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(54) **JOINT ULTRASOUND IMAGING SYSTEM AND METHOD**

(71) Applicant: **General Electric Company**, Schenectady, NY (US)

(72) Inventors: **Xiaodong Han**, ShangHai (CN); **Menachem Halmann**, Wauwatosa, WI (US); **Kun Tao**, ShangHai (CN); **Zhenyu Liu**, WuXi (CN); **Gang Cheng**, ShangHai (CN); **Dongqing Chen**, Wauwatosa, WI (US); **Hong Wang**, ShangHai (CN)

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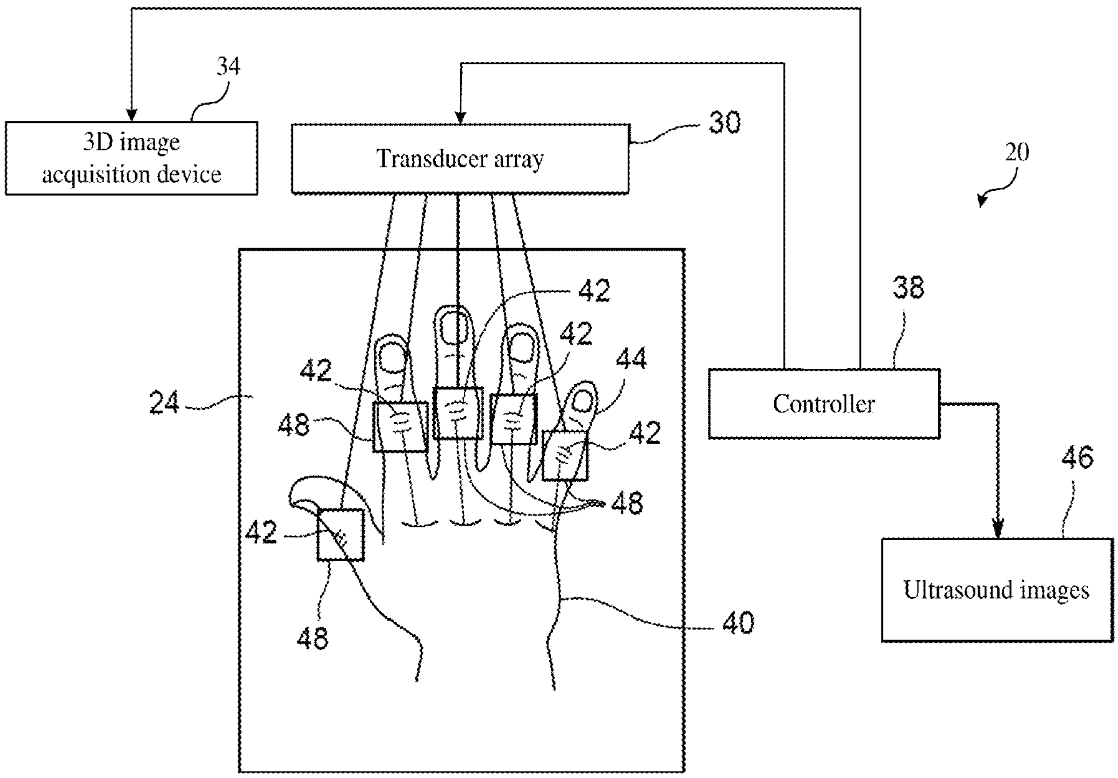
(57) **ABSTRACT**

An ultrasound imaging system includes a scanning assembly, a three-dimensional (3D) image acquisition device, and a controller. The scanning assembly is configured to receive a hand or foot and includes a transducer array and an acoustic coupling fluid. The 3D image acquisition device is configured for obtaining a 3D image of the hand or foot. The controller is configured for automatically adjusting direction or orientation of the transducer array with respect to the hand or foot based on the 3D image of the hand or foot.



