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(54) **METHOD AND APPARATUS FOR REGISTERING LIVE MEDICAL IMAGE WITH ANATOMICAL MODEL**

(71) Applicant: **BioProber Corporation**, Bellevue, WA (US)

(72) Inventors: **Junzheng Man**, Bellevue, WA (US); **Xuegong Shi**, Bellevue, WA (US); **Guo Tang**, Bellevue, WA (US)

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

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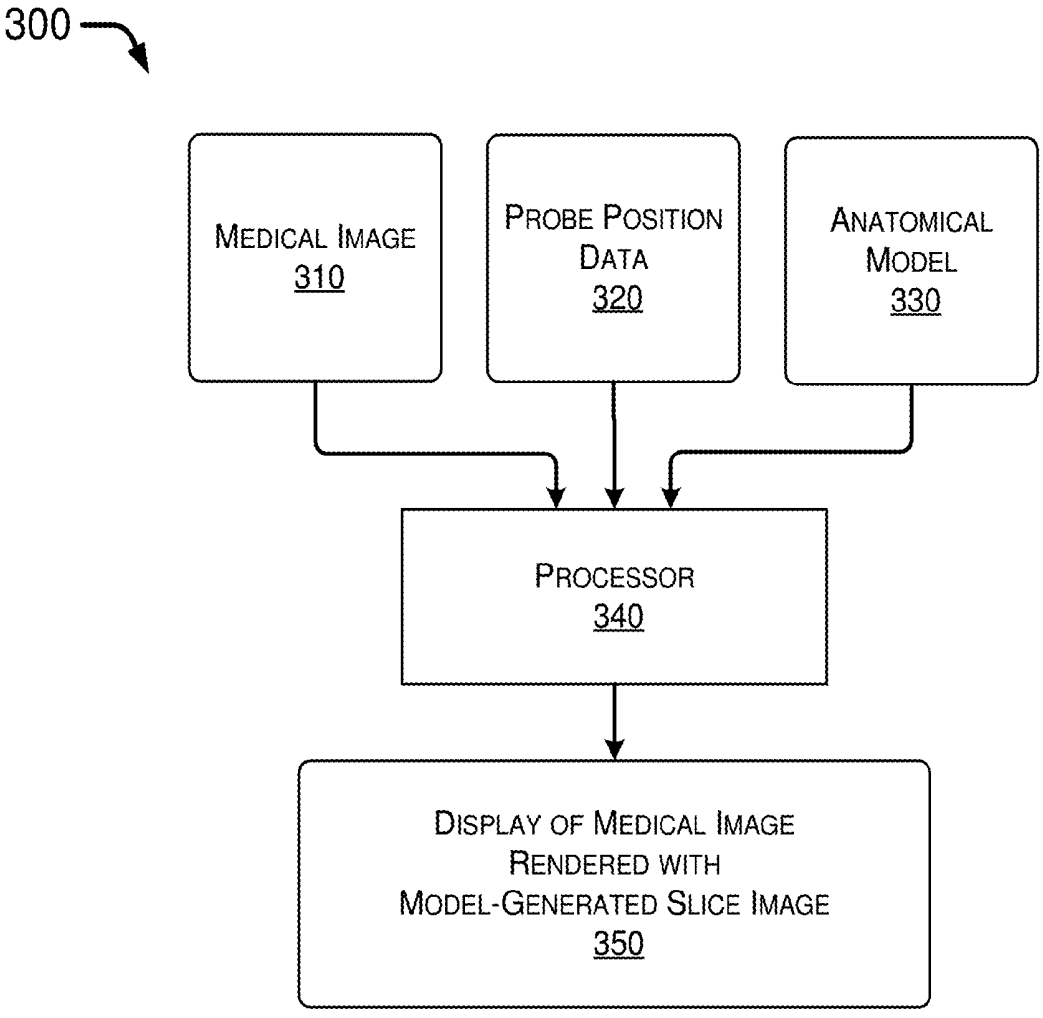
(57) **ABSTRACT**

Techniques and examples pertaining to registering a medical image of a patient with an anatomical model of the patient are described. A processor of an apparatus may calculate a mapping matrix between a real space and a virtual space using one or more mapping objects. The processor may receive data indicating a physical position of a probe relative to the patient. The processor may subsequently determine a virtual position of the probe in the virtual space based on the mapping matrix such that the virtual position as defined in the virtual space corresponds to the physical position in the real space. The processor may then determine a cut plane of the anatomical model, wherein the medical image may represent an anatomical cross-section of the patient at the cut plane.



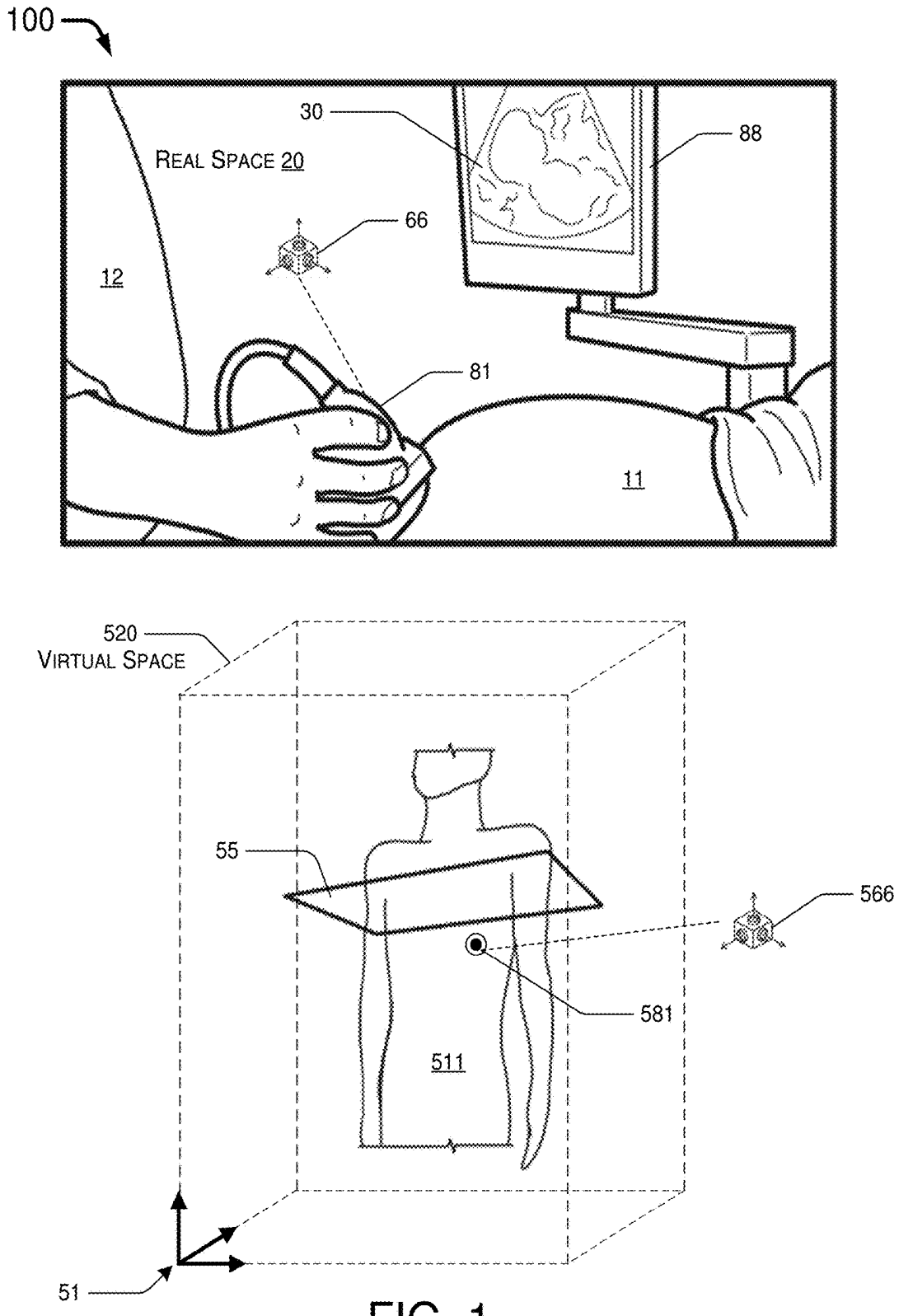
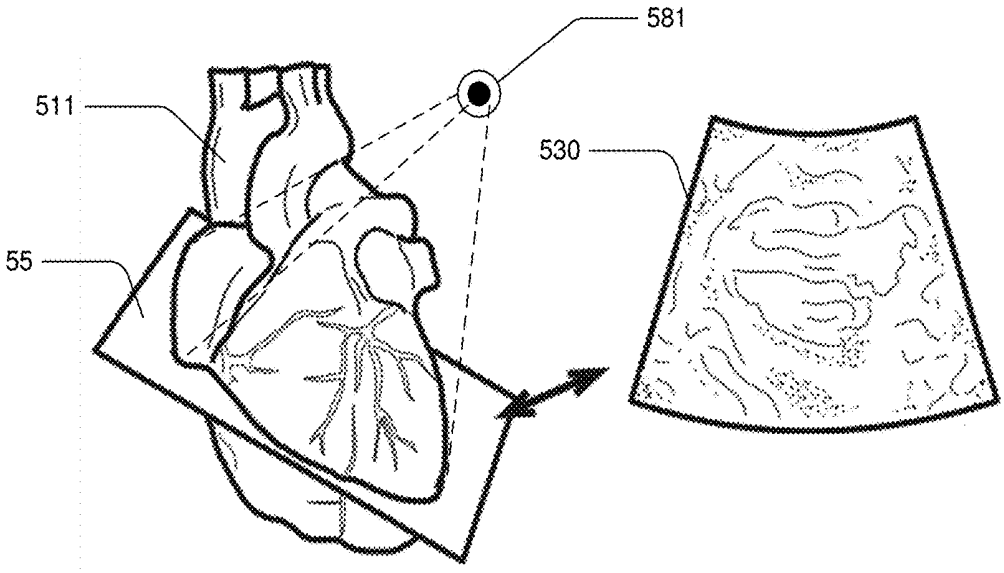

