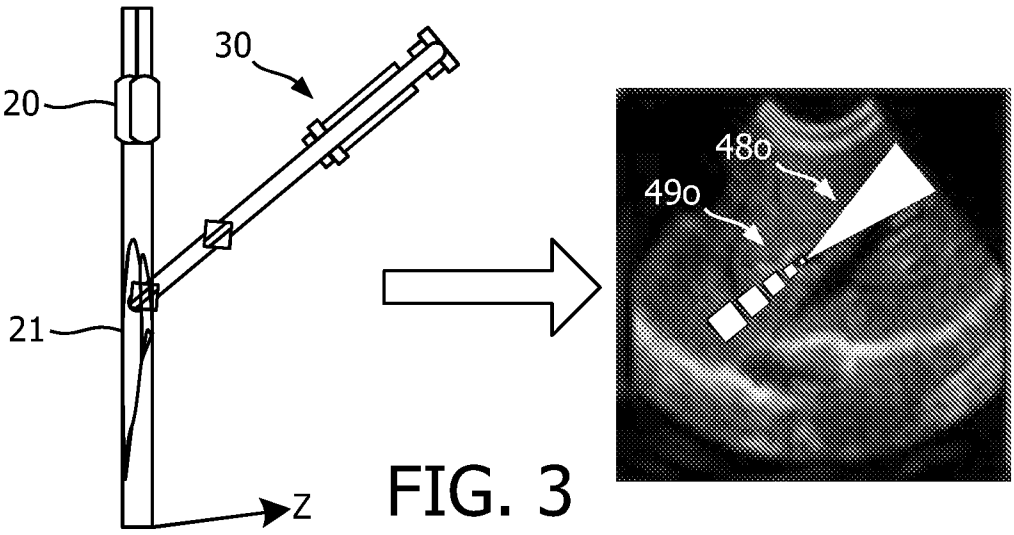

FIG. 3

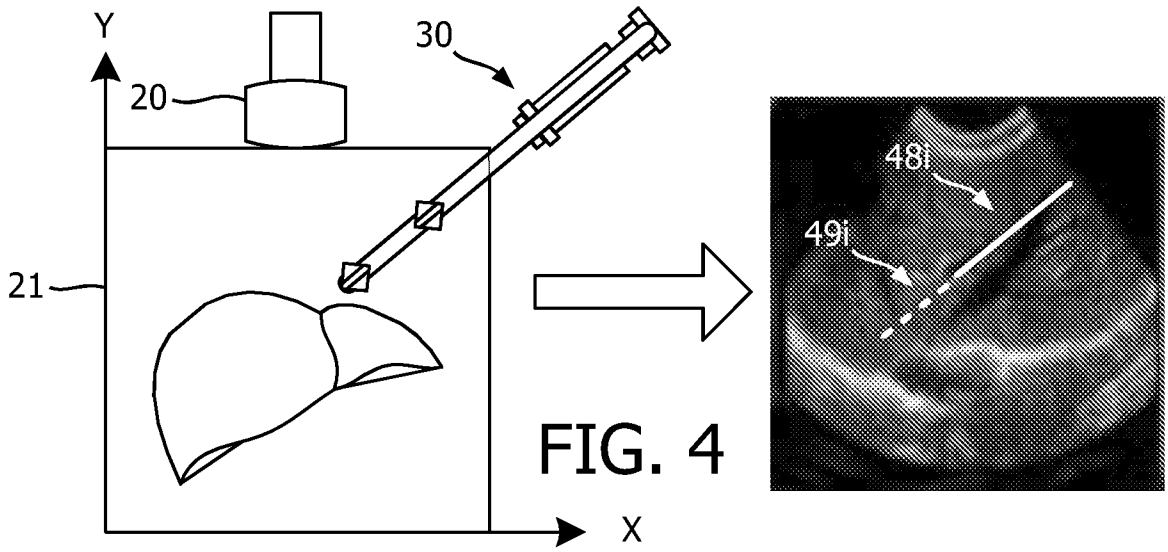

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2015/059494

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B8/08 A61B8/00
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

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	WO 2012/172458 A1 (KONINKL PHILIPS ELECTRONICS NV [NL]; JAIN AMEET KUMAR [US]; VIGNON FRA) 20 December 2012 (2012-12-20)	1,2,4-15
Y	page 1, line 20 - page 9, line 20; claims; figures	3

Y	US 2005/159676 A1 (TAYLOR JAMES D [US] ET AL) 21 July 2005 (2005-07-21) paragraphs [0009] - [0012], [0024] - [0027], [0120], [0124]; claims; figures	3

A	JP H11 76241 A (NIPPON VINYL KOGYO KK; MYATA SEIZO) 23 March 1999 (1999-03-23) the whole document	1-15

	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"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
11 March 2016	22/03/2016

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

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Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 97/03609 A1 (PALTIELI YOAV [IL]) 6 February 1997 (1997-02-06) the whole document	1-15
A	WO 2011/138698 A1 (KONINKL PHILIPS ELECTRONICS NV [NL]; VIGNON FRANCOIS GUY GERARD MARIE) 10 November 2011 (2011-11-10) the whole document	1-15
A	WO 2006/116163 A2 (BIOTELLIGENT INC [US]) 2 November 2006 (2006-11-02) page 3, line 19 - line 22	1-15
A	WO 2005/055849 A1 (BREYER BRANKO [HR]; CIKES IVO [HR]) 23 June 2005 (2005-06-23) the whole document	1-15

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2015/059494

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2012172458 A1	20-12-2012	CN 103747729 A	23-04-2014
		EP 2717772 A1	16-04-2014
		JP 2014516738 A	17-07-2014
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		WO 2005055849 A1	23-06-2005

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2015/059494

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [X] Claims Nos.: 16-20
because they relate to subject matter not required to be searched by this Authority, namely:

see FURTHER INFORMATION sheet PCT/ISA/210

2. [ ] Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

[ ] The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

[ ] No protest accompanied the payment of additional search fees.

Continuation of Box II.1

Claims Nos.: 16-20

Claims 16-20 are directed to a target biopsy method comprising the step of: sensing an ultrasound plane by the ultrasound receivers as a target biopsy needle is inserted into an anatomical region.This step includes an invasive step representing substantial physical interventions on the body which require professional medical expertise to be carried out and which entail a health risk even when carried out with the required professional care and expertise. It is further clear that, in the methods of claims 16-20, maintaining the life and health of the subject patient is important. Thus, the method of the claims is a method for treatment of the human body by surgery (Rules 67.1(iv) and 39.1(iv) PCT).