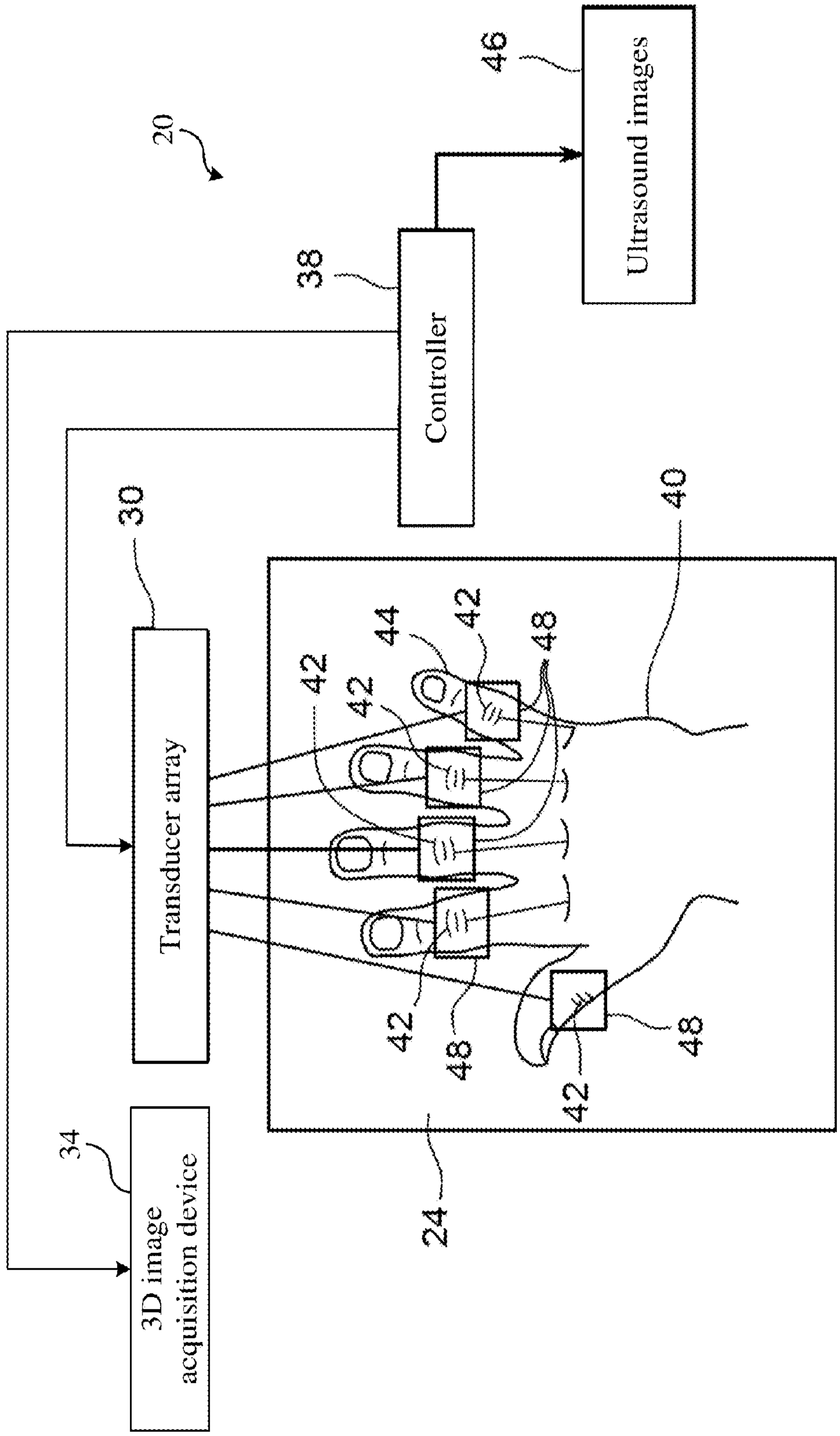

20
46
Ultrasound images
38
Controller
30
Transducer array
40
44
42
48
34
3D image acquisition device
24