100
30
88
REAL SPACE 20
66
12
81
11
520
VIRTUAL SPACE
55
566
581
511
51

FIG. 1



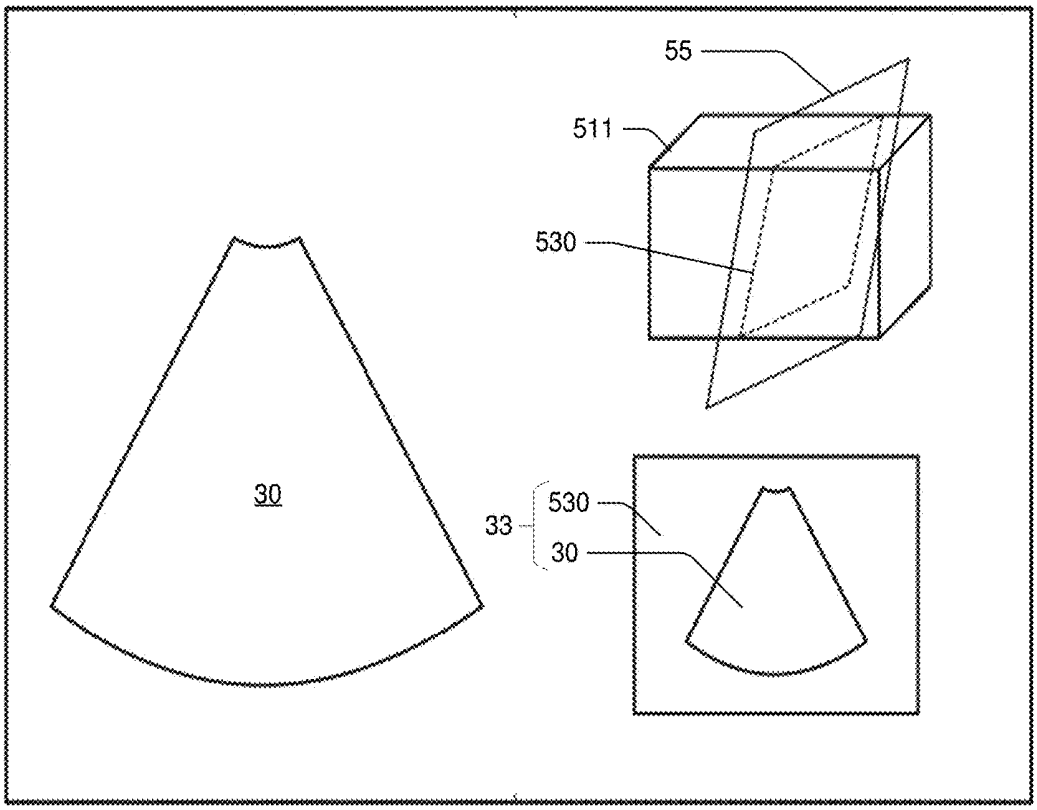


FIG. 2

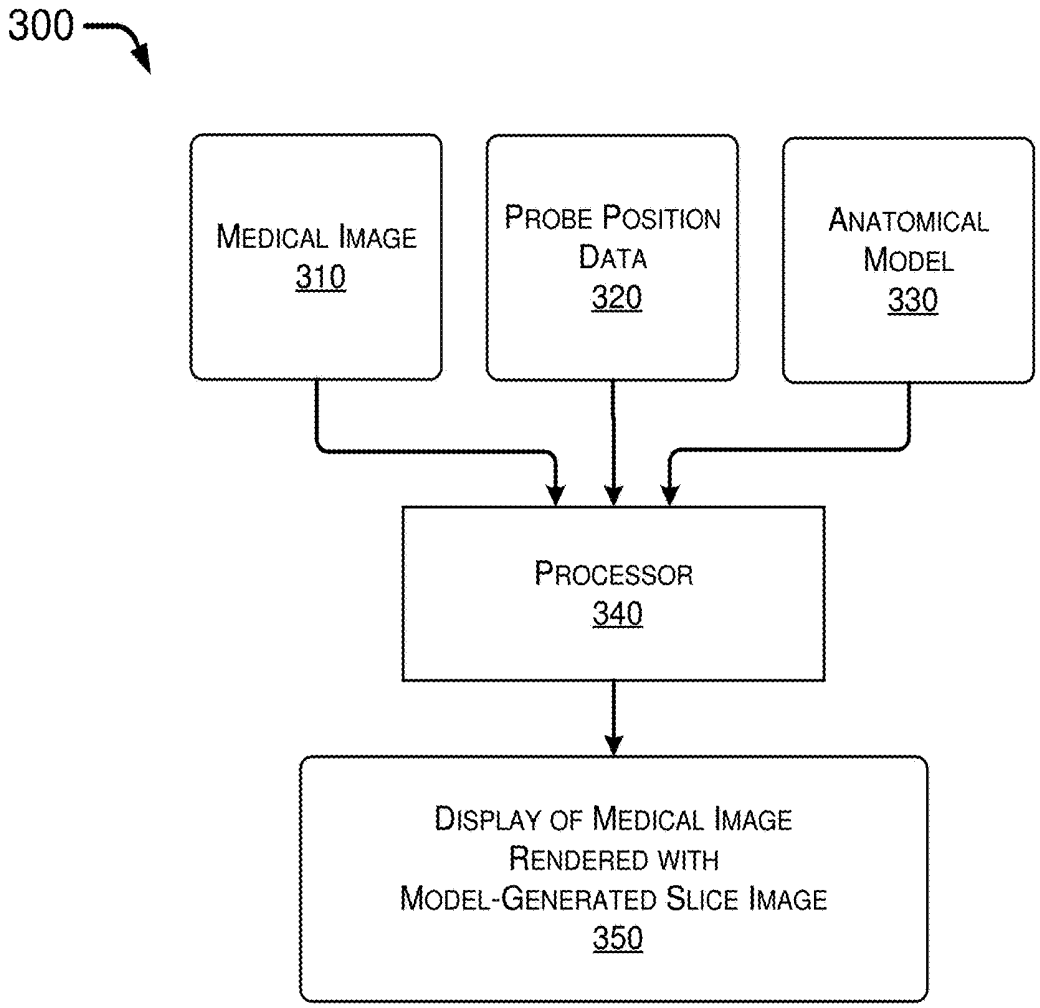

300
MEDICAL IMAGE
310
PROBE POSITION
DATA
320
ANATOMICAL
MODEL
330
PROCESSOR
340
DISPLAY OF MEDICAL IMAGE
RENDERED WITH
MODEL-GENERATED SLICE IMAGE
350

FIG. 3

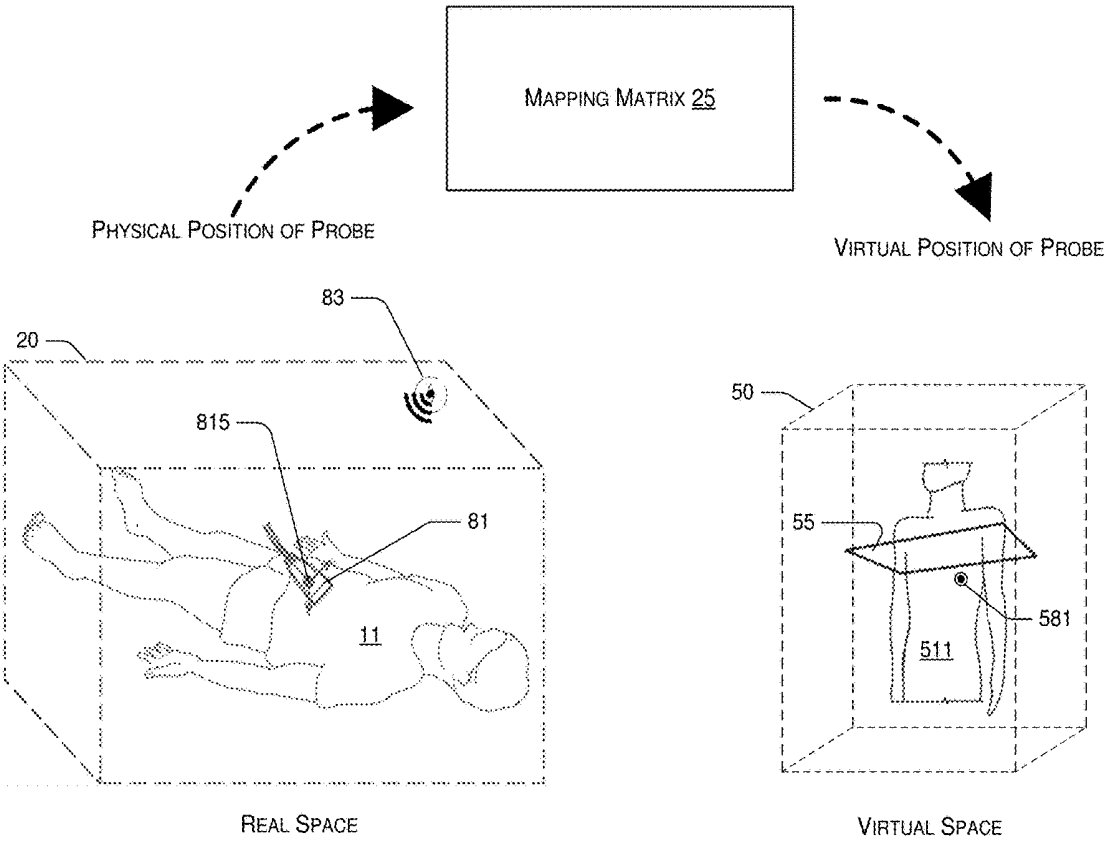

MAPPING MATRIX 25
PHYSICAL POSITION OF PROBE
VIRTUAL POSITION OF PROBE
83
20
815
81
11
REAL SPACE
50
55
581
511
VIRTUAL SPACE