FIG. 1

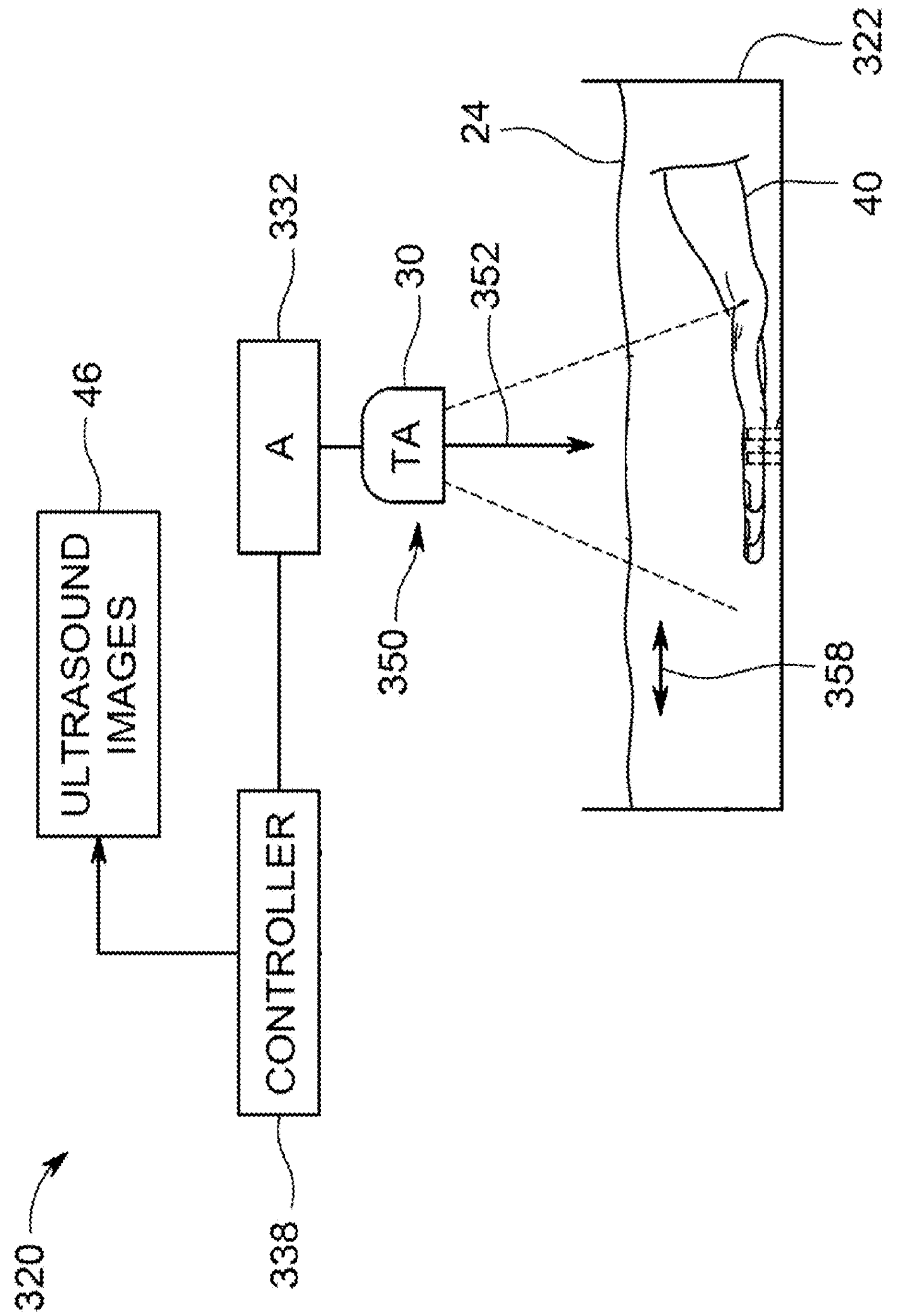

320
ULTRASOUND IMAGES
46
CONTROLLER
338
A
332
TA
30
350
352
24
40
322
358

FIG. 2

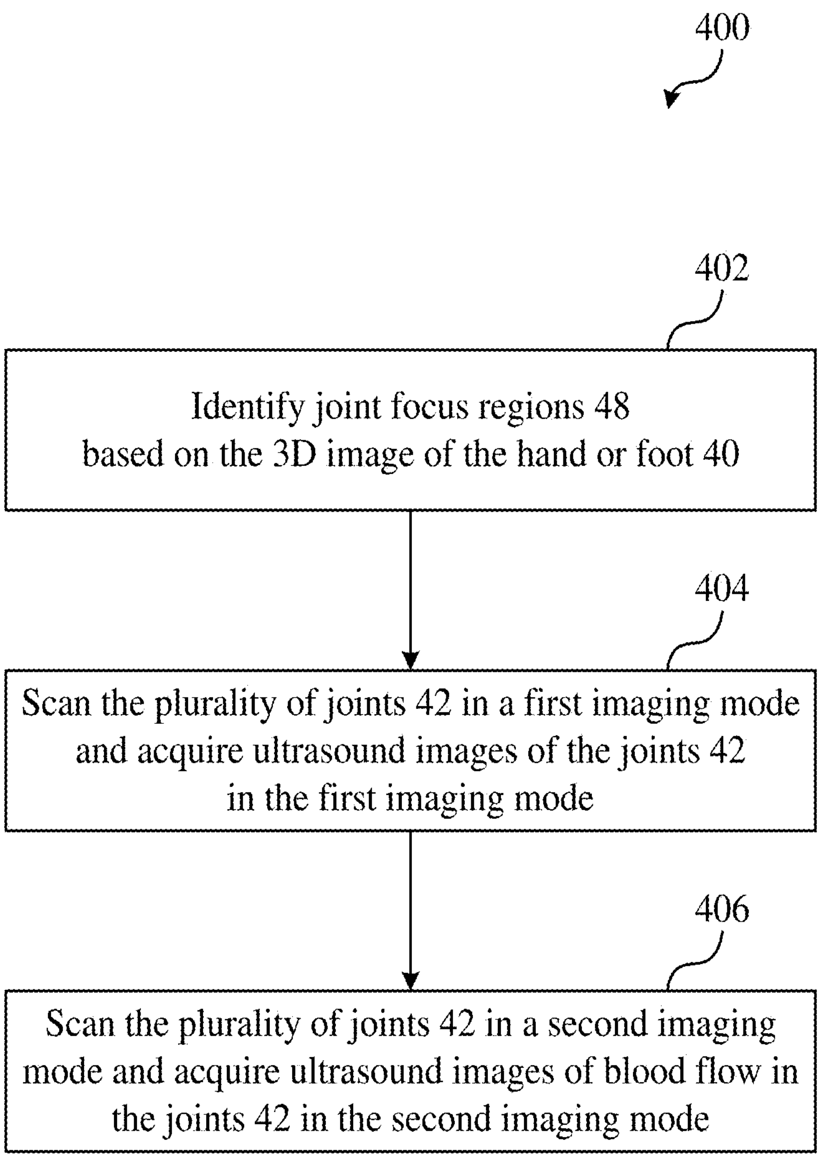

400
402
Identify joint focus regions 48 based on the 3D image of the hand or foot 40
404
Scan the plurality of joints 42 in a first imaging mode and acquire ultrasound images of the joints 42 in the first imaging mode
406
Scan the plurality of joints 42 in a second imaging mode and acquire ultrasound images of blood flow in the joints 42 in the second imaging mode

FIG. 3

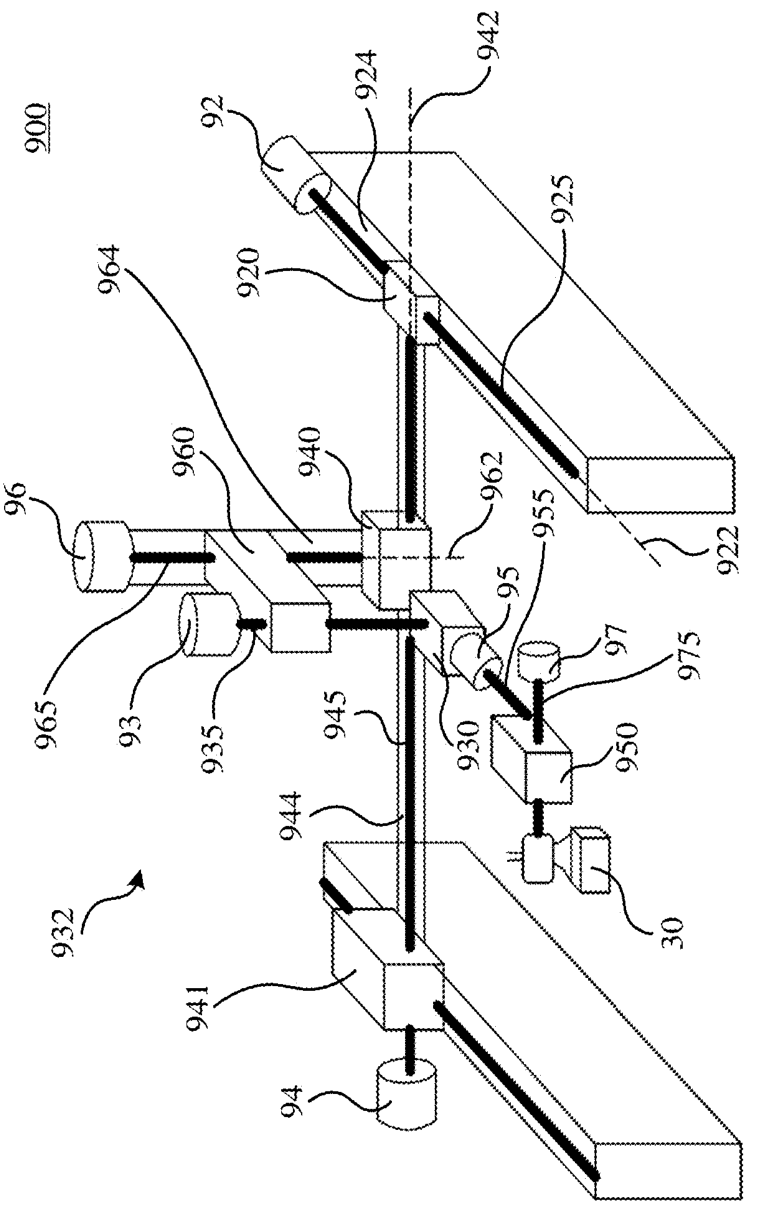

900
92
924
942
920
925
964
960
940
962
955
96
95
97
975
922
965
93
935
945
930
950
944
932
30
941
94

FIG. 4

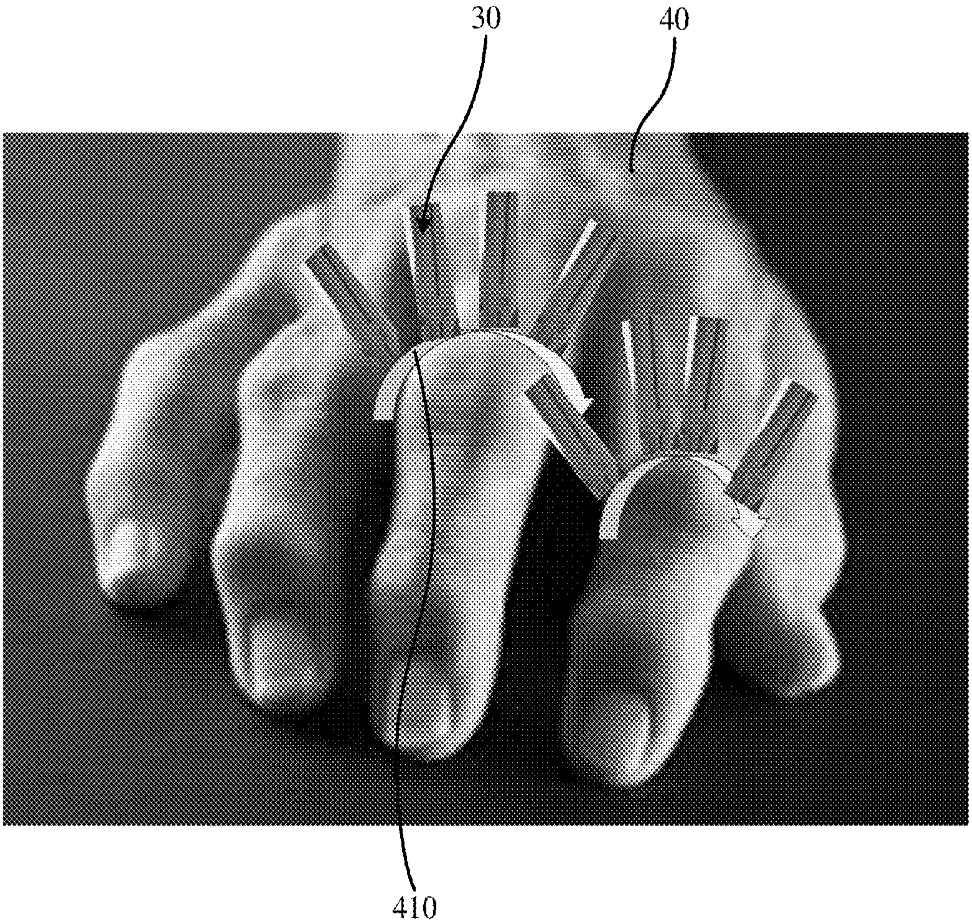


FIG. 5

JOINT ULTRASOUND IMAGING SYSTEM AND METHOD

BACKGROUND

[0001] The field of the disclosure relates generally to joint ultrasound imaging systems and methods and, more particularly, to an automated joint ultrasound imaging system and method.