FIG. 4

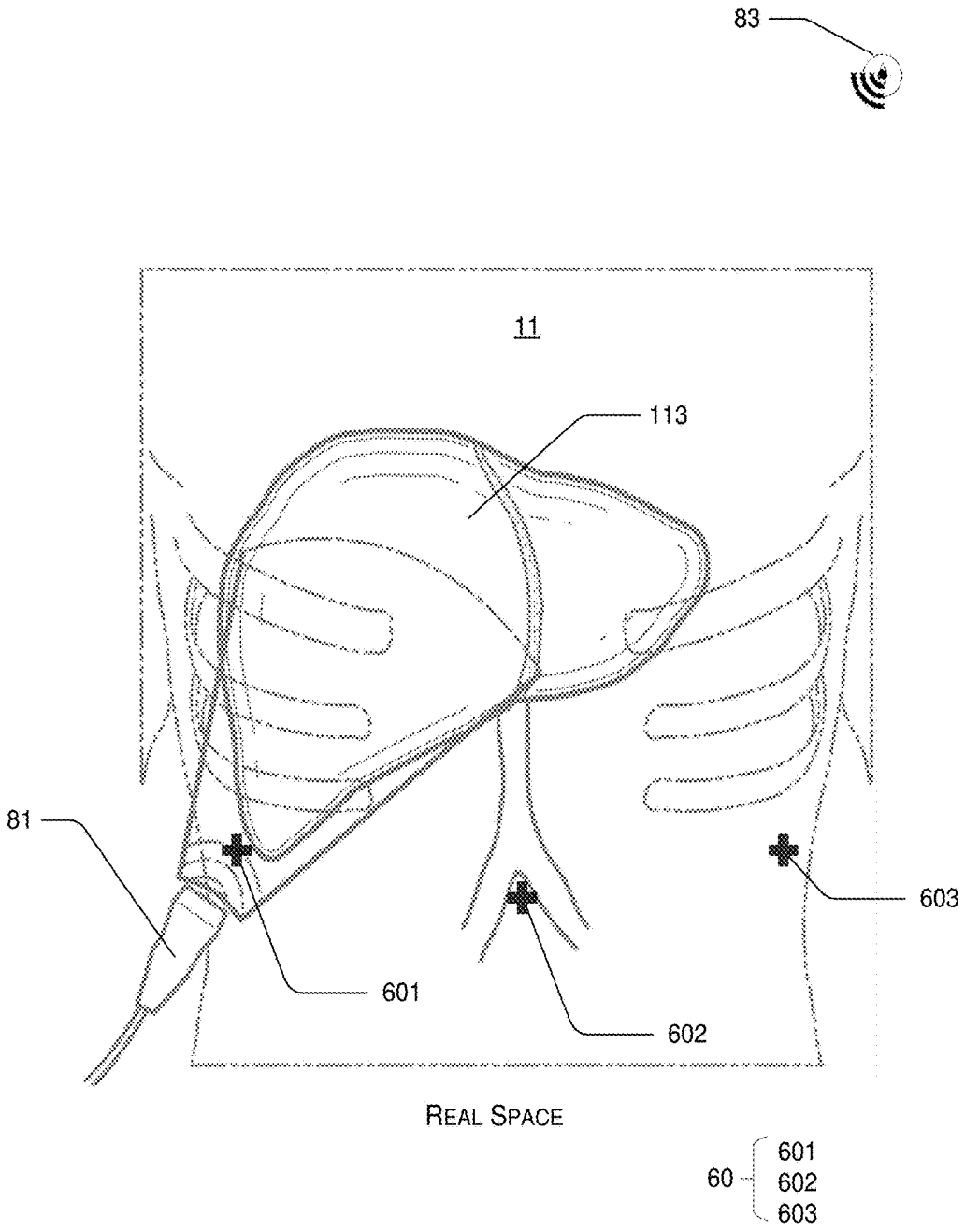


FIG. 5

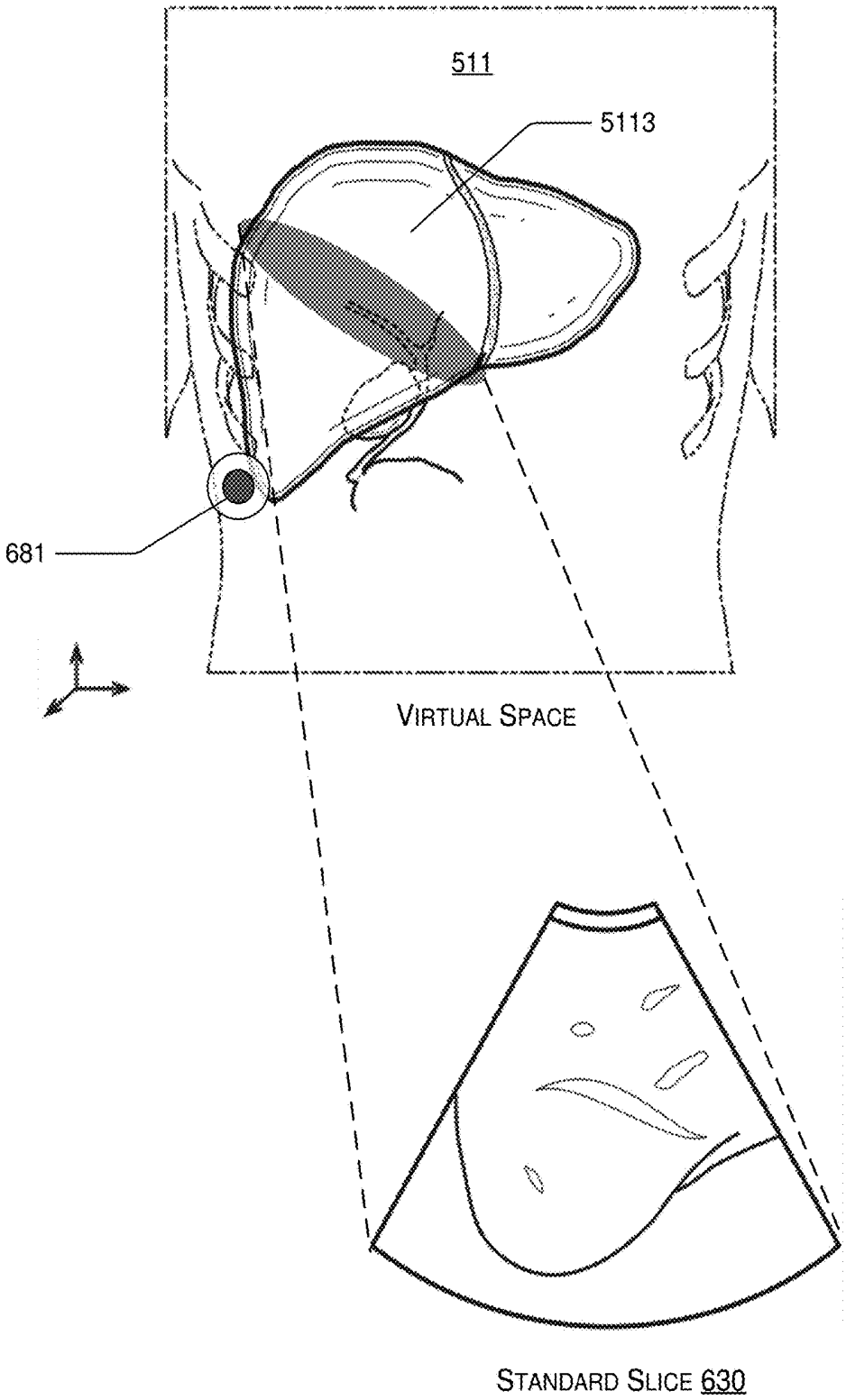


FIG. 6

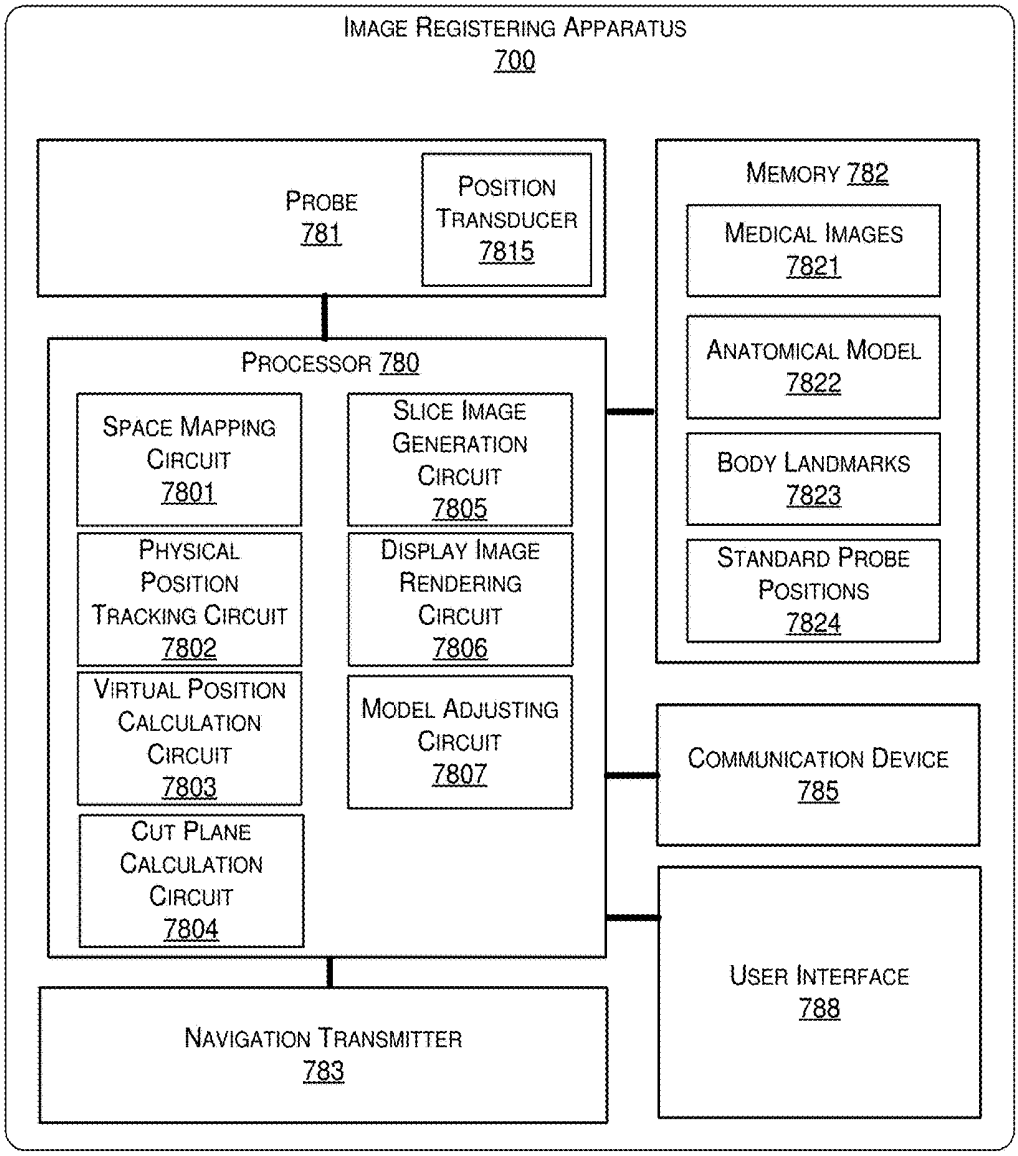


IMAGE REGISTERING APPARATUS
700
PROBE
781
POSITION TRANSDUCER
7815
MEMORY 782
MEDICAL IMAGES
7821
ANATOMICAL MODEL
7822
BODY LANDMARKS
7823
STANDARD PROBE POSITIONS
7824
PROCESSOR 780
SPACE MAPPING CIRCUIT
7801
SLICE IMAGE GENERATION CIRCUIT
7805
PHYSICAL POSITION TRACKING CIRCUIT
7802
DISPLAY IMAGE RENDERING CIRCUIT
7806
VIRTUAL POSITION CALCULATION CIRCUIT
7803
MODEL ADJUSTING CIRCUIT
7807
CUT PLANE CALCULATION CIRCUIT
7804
COMMUNICATION DEVICE
785
USER INTERFACE
788
NAVIGATION TRANSMITTER
783