[0002] In many circumstances, it is beneficial to obtain ultrasound images of joints such as when diagnosing hand or foot injuries or when the joints become inflicted with a disease such as rheumatoid arthritis or gout. With current methods and systems, it is often difficult to capture ultrasound images of such joints in a consistent and efficient manner

[0003] Therefore, there is a need for an improved joint ultrasound imaging system and method to address the aforementioned issues.

BRIEF DESCRIPTION

[0004] In accordance with one or more embodiments disclosed herein, an ultrasound imaging system includes a scanning assembly, a three-dimensional (3D) image acquisition device, and a controller. The scanning assembly is configured to receive a hand or foot and includes a transducer array and an acoustic coupling fluid. The 3D image acquisition device is configured for obtaining a 3D image of the hand or foot. The controller is configured for automatically adjusting direction or orientation of the transducer array with respect to the hand or foot based on the 3D image of the hand or foot.

DRAWINGS

[0005] These and other features, aspects, and advantages of the present disclosure will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0006] FIG. **1** is a schematic view of a joint ultrasound imaging system in accordance with one exemplary embodiment of the present invention.

[0007] FIG. **2** is a schematic view of a joint ultrasound imaging system in accordance with another exemplary embodiment of the present invention.

[0008] FIG. **3** is a flow diagram of a method for imaging the joints of the hand or foot in accordance with an exemplary embodiment of the present invention.

[0009] FIG. **4** is a schematic view of the actuator in accordance with another exemplary embodiment of the present invention.

[0010] FIG. **5** is a schematic view showing the transducer array that is perpendicular to a tangent plane of the hand or foot surface.

DETAILED DESCRIPTION

[0011] In an effort to provide a concise description of these embodiments, not all features of an actual implementation are described in one or more specific embodiments. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another.

[0012] Unless defined otherwise, technical and scientific terms used herein have the same meaning as is commonly understood by one of ordinary skill in the art to which this disclosure belongs. The terms "first," "second," and the like, as used herein do not denote any order, quantity, or importance, but rather are used to distinguish one element from another. Also, the terms "a" and "an" do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced items. The term "or" is meant to be inclusive and mean either any, several, or all of the listed items. The use of "including," "comprising," or "having" and variations thereof herein are meant to encompass the items listed thereafter and equivalents thereof as well as additional items. The terms "connected" and "coupled" are not restricted to physical or mechanical connections or couplings, and can include electrical connections or couplings, whether direct or indirect. The terms "circuit," "circuitry," and "controller" may include either a single component or a plurality of components, which are either active and/or passive components and may be optionally connected or otherwise coupled together to provide the described function.

[0013] FIG. **1** is a schematic view of a joint ultrasound imaging system **20** in accordance with one exemplary embodiment of the present invention. As described hereafter, the joint ultrasound imaging system **20** consistently captures ultrasound images of joints in an efficient manner. In the example illustrated, the joint ultrasound imaging system **20** includes a scanning assembly comprising a fluid **24**, a transducer array **30**, a three-dimensional (3D) image acquisition device **34** and a controller **38**.

[0014] The fluid **24** includes a volume of fluid which serves as an acoustic coupling between a person's hand or foot **40** and the transducer array **30**. In one implementation, the fluid **24** includes a bath of water in which the hand or foot **40** is immersed during scanning by the transducer array **30** of the imaging system **20**. In other implementations, the fluid **24** may include other forms of a fluid, such as other forms of a liquid, gel or the like, which serve as an acoustic coupling between the hand or foot **40** and the transducer array **30**.

[0015] The transducer array **30** includes an array of transducers that output signals to facilitate the acquisition of ultrasound images of the joints of the hand or foot **40**. In the example illustrated, the transducer array **30** includes quartz crystals, piezoelectric crystals, that change shape in response to the application electrical current so as to produce vibrations or sound waves. Likewise, the impact of sound or pressure waves upon such crystals produce electrical currents. As a result, such crystals are used to send and receive sound waves. Each of the transducers of the transducer array **30** may additionally include a sound absorbing substance to eliminate back reflections and an acoustic lens to focus emitted sound waves. In other embodiments, the acoustic lens may not be included in each of the transducers of the transducer array **30**.

[0016] The 3D image acquisition device **34** is configured to obtain a 3D image of the hand or foot **40**. In the exemplary embodiment, the 3D image acquisition device **34** may include a 3D camera or a 3D coordinate measuring device for example. The controller **38** is configured to identify location of the joint **42** based on the 3D image of the hand or foot **40**. As described herein, the joint **42** can be the finger joint of the hand or the toe joint of the foot.

[0017] The controller **38** includes a processor or a processing unit that utilizes the identified locations of the finger joints **42** of the hand **40** or the toe joints of the foot to control the operation and/or positioning of the transducer array **30**.

[0018] The controller **38** controls the operation and/or positioning of the transducer array **30** so as to generate joint ultrasound images **46** of the focus regions **48**, which are less than the entire area of the hand or foot **40**. Each focus region **48** serves as a window from which the ultrasound images of the joints are taken. In one implementation, the controller **38** controls the operation and/or positioning of the transducer array **30** such that ultrasound pulses are directed at and/or from just those focus regions **48**, wherein ultrasound pulses are not directed at regions outside of the focus regions **48** and/or are not received from regions of the hand or foot **40** outside of the focus regions **48**. In another implementation, the controller **38** controls the operation and/or positioning of the transducer array **30** such that the transducer array **30** directs ultrasound pulses at and receives ultrasound pulses with respect to portions of the hand or foot **40** that are larger than the focus regions **48**, but where the transducer array **30** operates differently with respect to the focus regions **48** as compared to portions of the hand or foot **40** outside of the focus regions **48**. For example, in one implementation, the controller **38** controls the transducer array **30** such that a higher density, closer spacing or greater frequency of ultrasound pulses is directed at and received from the focus regions **48** as compared to portions of the hand or foot **40** outside of the focus regions **48**. In one implementation, each of the focus regions **48** has an area less than or equal to **9** square centimeters. In one implementation, each of the focus regions **48** has a width of less than or equal to 3 cm.

[0019] In one implementation, the controller **38** adjusts the positioning of the transducer array **30** based upon identified locations of the joints **42**. For example, in one implementation, the controller **38** outputs control signals which cause an actuator to move the transducer array **30** so as to focus ultrasound imaging on the focus regions **48** extending about the identified locations of the joints **42**.

[0020] The controller **38** uses the identified locations of the joints **42** to generate or establish a focus region **48** about each of the joints **42**, wherein the controller **38** outputs control signal to locate the transducer array **30** in closer proximity to the hand or foot **40** and to move the transducer array **30** between different positions in close proximity to each of the focus regions **48**. For example, in one implementation, once the location of the joints **42** have been determined and the focus regions **48** have been generated for each of the determined locations of the joints **42**, the controller **38** generates control signals directing an actuator to move the transducer array **30** at a greater first locating speed into close proximity with the hand or foot **40** and adjacent to the focus region **48** over the joint **42** of the person's thumb. In one implementation, the controller **38** generates control signals directing the actuator to move the transducer array **30** at a slower second imaging speed to scan across the focus region **48** over the joint **42** of the person's thumb. Once ultrasound images are acquired for the focus region **48** across the joint **42** of the thumb, the controller **38** generates control signals directing the actuator to move the transducer array **30** at the greater first locating speed to a location adjacent the next focus region to be imaged. This process is repeated until joint ultrasound images **46** have been completed for each of the joints **42** to be imaged. The acquired joint ultrasound images **46** are stored in memory. In one implementation, the acquired joint focus ultrasound images **46** are further displayed.

[0021] Because the controller **38** utilizes the determined locations of the joints **42** to form the focus regions **48** and because the controller **38** focuses the transducer array **30** on just those focus regions **48**, rather than the entire hand or foot **40**, imaging time is reduced and efficiency is increased. As a result, additional time may be spent on such focus regions **48** to increase the amount of imaging data acquired for the joints **42**. In implementations where the controller **38** repositions the transducer array **30** at each of the focus regions **48** by moving the transducer array **30** at different speeds, a first greater speed when moving between the focus regions **48** and a second slower speed when scanning across each focus region **48**, imaging time is reduced and efficiency is increased.

[0022] Although the example illustrated in FIG. **1** illustrates each focus region **48** as being square in shape, in other implementations, each focus region **48** may have other shapes, such as a circular shape, and oval shape or the like. In one implementation, the shape of each focus region **48** corresponds to a general outline of the area of the hand or foot **40** constituting the joint **42**. Although the example of FIG. **1** illustrates each focus region **48** as having the same size across each of the joints **42** of the hand or foot **40**, in other implementations, the focus regions **48** have different sizes and/or different shapes amongst the different joints **42** of the hand or foot **40**.

[0023] FIG. **2** is a schematic view of a joint ultrasound imaging system **320**, another example of the joint ultrasound imaging system **20**, in accordance with another exemplary embodiment of the present invention. The joint ultrasound imaging system **320** includes a fluid container **322**, fluid **24**, a transducer array **30**, an actuator **332**, and a controller **338**. The fluid container **322** includes a receptacle for containing the fluid **24** (described above). The fluid container **322** is sized and configured to receive the hand or foot **40** such that the hand or foot **40** is immersed within the fluid **24**.

[0024] The actuator **332** includes a mechanism for selectively positioning the transducer array **30** (described above) with respect to the hand or foot **40** submersed in the fluid **24** in response to signals received from the controller **338**. In the exemplary embodiment, the actuator **332** includes one or more guide rails slidably or movably supporting the transducer array **30** and one or more linear motors, such as stepper motors, which drive the transducer array **30** to move along one or more guide rails. The actuator **332** further includes one or more rotational motors which drive the transducer array **30** to rotate around one or more guide rails.