FIG. 7

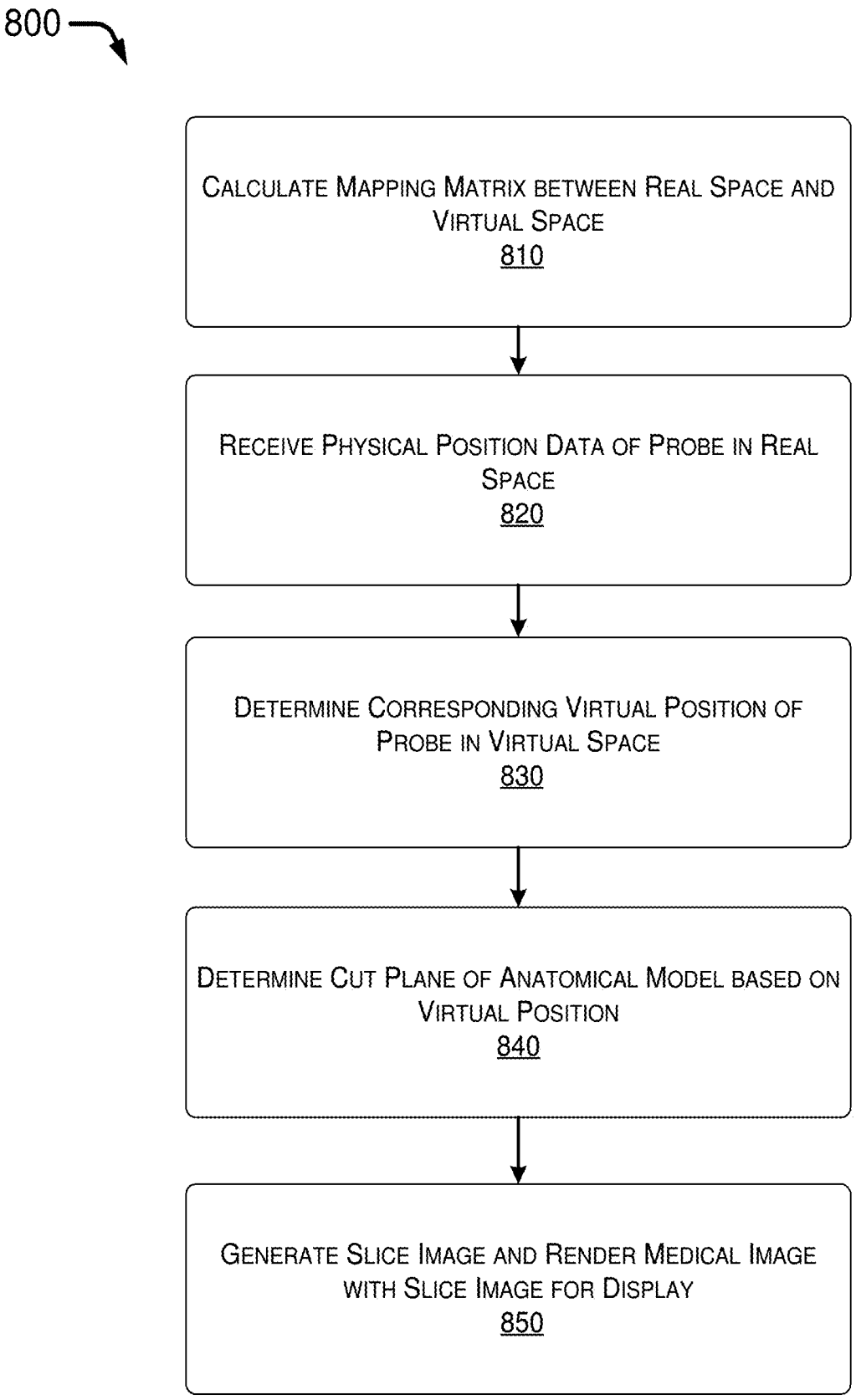

800
CALCULATE MAPPING MATRIX BETWEEN REAL SPACE AND VIRTUAL SPACE
810
RECEIVE PHYSICAL POSITION DATA OF PROBE IN REAL SPACE
820
DETERMINE CORRESPONDING VIRTUAL POSITION OF PROBE IN VIRTUAL SPACE
830
DETERMINE CUT PLANE OF ANATOMICAL MODEL BASED ON VIRTUAL POSITION
840
GENERATE SLICE IMAGE AND RENDER MEDICAL IMAGE WITH SLICE IMAGE FOR DISPLAY
850

FIG. 8

METHOD AND APPARATUS FOR REGISTERING LIVE MEDICAL IMAGE WITH ANATOMICAL MODEL

TECHNICAL FIELD

[0001] The present disclosure generally relates to medical imaging techniques and, more particularly, to a method and an apparatus for registering live medical images of a patient with an anatomical model of the patient.

BACKGROUND

[0002] Medical imaging involves techniques and processes for creating a visual representation of an interior of a living body, such as a patient. The visual representation, often referred to as a "medical image", reveals operations or functioning of an organ, a tissue, or a structure of the living body that are not otherwise observable from an exterior of the living body. A medical practitioner, such as a medical doctor or a veterinarian, may refer to the visual representation as part of a medical diagnosis or clinical analysis, and subsequently determine whether or how a medical intervention or treatment may be applied to the living body.

[0003] A major challenge of medical imaging resides in a non-intuitive nature of the visual representation, which makes a correct interpretation of the medical image more difficult than it is desired. Typically, it takes a practitioner years of extensive medical training for him or her to be able to interpret or otherwise comprehend a medical image with satisfactory accuracy and detail. In many applications, a medical image constitutes a two-dimensional (2D) cross-section of a body anatomy of a patient, rather than a three-dimensional (3D) replica of the actual body object being examined, be it an organ, tissue or structure. Therefore, it is not trivial to establish a correlation between the 2D medical image and the anatomy of the body object. That is, it is not trivial to identify which anatomical cross-section of the 3D body object the 2D medical image represents.

[0004] Therefore, it is desirable to find a more intuitive way to correlate the 2D medical image with the 3D body object being examined.

SUMMARY

[0005] The following summary is illustrative only and is not intended to be limiting in any way. That is, the following summary is provided to introduce concepts, highlights, benefits and advantages of the novel and non-obvious techniques described herein. Select implementations are further described below in the detailed description. Thus, the following summary is not intended to identify essential features of the claimed subject matter, nor is it intended for use in determining the scope of the claimed subject matter.

[0006] An objective of the present disclosure is to propose various novel concepts and schemes pertaining to registering a medical image of a patient with an anatomical model of the patient, which can be implemented in various clinical medical or diagnosis applications including ultrasonography scanning. The anatomical model of the patient may be a generic or universal model that is equally applicable to various patients of different genders, heights, weights, ethnicities, ages, and the like, such that patient-specific data may not be required for the registering of the medical image with the anatomical model.

[0007] According to an aspect of the present disclosure, an apparatus that registers a medical image of a patient with an anatomical model of the patient is disclosed. The apparatus may include a memory capable of storing data representing the medical image and data representing the anatomical model. The apparatus may also include a processor, wherein the processor may include a space mapping circuit to calculate a mapping matrix between a real space and a virtual space using one or more mapping objects. The real space may be a physical space in which the patient is located, and the virtual space may be a simulation-generated space in which the anatomical model is defined. The processor may also include a physical position tracking circuit to receive data indicating a physical position of a probe relative to the patient, wherein the probe generates the medical image. The processor may also include a virtual position calculation circuit to determine a virtual position of the probe in the virtual space relative to the anatomical model based on the mapping matrix such that the virtual position as defined in the virtual space corresponds to the physical position in the real space. The processor may further include a cut plane calculation circuit to determine a cut plane of the anatomical model based on the virtual position. The medical image may represent an anatomical cross-section of the patient at the cut plane.

[0008] In some embodiments, the processor of the apparatus may also include a slice image generation circuit to generate a slice image based on the virtual position of the probe and the anatomical model. The slice image may represent an anatomical cross-section of the anatomical model at the cut plane. The processor may further include a display image rendering circuit to display the medical image overlaid with the slice image. The display image rendering circuit may also display a name of an organ, a tissue, a structure or an anatomical part on either or both of the medical image and the slice image.

[0009] According to another aspect of the present disclosure, a method of registering a medical image of a patient with an anatomical model of the patient is disclosed. The method may involve a processor of an apparatus calculating a mapping matrix between a real space and a virtual space using one or more mapping objects. The method may also involve the processor receiving data indicating a physical position of a probe relative to the patient, wherein the medical image is generated by the probe. The method may further involve the processor determining a virtual position of the probe in the virtual space relative to the anatomical model based on the mapping matrix such that the virtual position corresponds to the physical position in the real space. The method may also involve the processor determining a cut plane of the anatomical model based on the virtual position, such that the medical image may represent an anatomical cross-section of the patient at the cut plane.

[0010] In some embodiments, the method may involve the processor of the apparatus generating a slice image based on the virtual position of the probe and the anatomical model. The slice image may represent an anatomical cross-section of the anatomical model at the cut plane. The method may also involve the processor rendering the medical image with the slice image.

[0011] It is noteworthy that, although description of the proposed scheme and various examples is provided below in the context of ultrasonography scanning for medical purposes, the proposed concepts, schemes and any variation(s)/

derivative(s) thereof may be implemented in other non-invasive imaging applications where implementation is suitable. Thus, the scope of the proposed scheme is not limited to the description provided herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] These and other features, aspects, and advantages of the present disclosure will become better understood with regard to the following description, appended claims, and accompanying drawings where:

[0013] FIG. **1** is a diagram depicting an example application in accordance with an embodiment of the present disclosure.

[0014] FIG. **2** is a diagram depicting relations among an anatomical model, a cut plane of the anatomical model, and a medical image in accordance with an embodiment of the present disclosure.

[0015] FIG. **3** is a diagram depicting a data flow in accordance with an embodiment of the present disclosure.

[0016] FIG. **4** is a diagram depicting a mapping between a physical space and a simulation-generated space through a mapping matrix in accordance with an embodiment of the present disclosure.

[0017] FIG. **5** is a diagram depicting a first kind of mapping objects used for calculating a mapping matrix in accordance with an embodiment of the present disclosure.

[0018] FIG. **6** is a diagram depicting a second kind of mapping objects used for calculating a mapping matrix in accordance with an embodiment of the present disclosure.

[0019] FIG. **7** is a block diagram depicting an example apparatus in accordance with an embodiment of the present disclosure.

[0020] FIG. **8** is a flowchart depicting an example process in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0021] The detailed description of the present disclosure is presented largely in terms of procedures, steps, logic blocks, processing, or other symbolic representations that directly or indirectly resemble the operations of devices or systems contemplated in the present disclosure. These descriptions and representations are typically used by those skilled in the art to most effectively convey the substance of their work to others skilled in the art.

[0022] Reference herein to "one embodiment" or "an embodiment" means that a particular feature, structure, or characteristic described in connection with the embodiment can be comprised in at least one embodiment of the present disclosure. The appearances of the phrase "in one embodiment" in various places in the specification are not necessarily all referring to the same embodiment, nor are separate or alternative embodiments mutually exclusive of other embodiments. Further, the order of blocks in process flowcharts or diagrams or the use of sequence numbers representing one or more embodiments of the present disclosure do not inherently indicate any particular order nor imply any limitations in the present disclosure.

[0023] To make the above objects, features and advantages of the present disclosure more obvious and easier to understand, the present disclosure is further described in detail below using various embodiments.

[0024] Medical imaging processes and techniques are widely used in contemporary clinical practices to examine or otherwise reveal body operations inside a patient in a non-invasive manner. As mentioned above, a medical practitioner may perform medical diagnosis and clinical analysis using medical imaging techniques, and accordingly determine a medical intervention or treatment to a patient. For example, medical ultrasound, or ultrasonography, is a diagnostic imaging technique based on an application of ultrasound. In general, ultrasound refers to sound waves that are beyond an audible range of frequency to human ears, typically above 20,000 Hz. In a medical application scenario utilizing ultrasound, such as scenario **100** as shown in FIG. **1**, short bursts of ultrasound wave may be generated by a hand-held ultrasound transducer (often referred to as a "probe") **81** that is operated by a practitioner **12**. The ultrasound wave may be applied to a patient **11** with probe **81** held close to or touching an external body surface (e.g., abdominal skin) of patient **11**. The ultrasound wave would partially penetrate the skin of patient **11** and reach the interior of the patient's body. Various organs, tissues and/or structures inside the body of patient **11** would subsequently echo or otherwise reflect part of the incident ultrasound wave back to probe **81**. The reflected ultrasound signal would be picked up, at least partially, by probe **81** and used for constructing or otherwise rendering a visual representation of the internal organs, tissues and/or structures of patient **11**, such as an ultrasound image **30** shown in FIG. **1**. Ultrasound image **30** may be visually displayed on a monitor or display **88**, and may also be digitally recorded or stored in a storage medium such as a computer memory or a hard drive.

[0025] An ultrasound image usually constitutes a visual representation of a 2D cross-section of the body anatomy of the patient. For example, ultrasound image **30** of FIG. **1** constitutes a visual representation of a 2D cross-section of the body of patient **11**. To explain this idea more clearly, a three-dimensional (3D) human body model **511** of FIG. **1** may be used. Model **511** is an anatomical model of patient **11**. As shown in FIG. **1**, an imaginary 2D cut plan **55** that intersects with model **511** may identify or otherwise represent a cross-section of patient **11** that is represented by ultrasound image **30**, which is generated by probe **81** and shown on display **88**. Specifically, cut plan **55** shows where a field of view of probe **81** cuts through a limited area of the patient's body. As shown in FIG. **1**, cut plan **55** intersects with model **511** around the chest of model **511**, and ultrasound image **30** is a visual representation of an organ, a tissue, a structure **11**, or the like, that is internal to the body of patient **11** at cut plane **55**.

[0026] As presented above, however, it requires a long-term extensive medical training for practitioner **12** to identify in his or her mind what ultrasound image **30** from probe **81** really represents about patient **11**. That is, it is neither trivial nor intuitive for practitioner **12** to correlate ultrasound image **30** with cut plane **55** a cross-section of patient at which ultrasound image **30** represents. That posts a major challenge or problem of medical imaging for a practitioner without an extensive medical training to effectively and efficiently identify which anatomical cross-section of a patient a 2D medical image represents. One aspect of the present application is to disclose a method and an apparatus which help or assist practitioner **12** to correctly identify cut plane **55** that is associated with ultrasound image **30**. That is,

the present application aims to solve this problem by "registering" the medical image with an anatomical model of the patient so that a correlation between the medical image and the anatomy of the body of the patient may be easily established. In the context of the present application, registering A with B means that a spatial relation of A with respect to B is made known. Therefore, if a medical image has been registered with an anatomical model, the cross-section of the anatomical model which the medical image represents is readily identified on the anatomical model. Referring to FIG. **1**, an aim of the present application is to register ultrasound image **30** with human body model **511** such that cut plane **55** can be identified.

[0027] Typically, probe **81** has a limited field of view. That is, probe **81** is able to sense only a region or area of a limited size, usually in a vicinity of an immediate location of probe **81**. As probe **81** moves about the body surface of patient **11**, ultrasound image **30** would change accordingly and reveal different parts to the internal of the patient's body. It is also typical that the field of view of the probe is directional. Therefore, even without a translational movement of probe **81** with respect to the patient, the corresponding ultrasound image **30** would change if probe **81** changes its orientation by a rotational movement at a same location. A coordinate system, represented by symbol **66** of FIG. **1**, may be used to define, describe or refer to a real space **20** as shown in FIG. **1**, a physical space in which patient **11** undergoes the ultrasound process. A movement of probe **81** in real space **20** may then be described or otherwise recorded using the coordinate system of real space **20**. The number of coordinates used by the coordinate system typically equals to the degrees of freedom probe **81** can have in real space **20**. In scenario **100**, probe **81** can have a translational movement as well as a rotational movement in real space **20**, having 6 degrees of freedom. The 6 degrees of freedom are illustrated using symbol **66** shown in FIG. **1**, which has three mutually orthogonal axes, and each of the axes is associated with a rotation freedom around that respective axis. Namely, a physical position of probe **81** in real space **20** may be uniquely defined using a set of 6 real numbers as its coordinates. For example, 3 of the 6 real numbers may be used to specify a location of probe **81** in real space **20**, whereas the rest 3 of the 6 real numbers may be used to specify an orientation of probe **81** in real space **20**. In some embodiments, the 3 real numbers specifying the orientation of probe **81** may constitute a normal direction of a primary surface of probe **81** that faces patient **11**.

[0028] In some embodiments, human body model **511** may be simulation-generated or otherwise manifested in a digital form, which enables a readily determination, through numerical calculation or simulation, of cut plane **55** associated with medical image **30** from probe **81** as long as a spatial relation between probe **81** and patient **11** may also be modeled. As shown in FIG. **1**, whereas patient **11** may be modeled by simulation-generated model **511**, a spatial relation between the physical position of probe **81** and patient **11** in real space **20** may also be modeled using a simulation-generated virtual space **520**. Similar to real space **20** which uses a coordinate system **66**, virtual space **520** may employ a coordinate system, represented by symbol **566** of FIG. **1**, that also has 6 degrees of freedom. Specifically, model **511** of patient **11** and a virtual position **581** of the physical position of probe **81** may co-exist, by simulation, in virtual space **520**, with both referencing to a common origin **51** thereof. Similar to the physical position of probe **81** that uses the 6 coordinates of coordinate system **66** to specify the location and the orientation of probe **81** in real space **20**, virtual position **581** may also use 6 coordinates to correspondingly specify in virtual space **520** a location and an orientation, with respect to origin **51**, of the corresponding virtual position **581** of probe **81**. The 6 coordinates of coordinate system **566** employed by virtual space **520** may have 3 translational degrees of freedom and 3 rotational degrees of freedom, just as coordinate system **66** of real space **20**.

[0029] As stated above, since both model **511** and virtual position **581** of probe **81** are simultaneously modeled in a same virtual space (i.e., virtual space **520**), a spatial relation of virtual position **581** with respect to model **511** is readily known, and thus the determination of cut plane **55** may be achieved through numerical calculation or simulation. Moreover, a simulated version of ultrasound image **30**, often referred to as a "slice image", may also be achieved based on virtual position **581** and model **511**, as well as the spatial relation between the two. The concept is illustrated in FIG. **2** with references to FIG. **1**. Firstly, cut plane **55** of anatomical model **511** may be determined based on the spatial relation between virtual position **581** and anatomical model **511**. Secondly, the simulated version of ultrasound image **30**, or the slice image **530**, may be generated or otherwise simulated based on virtual position **581** and model **511**. Although slice image **530** may not be completely the same as ultrasound image **30** for various reasons (more details later), they should be quite similar to one another. In some embodiments, 3D model **511** may include names of various anatomical parts it models, such as an organ, a tissue or a structure. Names of at least a few of the various anatomical parts may be included in or otherwise labeled on slice image **530**. Slice image **530** may be presented to practitioner **12** side-by-side with the actual ultrasound image **30** to assist a comprehension of the correlation between ultrasound image **30** and model **511**. In some embodiments, ultrasound image **30** may be analyzed in view of slice image **530**, and various anatomical parts of ultrasound image **30** may thus be identified, and the names of those identified anatomical parts may also be labeled on ultrasound image **30** as they are on slice image **530**. In some embodiments, ultrasound image **30** may be rendered with slice image **530**. For example, ultrasound image **30** may be overlaid with slice image **530**, illustrated as overlaid presentation **33** of FIG. **2**, and presented to practitioner **12** through a user interface such as display **88** of FIG. **1**. In some embodiments, 3D model **511** along with cut plane **55** identified or otherwise specified on model **511** may also be presented to practitioner **12** to provide further visual aids.

[0030] Apparently, every human body is unique. However, it is worth noting that model **511** of FIG. **1** or FIG. **2**, though being an anatomical model of patient **11**, may be a generic or universal model of a human body, rather than a model specifically tailored to patient **11** or any other particular patient. That is, even without a detailed anatomical model that is specific to a particular patient, the present disclosure enables techniques to register a medical image of the particular patient with a generic anatomical model, such that a medical practitioner is able to readily visualize a spatial relationship between the medical image and the body of the patient, which provides a huge benefit of convenience in practical applications. For example, with anatomical model

511 being a generic human body model and not required to include specific details of patient 11, practitioner 12 of FIG. 1 is still able to visualize a spatial relationship of cut plane 55 of medical image 30 in relation to anatomical model 511 of patient 11, in a real-time fashion, as practitioner 12 moves probe 81 and scans patient 11 with different orientations of probe 81 and/or at different locations in real space 20.

[0031] While anatomical model 511 being generic may provide the convenience of not requiring patient-specific details included in anatomical model 511, customization to anatomical model 511 based on certain features related to the particular patient 11 may enhance the accuracy of the registration of medical image 30 with anatomical model 511. For example, anatomical model 511 may be a generic human body model having been customized or otherwise adjusted to capture certain aspects of patient 11 such that a better matching between with anatomical model 511 and patient 11 may be achieved. In some embodiments, anatomical model 511 may include a generic human body model that is customized or adjusted according the gender, height, weight, age, or ethnicity of a particular patient 11. For example, the generic model may be adjusted or stretched longer to fit a patient that is taller than the average. More details regarding adjusting a generic model will be discussed in a later part of the present disclosure.