[0025] In the exemplary embodiment, the actuator **332** may include one or more guide rails including a horizontal rail, a lateral rail, a vertical rail, one or more linear motors, for example. The lateral rail is perpendicular to the horizontal rail and the vertical rail. One or more linear motors include the motor **92**, the motor **94**, and the motor **96** (shown in FIG. **4**).

[0026] The transducer array **30** is moved along the lateral rail extending along a lateral axis by the motor **92** connected to the transducer array **30**. The transducer array **30** is also moved along the horizontal rail extending along a horizontal axis, perpendicular to the lateral axis and a vertical axis, by the motor **94** connected to the transducer array **30**. The transducer array **30** is moved along the vertical rail extending along the vertical axis by the motor **96** connected to the transducer array **30**.

[0027] In the exemplary embodiment, the actuator **332** may further include one or more rotational motors, for example. One or more rotational motors include the motor **93**, the motor **95**, and the motor **97** (shown in FIG. **4**).

[0028] The transducer array **30** is rotated around the vertical rail by the motor **93** connected to the transducer array **30**. The transducer array **30** is also rotated around the lateral rail by the motor **95** connected to the transducer array **30**. The transducer array **30** is also rotated around the horizontal rail by the motor **97** connected to the transducer array **30**.

[0029] The motors **92**, **94**, **96**, **93**, **95**, and **97** will be described in more detail in FIG. **4**.

[0030] In yet other embodiments, the actuator **332** may have other configurations.

[0031] FIG. **3** is a flow diagram of a method **400** for imaging the joints **42** of the hand or foot **40** in accordance with an exemplary embodiment of the present invention. As indicated in block **402** of FIG. **3**, the controller **338** is configured to identify focus regions **48** (shown and described above with respect to FIG. **1**) based on the 3D image of the hand or foot **40**. In detail, a current focus region **48** and a subsequent/next focus region **48** are identified based on the 3D image of the hand or foot **40**.

[0032] As indicated in block **404** of FIG. **3**, the controller **338** is configured to control the actuator **332** to move the transducer array **30**, in the direction of arrows **358** to first joint locations at or adjacent to each of the identified focus regions **48**. While the transducer array **30** is opposite to each of the identified focus regions **48**, the controller **338** directs the transducer array **30** to scan the plurality of joints **42** in a first imaging mode and acquire ultrasound images of the joints **42** in the first imaging mode. In the embodiment, the first imaging mode may be b-mode, for example.

[0033] As indicated in block **406** of FIG. **3**, the controller **338** is configured to control the actuator **332** to move the transducer array **30**, in the direction of arrows **358** to second joint locations at or adjacent to each of the identified focus regions **48**. While the transducer array **30** is opposite to each of the identified focus regions **48**, the controller **338** directs the transducer array **30** to scan the plurality of joints **42** in a second imaging mode and acquire ultrasound images of blood flow in the joints **42** in the second imaging mode. In the embodiment, the second imaging mode may be a Power Doppler Imaging (PDI) mode or a high resolution PDI mode, for example.

[0034] In one embodiment, the controller **338** is further configured to automatically adjust location or position and/or direction or orientation of the transducer array **30** with respect to the hand or foot **40** based on the 3D image of the hand or foot **40**, such that the transducer array **30** is perpendicular to a tangent plane **410**, as shown in FIG. **5**, of the hand or foot surface during a scanning process.

[0035] In another embodiment, the controller **338** is further configured to automatically adjust location or position and/or direction or orientation of the transducer array **30** with respect to the hand or foot **40** based on the 3D image of the hand or foot **40**, such that ultrasound beam emitted by the transducer array **30** is perpendicular to the hand or foot surface during a scanning process. Therefore, the emitted ultrasound beam will be reflected back to the transducer array **30**, but not to other directions.

[0036] In one exemplary embodiment, the controller **338** is further configured to automatically adjust location or position of the transducer array **30** with respect to the hand or foot **40** based on the 3D image of the hand or foot **40**, such that the transducer array is in close proximity to the hand or foot **40** but without touching the hand or foot **40** during scanning processes. In one embodiment, a distance between the transducer array **30** and the hand or foot **40** may be approximately 2 mm or less, for example.

[0037] In another exemplary embodiment, the controller **338** is further configured to automatically adjust location or position of the transducer array **30** with respect to the hand or foot **40** based on the 3D image of the hand or foot **40**, such that a distance between the transducer array **30** and the hand or foot **40** is equal to a constant value of approximately 2 mm or less during scanning processes. In one embodiment, the constant value may be 1 mm, for example.

[0038] In detail, the ultrasound emitted by the transducer array **30** can real time measure the distance between the transducer array **30** and the hand or foot **40**. A planned distance between the transducer array **30** and the hand or foot **40** can be calculated based on the 3D image of the hand or foot **40**, because each of the focus regions **48** is identified based on the 3D image of the hand or foot **40**. If the measured distance is inconsistent with the planned distance, the controller **338** controls the actuator **332** to adjust the location or position of the transducer array **30**, so as to maintain the distance between the transducer array **30** and the hand or foot **40** is equal to the planned distance.