[0032] FIG. 3 summarizes a data flow 300 of the process described above regarding registering a medical image of a patient with a digitized 3D anatomical model of the patient such that the medical image may be rendered by a simulated slice image that is generated based on the 3D model. Specifically, processor 340 receives a medical image 310 (such as ultrasound image 30) from a probe (such as probe 81), as well as data 320 indicating a physical position of the probe with respect to the patient. Data 320 may be referred to hereinafter as "probe position data". In addition, processor 340 receives or otherwise has access to the anatomical model 330. Processor 340 subsequently renders medical image 310 with a slice image (such as slice image 530 of FIG. 2) generated based on anatomical model 330 and probe position data 320, and display the result of the slice-image-rendered medical image.

[0033] Further details of the process described above are given below along with FIGS. 4-6. In order for probe 81 to provide probe position data 320 of its physical position to processor 340, a navigation transmitter 83 is disposed in real space 20 close to where patient 11 is located, as shown in FIG. 4. Navigation transmitter 83 typically operates with either optical waves or electromagnetic (EM) waves. Using EM waves as an example, navigation transmitter 83 broadcasts the EM waves in real space 20. The EM waves, much like EM signals transmitted by satellites of a global positioning system (GPS), may contain positioning information therein. A EM wave sensor 815 that is embedded in, disposed on or otherwise attached to probe 81 may pick up or otherwise receive some of the EM waves transmitted by navigation transmitter 83. EM wave sensor 815 serves as a position transducer in this context (and maybe referred to as "position transducer" hereinafter), and generates probe position data 320 that indicates the physical position of probe 81 in real space 20 based on the EM waves it receives.

[0034] With probe position data 320 provided by position transducer 815 of probe 81, processor 340 of FIG. 3 may determine corresponding virtual position 581 of probe 81 in virtual space 50 relative to anatomical model 511 using a mapping matrix 25 as shown in FIG. 4. As mentioned above, virtual position 581 of probe 81 as defined in virtual space 50 corresponds to the physical position of probe 81 in real space 20. With mapping matrix 25, processor 340 is able to map a physical position relative to patient 11 in real space 20 to a corresponding virtual position relative to anatomical model 511 in virtual space 50. To achieve this purpose, it is also required to establish a mapping between patient 11 in real space 20 and 3D model 511 in virtual space 50, in addition to the mapping between the physical position and the virtual position of probe 81.

[0035] Although mapping matrix 25 is unique for a given pair of real space 20 and virtual space 50, mapping matrix 25 is not given or readily available to processor 340. Instead, it requires processor 340 to go through certain calibration or correlation between real space 20 and virtual space 50 using one or more mapping objects to calculate mapping matrix 25. Mapping matrix 25, as calculated, may yield a satisfactory mapping between real space 20 and virtual space 50, and more specifically, to establish the mapping between patient 11 in real space 20 and 3D model 511 in virtual space 50. Each of FIGS. 5 and 6 demonstrates a respective method of calculating mapping matrix 25 of FIG. 4 through calibration, and each method utilizes one or more mapping objects for the calibration. The calculation of mapping matrix 25 typically involves interpolation of matched positions in real space 20 and virtual space 50 related to the matching objects. Therefore, a higher number of mapping objects involved will generally enhance the performance of matching matrix 25 regarding matching real space 20 and virtual space 50.

[0036] FIG. 5 illustrates a method of calculating mapping matrix 25 of FIG. 4 through calibration using matching objects. Specifically, a few predetermined body landmarks, such as body landmarks 60 shown in FIG. 5, are used as the mapping objects. Body landmarks 60 are predetermined locations on the body of patient 11, at which probe 81 may be placed to establish a correlation between real space 20 and virtual space 50. Namely, body landmarks 60 serve as fiducial markers on the body of patient 11 for the mapping between real space 20 and virtual space 50. Typically, the locations of body landmarks 60 are related to a specific body area of patient 11 where the ultrasonography scan is to be performed. For example, for an ultrasonography scan of an area around the liver 113 of patient 11, or any other patient, the locations of body landmarks 60 may be purposefully predetermined at the lower end of sternum of patient 11, the lower end of the rib cage on the left side of the body of patient 11, as well as the lower end of the rib cage on the right side of the body of patient 11, as shown by body landmarks 602, 603 and 601 in FIG. 5, respectively.

[0037] When the calibration is performed for the calculation of matching matrix 25, probe 81 is sequentially placed on patient 11 at body landmarks 60 (i.e., body landmarks 601, 602 and 603) of FIG. 5, and corresponding virtual locations (such as a location of virtual position 581 of probe 81 as described in coordinate system 566) of the respective body landmarks 60 are located in virtual space 50 and recorded respectively. That is, probe 81 may firstly be placed at or close to body landmark 601 located at the lower end of the rib cage on the right side of the body of patient 11, and a corresponding location of body landmark 601 in virtual space 50 may be located and recorded. As an example, the three translational coordinates of virtual position 581 of

probe **81** may be recorded as the corresponding location of body landmark **601** in virtual space **50**. Next, probe **81** may be moved to body landmark **602** located at the lower end of the sternum of patient **11**, and the translational coordinates of corresponding virtual position **581** of probe **81** may be recorded as the corresponding location of body landmark **602** in virtual space **50**. Finally, probe **81** may subsequently be moved to body landmark **603** located at the lower end of the rib cage on the left side of the body of patient **11**, and the translational coordinates of corresponding virtual position **581** of probe **81** may be recorded as the corresponding location of body landmark **603** in virtual space **50**. With the corresponding locations of body landmarks **601**, **602** and **603** recorded in virtual space **50** by sequentially placing probe **81** on patient **11** at each of body landmarks **601**, **602** and **603**, processor **340** may calculate mapping matrix **25** accordingly using principles of interpolation.

[0038] In general, the more number of the body landmarks **60** are used for the calibration process described in FIG. **5**, the more accurate the mapping between real space **20** and virtual space **50** may be achieved through the calculation of mapping matrix **25**. While the calculating of mapping matrix **25** may be performed with one or two body landmarks **60** to result in an acceptable mapping accuracy, three or more body landmarks **60** are preferred. A reason for having at least three body landmarks **60** is that the three body landmarks **60** may uniquely determine a cross-section of patient **11** in real space **20**. With the three corresponding locations of the three body landmarks **60** located in virtual space **50**, a corresponding cut plane of 3D model **511** may also be uniquely determined. With the correlated cross-section of patient **11** and the corresponding cut plane uniquely determined in real space **20** and virtual space **50**, respectively, the spatial mapping between real space **20** and virtual space **50** is completed, and mapping matrix **25** of FIG. **4** can be uniquely calculated. As mentioned above, the inherent nature of interpolation used in calculating mapping matrix **25** encourages using a higher number of body landmarks **60**, which would enhance the mapping accuracy.

[0039] FIG. **6** illustrates another method of calculating mapping matrix **25** of FIG. **4** through calibration using matching objects. In this method, the mapping objects include one or more slice images of anatomical model **511** of patient **11**, called "standard slices". Each of the one or more slice images is associated with a predetermined position in virtual space **50**, called "standard position" or "standard probe position". FIG. **6** shows a standard slice **630** and a standard position **681** associated with standard slice **630**. Specifically, standard slice **630** is a slice image of model **511** perceived by probe **81** as probe **81** is placed at a physical position in real space **20** that corresponds to standard position **681** in virtual space **50**. Processor **340** of FIG. **3** is able to simulate or otherwise generate standard slice image **630** of anatomical model **511** based on standard position **681**.

[0040] Typically, a standard position is predetermined based on a specific body area of a patient where the ultrasonography scan is to be performed. For example, for an ultrasonography scan of an area around the liver of patient **11**, or any other patient, standard position **681** in virtual space **50** may be purposefully predetermined at the lower end of the rib cage on the right side of anatomical model **511** of patient **11**, with an orientation toward a liver **5113** of anatomical model **511**, as shown in FIG. **6**. Since standard slice **630** is associated with standard position **681**, as standard position **681** is purposefully predetermined, standard slice **630** is also considered predetermined.

[0041] In general, one standard position (that is, standard position **681**) and one standard slice image (that is, standard slice **630**) as shown in FIG. **6** are sufficient for the calculation of mapping matrix **25** of FIG. **4**. This is because one standard slice image typically has included enough features that, when matched between real space **20** and virtual space **50**, would facilitate calculation of a sufficiently accurate mapping matrix **25**. Nevertheless, in some embodiments, more standard positions, and thus more standard slice images associated with the standard positions, may be employed to enhance the mapping accuracy of mapping matrix **25**.

[0042] With standard slice image **630** generated based on standard position **681**, probe **81** is moved by practitioner **12** to various positions (i.e., various locations and/or orientations) on the body surface of patient **11** until probe **81** is moved to a so-called "optimal matching position" and an optimal matching is achieved. That is, with probe **81** in the optimal matching position, ultrasound image **30** substantially matches standard slice image **630** to the best ability of practitioner **12** who moves probe **81** around. Since predetermined standard position **681** associated with standard slice image **630** of FIG. **6** is located at the lower end of the rib cage on the right side of anatomical model **511**, the optimal matching position associated with standard slice image **630**, as decided by practitioner **12**, shall be quite close to a physical position in real space **20** that is around body landmark **601** of FIG. **5**, which is located at the lower end of the rib cage on the right side of patient **11**. Should practitioner **12** move probe **81** to another physical position of real space **20** farther from body landmark **601**, such as a physical position near body landmark **602** or body landmark **603**, the resulted ultrasound image **30** would not match closely to standard slice image **630**, and thus the physical position near body landmark **602** or **603** would not be the optimal matching position for standard slice image **630** associated with standard position **681**.

[0043] Once the optimal matching position associated with standard position **681** is determined as described above, data indicating the optimal matching position, as detected by navigation transmitter **83** and position transducer **815**, may then be sent to processor **340** from probe **81**. Processor **340** thereby calculates mapping matrix **25** based on the data indicating the optimal matching position. Similar to the other method of calculating matching matrix **25** using body landmarks **60** of FIG. **5**, the more the standard slice images are used for the calibration process described with FIG. **6**, the more accurate the mapping between real space **20** and virtual space **50** may be achieved through the calculation of mapping matrix **25**. Namely, although the calculating of mapping matrix **25** may be performed with one single standard slice image **630** and the associated optimal matching position and result in an acceptable mapping accuracy, use of more standard splice images is preferred. Due to the inherent nature of interpolation used in calculating mapping matrix **25**, a higher number of standard slice image would enhance the mapping accuracy.

[0044] FIG. **7** illustrates an example apparatus, image registering apparatus **700**, in accordance with an embodiment of the present disclosure. Apparatus **700** may perform various functions related to techniques, methods and sys-

tems described herein, including those described above with FIGS. **1-6**, as well as those described below with respect to process **800** of FIG. **8**. Apparatus **700** may include at least some of the components of processor **340** of FIG. **3**.

[0045] Referring to FIG. **7**, human health evaluation apparatus **700** may include processor **780** and memory **782**. Memory **782** may store data **7821** that represents medical images such as medical image **310** of FIG. **3** or ultrasound image **30** of FIGS. **1** and **2**. Memory **782** may also store data **7822** that represents anatomical model **511** of FIGS. **1**, **2**, **4** and **6**, or anatomical model **330** of FIG. **3**. Memory **782** may also store data **7823** that represents body landmarks **60** of FIG. **5**. Memory **782** may further store data **7824** that represents standard probe positions such as standard probe position **681** of FIG. **6**. Memory **782** may be implemented by any suitable technology and may include volatile memory and/or non-volatile memory. For example, memory **782** may include a type of random access memory (RAM) such as dynamic RAM (DRAM), static RAM (SRAM), thyristor RAM (T-RAM) and/or zero-capacitor RAM (Z-RAM). Alternatively or additionally, memory **782** may include a type of read-only memory (ROM) such as mask ROM, programmable ROM (PROM), erasable programmable ROM (EPROM) and/or electrically erasable programmable ROM (EEPROM). Alternatively or additionally, memory **782** may include a type of non-volatile random-access memory (NVRAM) such as flash memory, solid-state memory, ferroelectric RAM (FeRAM), magnetoresistive RAM (MRAM) and/or phase-change memory.

[0046] Processor **780** of human health evaluation apparatus **700** may be an embodiment of processor **340** of FIG. **3**. In one aspect, processor **780** may be implemented in the form of one or more single-core processors, one or more multi-core processors, or one or more CISC processors. That is, even though a singular term "a processor" is used herein to refer to processor **780**, processor **780** may include multiple processors in some implementations and a single processor in other implementations in accordance with the present disclosure. In another aspect, processor **780** may be implemented in the form of hardware (and, optionally, firmware) with electronic components including, for example and without limitation, one or more transistors, one or more diodes, one or more capacitors, one or more resistors, one or more inductors, one or more memristors and/or one or more varactors that are configured and arranged to achieve specific purposes in accordance with the present disclosure. In other words, in at least some implementations, processor **780** is a special-purpose machine specifically designed, arranged and configured to perform specific tasks including registering a medical image with a living body model in accordance with various implementations of the present disclosure.

[0047] Processor **780**, as a special-purpose machine, may include non-generic and specially-designed hardware circuits that are designed, arranged and configured to perform specific tasks pertaining to registering a medical image of a patient in a physical space with an anatomical model defined in a simulation-generated space in accordance with various implementations of the present disclosure. In one aspect, processor **780** may include a space mapping circuit **7801** that performs specific tasks and functions to calculate a mapping matrix (such as mapping matrix **25** of FIG. **4**) between the physical space (such as real space **20**) and the simulation-generated space (such as virtual space **50**). For instance, space mapping circuit **7801** may be configured to use either body landmarks **60** of FIG. **5** or standard slice image **630** of FIG. **6** as mapping objects to calculate mapping matrix **25** of FIG. **4**. In one aspect, processor **780** may include a physical position tracking circuit **7802** that performs specific tasks and functions to receive data indicating a physical position of probe **81** of FIG. **1** in the physical space. For instance, physical position tracking circuit **7802** may be configured to receive data from position transducer **815** embedded in probe **81** of FIG. **4**, with the data indicating the physical position of probe **81** relative to patient **11** in real space **20**. In one aspect, processor **780** may also include a virtual position calculation circuit **7803** that performs specific tasks and functions to determine a virtual position of probe **81** relative to the anatomical model in virtual space **50**. For instance, virtual position calculation circuit **7803** may be configured to determine virtual position **581** of probe **81** relative to anatomical model **511** in virtual space **50** of FIG. **4** based on mapping matrix **25** that is calculated by space mapping circuit **7801**. In one aspect, processor **780** may further include a cut plane calculation circuit **7804** that performs specific tasks and functions to determine a cut plane of the anatomical model based on a virtual position, with the medical image representing an anatomical cross-section of the patient at the cut plane. For instance, cut plane calculation circuit **7804** may be configured to determine cut plane **55** of anatomical model **511** of FIG. **4** based on virtual position **581** thereof.

[0048] Processor **780**, as a special-purpose machine, may include non-generic and specially-designed hardware circuits that are designed, arranged and configured to perform specific tasks pertaining to registering a medical image of a patient in a physical space with an anatomical model defined in a simulation-generated space in accordance with various implementations of the present disclosure. In one aspect, processor **780** may include a slice image generation circuit **7805** that performs specific tasks and functions to generate a slice image based on the virtual position of the probe and the anatomical model. For instance, slice image generation circuit **7805** may be configured to generate slice image **530** of FIG. **2** based on virtual position **581** and anatomical model **511** thereof. Slice image generation circuit **7805** may also be configured to generate standard slice image **630** of FIG. **6** based on predetermined standard position **681** and anatomical model **511** which includes liver **5113**. In one aspect, processor **780** may also include a display image rendering circuit **7806** that performs specific tasks and functions to display the medical image overlaid with the slice image generated by slice image generation circuit **7805**. Additionally, display image rendering circuit **7806** may also display or generate a 3D image of the anatomical model with the cut plane, as determined by cut plane calculation circuit **7804**, identified on the 3D image. Moreover, display image rendering circuit **7806** may further display a name of an organ, a tissue, a structure or an anatomical part on the medical image and/or the slice image. For instance, display image rendering circuit **7806** may be configured to display overlaid presentation **33** having ultrasound image **30** overlaid with slice image **530** as shown in FIG. **2**. Alternatively or additionally, display image rendering circuit **7806** may also be configured to display a 3D image of anatomical model **511**, with cut plane **55** identified thereon, as shown in FIG. **2**.

[0049] Processor **780**, as a special-purpose machine, may include non-generic and specially-designed hardware circuits that are designed, arranged and configured to perform specific tasks pertaining to registering a medical image of a patient in a physical space with an anatomical model defined in a simulation-generated space in accordance with various implementations of the present disclosure. In one aspect, processor **780** may include a model adjusting circuit **7807** that performs specific tasks and functions to adjust the anatomical model based on some adjustment parameters that are specific to either the patient or a probe that generates the medical image. For instance, model adjusting circuit **7807** may be configured to customize anatomical model **511** of FIGS. **1-4** or anatomical model **330** of FIG. **6** according to some adjustment parameters. The adjustment parameters are further explained below.

[0050] In some embodiments, anatomical model **511** or **330** of FIGS. **1-4** and **6** may be a generic model without features or characteristics specific to a particular patient. However, in order to better model a particular patient, in some embodiments, the generic model may be customized using a few adjustment parameters that may reflect certain features or characteristics of the particular patient, and subsequently serve as anatomical model **511** of FIGS. **1-4** or anatomical model **330** of FIG. **6**. The adjustment parameters may include characteristics of the particular patient, such as gender, height, weight, age, ethnicity, and the like.

[0051] Moreover, probe **81** may have a few probe parameters or operation states that can be set or changed by practitioner **12** to obtain different field of view of ultrasound image **30**, even without changing the position (i.e., the location and/or the orientation) of probe **81**. Through the probe parameters or operation states, the image depth (i.e., the distance of the cut plane from the probe) may be adjusted. In addition, the zoom factor of the image (i.e., the coverage of the body cross-section represented by the medical image at the cut plane) may also be adjusted for probe **81** in generating ultrasound image **30**. Namely, probe parameters and operation states such as image depth and zoom factor are specific to ultrasound image **30** generated by probe **81**. To achieve a better correlation between ultrasound image **30** and anatomical model **511**, anatomical model **511** may not directly employ a generic model of patient **11**. Rather, anatomical model **511** may employ the generic model adjusted or otherwise customized by model adjusting circuit **7807** according to image-specific parameters described above, such as settings of image depth or zoom factor of probe **81**.

[0052] In some embodiments, apparatus **700** may include a probe **781** (such as probe **81** of FIGS. **1**, **4** and **5**), movable in the physical space (such as real space **20**), as well as a navigator transmitter **783** (such as navigator transmitter **83** of FIG. **4**) so as to track movement of probe **781** in the physical space (such as real space **20**). Probe **781** may include a position transducer **7815** (such as position transducer **815** of FIG. **4**) that is embedded in or otherwise attached to probe **781**. In some embodiments, apparatus **700** may also include a communication device **785** capable of wirelessly transmitting and receiving data. For example, communication device **785** may be used by processor **780** to remotely access a data server and receive, transmit or update data **7821**, **7822**, **7823** and **7824** that may be stored in memory **782**. In some embodiments, communication device **785** may also be used by processor **780** to transmit rendered medical images generated by display image rendering circuit **7806** to a display accessible by another medical practitioner located at a remote location for analysis or diagnosis. In some embodiments, apparatus **700** may further include a user interface **788** (such as monitor or display **88** of FIG. **1**) for showing the rendered medical images to the patient or a local medical practitioner.

[0053] FIG. **8** illustrates an example process **800**, in accordance with the present disclosure, for registering a medical image of a patient in a physical space with an anatomical model of the patient defined in a simulation-generated space. Process **800** may include one or more operations, actions, or functions shown as blocks such as **810**, **820**, **830**, **840**, and **850**. Although illustrated as discrete blocks, various blocks of process **800** may be divided into additional blocks, combined into fewer blocks, or eliminated, depending on the desired implementation. Process **800** may be realized by image registering apparatus **700** of FIG. **7**. Process **800** may begin with block **810**.

[0054] At **810**, process **800** may involve a processor (such as processor **340** of FIG. **3** or processor **780** of FIG. **7**) calculating a mapping matrix (such as mapping matrix **25** of FIG. **4**) between a real space (such as real space **20**) and a virtual space (such as virtual space **50**) using one or more mapping objects (such as body landmarks **60** of FIG. **5** or standard splice image **630** of FIG. **6**). The real space is a physical space in which the patient (such as patient **11** of FIG. **4**) is located, whereas the virtual space is a simulation-generated space in which the anatomical model (such as model **511** of patient **11**) is defined. Process **800** may proceed from **810** to **820**.

[0055] At **820**, process **800** may involve the processor receiving data indicating a physical position of a probe (such as probe **81** of FIG. **4**) relative to the patient. The probe may be an ultrasonography transducer that generates an ultrasonography image of the patient as the medical image. The probe may be provided with a position transducer (such as position transducer **815** of FIG. **4**) integrated with the probe. The position transducer may operate by receiving a EM wave transmitted by a navigation transmitter (such as navigation transmitter **83** of FIG. **4**) disposed in the real space. Process **800** may proceed from **820** to **830**.

[0056] At **830**, process **800** may involve the processor determining a virtual position (such as virtual position **581** of FIG. **4**) of the probe in the virtual space relative to the anatomical model based on the mapping matrix determined in block **810**. Specifically, the virtual position as defined in the virtual space corresponds to the physical position of the probe in the real space. Process **800** may proceed from **830** to **840**.

[0057] At **840**, process **800** may involve the processor determining a cut plane (such as cut plane **55** of FIG. **4**) of the anatomical model based on the virtual position determined in block **830**. The medical image represents an anatomical cross-section of the patient at the cut plane. Process **800** may proceed from **840** to **850**.

[0058] At **850**, process **800** may involve the processor generating a slice image (such as slice image **530** of FIG. **2**) based on the virtual position of the probe, as determined in block **830**, and the anatomical model. The slice image may represent an anatomical cross-section of the anatomical model at the cut plane as determined in block **840**. At **850**, process **800** may also involve the processor rendering the medical image with the slice image for display. In some

embodiments, the rendering of the medical image with the slice image may involve the processor overlaying the slice image with the medical image to generate an overlaid presentation (such as overlaid presentation **33** of FIG. **2**). The overlaid presentation may be shown by the processor on a display device (such as display **88** of FIG. **1**). In some embodiments, the rendering of the medical image with the slice image may involve the processor presenting the splice image side-by-side with the medial image. In some embodiments, the rendering of the medical image with the slice image may involve the processor generating a 3D image of the anatomical model with the cut plane identified on the 3D image. The 3D image along with the cut plane identified on the 3D image may be shown by the processor on a display device (such as display **88** of FIG. **1**). In some embodiments, the rendering of the medical image with the slice image may also involve the processor labeling a name of an organ, a tissue, a structure, an anatomical part or a body landmark on the medical image and/or the slice image.

[0059] The present disclosure has been described in sufficient details with a certain degree of particularity. It is understood to those skilled in the art that the present disclosure of embodiments has been made by way of examples only and that numerous changes in the arrangement and combination of parts may be resorted without departing from the spirit and scope of the present disclosure as claimed. Accordingly, the scope of the present disclosure is defined by the appended claims rather than the foregoing description of embodiments.

Additional Notes

[0060] The herein-described subject matter sometimes illustrates different components contained within, or connected with, different other components. It is to be understood that such depicted architectures are merely examples, and that in fact many other architectures can be implemented which achieve the same functionality. In a conceptual sense, any arrangement of components to achieve the same functionality is effectively "associated" such that the desired functionality is achieved. Hence, any two components herein combined to achieve a particular functionality can be seen as "associated with" each other such that the desired functionality is achieved, irrespective of architectures or intermedial components. Likewise, any two components so associated can also be viewed as being "operably connected", or "operably coupled", to each other to achieve the desired functionality, and any two components capable of being so associated can also be viewed as being "operably couplable", to each other to achieve the desired functionality. Specific examples of operably couplable include but are not limited to physically mateable and/or physically interacting components and/or wirelessly interactable and/or wirelessly interacting components and/or logically interacting and/or logically interactable components.

[0061] Further, with respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

[0062] Moreover, it will be understood by those skilled in the art that, in general, terms used herein, and especially in the appended claims, e.g., bodies of the appended claims, are generally intended as "open" terms, e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc. It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to implementations containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an," e.g., "a" and/or "an" should be interpreted to mean "at least one" or "one or more;" the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number, e.g., the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations. Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention, e.g., "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc. In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention, e.g., "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc. It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

[0063] From the foregoing, it will be appreciated that various implementations of the present disclosure have been described herein for purposes of illustration, and that various modifications may be made without departing from the scope and spirit of the present disclosure. Accordingly, the various implementations disclosed herein are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

What is claimed is:

1. A method of registering a medical image of a patient with an anatomical model of the patient, comprising:

calculating, by a processor, a mapping matrix between a real space and a virtual space using one or more mapping objects, the real space being a physical space

in which the patient is located, the virtual space being a simulation-generated space in which the anatomical model is defined;

receiving, by the processor, data indicating a physical position of a probe relative to the patient, the probe generating the medical image, the physical position being defined in the real space;

determining, by the processor, a virtual position of the probe in the virtual space relative to the anatomical model based on the mapping matrix such that the virtual position as defined in the virtual space corresponds to the physical position in the real space; and

determining, by the processor, a cut plane of the anatomical model based on the virtual position, the medical image representing an anatomical cross-section of the patient at the cut plane.

2. The method of claim **1**, wherein:

the probe comprises an ultrasonography transducer,

the medical image comprises a two-dimensional (2D) ultrasonography cross-section, and

the anatomical model comprises a three-dimensional (3D) digital model of an organ, a tissue, a structure or an anatomical part.

3. The method of claim **1**, wherein the probe is provided with a position transducer integrated with the probe to generate and track the physical position of the probe.

4. The method of claim **1**, wherein:

the one or more mapping objects comprise three or more predetermined body landmarks of the patient,

the calculating of the mapping matrix comprises sequentially locating each of the three or more body landmarks in the virtual space with the probe sequentially placed on the patient at each of the three or more body landmarks in the real space.

5. The method of claim **1**, wherein:

the one or more mapping objects comprise one or more predetermined slice images of the anatomical model each generated by the processor based on a respective predetermined position of the probe in the virtual space, and

the calculating of the mapping matrix comprises, for a respective one of the one or more predetermined slice images, receiving data indicating a corresponding physical position of the probe at which the probe generates a respective medical image of the patient that substantially matches the respective one of the one or more predetermined slice images.

6. The method of claim **1**, wherein:

the probe is movable in the real space both translationally and rotationally,

the physical position comprises a location and an orientation of the probe in the real space, and

the virtual position comprises a location and an orientation of the probe in the virtual space.

7. The method of claim **1**, further comprising:

generating, by the processor, a three-dimensional (3D) image of the anatomical model with the cut plane identified on the 3D image.

8. The method of claim **1**, further comprising:

generating, by the processor, a slice image based on the virtual position of the probe and the anatomical model, the slice image representing an anatomical cross-section of the anatomical model at the cut plane; and

rendering, by the processor, the medical image with the slice image.

9. The method of claim **8**, wherein the rendering of the medical image with the slice image comprises overlaying the slice image with the medical image.

10. The method of claim **8**, further comprising:

labeling a name of an organ, a tissue, a structure or an anatomical part on one or both of the medical image and the slice image based on the anatomical model.

11. The method of claim **1**, wherein the anatomical model comprises a generic model customized with one or more adjustment parameters specific to the patient, and wherein the one or more adjustment parameters comprise one or more of a gender, a height, a weight, an ethnicity, and an age of the patient.

12. The method of claim **1**, wherein the anatomical model comprises a generic model customized with one or more adjustment parameters specific to the medical image, and wherein the one or more adjustment parameters comprise one or more of an image depth of the medical image and a zoom factor of the medical image.

13. An apparatus that registers a medical image of a patient with an anatomical model of the patient, comprising:

a memory capable of storing data representing the medical image and data representing the anatomical model; and

a processor, comprising:

a space mapping circuit to calculate a mapping matrix between a real space and a virtual space using one or more mapping objects, the real space being a physical space in which the patient is located, the virtual space being a simulation-generated space in which the anatomical model is defined;

a physical position tracking circuit to receive data indicating a physical position of a probe relative to the patient, the probe generating the medical image, the physical position being defined in the real space;

a virtual position calculation circuit to determine a virtual position of the probe in the virtual space relative to the anatomical model based on the mapping matrix such that the virtual position as defined in the virtual space corresponds to the physical position in the real space; and

a cut plane calculation circuit to determine a cut plane of the anatomical model based on the virtual position, the medical image representing an anatomical cross-section of the patient at the cut plane.

14. The apparatus of claim **13**, wherein the processor further comprises:

a display image rendering circuit to generate a three-dimensional (3D) image of the anatomical model with the cut plane identified on the 3D image, display the 3D image with the cut plane identified on the 3D image, and display a name of an organ, a tissue, a structure or an anatomical part on the 3D image.

15. The apparatus of claim **13**, wherein the operations further comprise:

a slice image generation circuit to generate a slice image based on the virtual position of the probe and the anatomical model, the slice image representing an anatomical cross-section of the anatomical model at the cut plane;

a display image rendering circuit to display the medical image overlaid with the slice image and display a name

of an organ, a tissue, a structure or an anatomical part on one or both of the medical image and the slice image.

16. The apparatus of claim **15**, further comprising:

a user interface to display the medical image overlaid with the slice image; and

a communication device to receive or transmit the data representing the medical image, the data representing the anatomical model, data representing the slice image, or a combination thereof.

17. The apparatus of claim **13**, further comprising:

a navigation transmitter disposed in a vicinity of the patient to transmit an optical or electromagnetic signal received by the probe; and

the probe, wherein the probe is provided with a position transducer integrated with the probe to generate and track the physical position of the probe based on the optical or electromagnetic signal.

18. The apparatus of claim **13**, wherein:

the one or more mapping objects comprise three or more predetermined body landmarks of the patient,

the space mapping circuit calculates the mapping matrix by sequentially locating each of the three or more body landmarks in the virtual space with the probe sequentially placed on the patient at each of the three or more body landmarks in the real space.

19. The apparatus of claim **13**, wherein:

the one or more mapping objects comprise one or more predetermined slice images of the anatomical model each generated by the processor based on a respective predetermined position of the probe in the virtual space, and

the space mapping circuit calculates the mapping matrix by, for a respective one of the one or more predetermined slice images, receiving data indicating a corresponding physical position of the probe at which the probe generates a respective medical image of the patient that substantially matches the respective one of the one or more predetermined slice images.

20. The apparatus of claim **13**, wherein:

the probe is movable in the real space both translationally and rotationally,

the physical position comprises a location and an orientation of the probe in the real space, and

the virtual position comprises a location and an orientation of the probe in the virtual space.

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专利名称(译)	用解剖模型登记实时医学图像的方法和装置		
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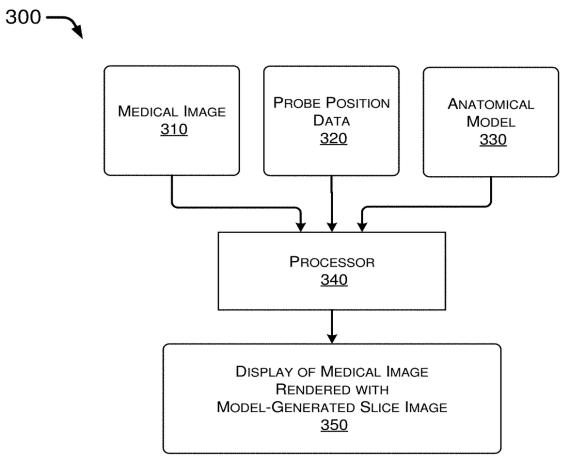
摘要(译)

描述了与用患者的解剖模型登记患者的医学图像有关的技术和示例。装置的处理器可以使用一个或多个映射对象来计算真实空间和虚拟空间之间的映射矩阵。处理器可以接收指示探针相对于患者的物理位置的数据。处理器随后可以基于映射矩阵确定虚拟空间中探测器的虚拟位置，使得虚拟空间中定义的虚拟位置对应于真实空间中的物理位置。然后，处理器可以确定解剖模型的切割平面，其中医学图像可以表示切割平面处的患者的解剖学横截面。