[0039] FIG. **4** illustrates a joint ultrasound imaging system **900**, an example implementation of the joint ultrasound imaging system **20** of FIG. **1** and the joint ultrasound imaging system **320** of FIG. **2**. The ultrasound imaging system **900** is similar to the ultrasound imaging system **320** except that the ultrasound imaging system **900** specifically illustrates the actuator **932**, an example of the actuator **832** shown in FIG. **2**. Those remaining components or elements of the ultrasound imaging system **900** which correspond to components or elements of the ultrasound imaging system **320** are numbered similarly or are shown in FIG. **2**.

[0040] As shown in FIG. **4**, the actuator **932** includes the motor **92**, the motor **94**, the motor **96**, the motor **93**, the motor **95**, the motor **97**, the horizontal rail **924**, the lateral rail **944**, the vertical rail **964**, threaded shaft **925**, and threaded shaft **945**.

[0041] The horizontal axis **922**, the lateral axis **942**, and the vertical axis **962** constitute coordinate axes.

[0042] The lateral rail **924** extends along the lateral axis **922** and movably supports the first arm **920** for lateral movement along the lateral rail **924**. The threaded shaft **925** is connected to the motor **92** and includes external threads that engage internal threads connected to the first arm **920**. The motor **92**, in response to signals from the controller **338** (shown in FIG. **2**), drive the threaded shaft **925** to laterally translate the first arm **920** along the lateral axis **922**. Such that the motor **94**, the second arm **940**; the motor **96**, the third arm **960**; the motor **93**, the fourth arm **930**; the motor **95**, the fifth arm **950**; the motor **97**, the sixth arm **970**; and the transducer array **30** are also movable along the lateral axis **922**.

[0043] The horizontal rail **944** extends along the horizontal axis **942** and movably supports the second arm **940** for horizontal movable along the horizontal rail **944**. One end of the threaded shaft **945** is connected to the first arm **920** through the sixth arm **941** and the second arm **940**, the other end of the threaded shaft **945** is connected to the motor **94**. The threaded shaft **945** includes external threads that engage internal threads connected to the second arm **940**. The motor **94**, in response to signals from the controller **338** (shown in FIG. **2**), drive the threaded shaft **945** to horizontally translate the second arm **940** along the horizontal axis **942**. Such that the motor **96**, the third arm **960**; the motor **93**, the fourth arm **930**; the motor **95**, the fifth arm **950**; the motor **97**, the sixth arm **970**; and the transducer array **30** are also movable along the horizontal axis **942**.

[0044] The vertical rail **964** extends along the vertical axis **962** and movably supports the third arm **960** for vertical movement along the vertical rail **964**. The threaded shaft **965** is connected to the motor **96** and includes external threads that engage internal threads connected to the third arm **960**. The motor **96**, in response to signals from the controller **338** (shown in FIG. **2**), drive the threaded shaft **965** to vertically translate the third arm **960** along the vertical axis **962**. Such that the motor **93**, the fourth arm **930**; the motor **95**, the fifth arm **950**; the motor **97**, the sixth arm **970**; and the transducer array **30** are also movable along the vertical axis **962**.

[0045] The actuator **932** further includes a first shaft **935**, a second shaft **955**, and a third shaft **975**.

[0046] One end of the first shaft **935** is connected to the motor **93** through the third arm **960**. The other end of the first shaft **935** is connected to the fourth arm **930**. The motor **93**, in response to signals from the controller **338** (shown in FIG. **2**), drive the first shaft **935** to cause the fourth arm **930** to rotate around the vertical axis **962**. Such that the motor **95**, the fifth arm **950**; the motor **97**, the sixth arm **970** and the transducer array **30** also rotate around the vertical axis **962**.

[0047] The motor **95** is connected to the fourth arm **930**, one end of the second shaft **955** is connected to the motor **95**, the other end of the second shaft **955** is connected to the fifth arm **950**. The motor **95**, in response to signals from the controller **338** (shown in FIG. **2**), drive the second shaft **955** to cause the fifth arm **950** to rotate around the lateral axis **922**. Such that the motor **97**, the sixth arm **970**, and the transducer array **30** also rotate around the lateral axis **922**.

[0048] One end of the third shaft **975** is connected to the motor **97** through the fifth arm **950**, the other end of the third shaft **975** is connected to the transducer array **30**. The motor **97**, in response to signals from the controller **338** (shown in FIG. **2**), drive the third shaft **975** to cause the transducer array **30** to rotate around the horizontal axis **942**.

[0049] While the disclosure has been described with reference to exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the disclosure. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the disclosure without departing from the essential scope thereof. Therefore, it is intended that the disclosure will not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this disclosure, but that the disclosure will include all embodiments falling within the scope of the appended claims.

1. An ultrasound imaging system, comprising:
- a scanning assembly configured to receive a hand or foot and comprising a transducer array and an acoustic coupling fluid;
- a three-dimensional (3D) image acquisition device for obtaining a 3D image of the hand or foot; and
- a controller for automatically adjusting direction or orientation of the transducer array with respect to the hand or foot based on the 3D image of the hand or foot.

2. The ultrasound imaging system of claim **1**, wherein the controller is configured to automatically adjust direction or orientation of the transducer array with respect to the hand or foot based on the 3D image of the hand or foot, such that the transducer array is perpendicular to a tangent plane of the hand or foot surface during a scanning process.

3. The ultrasound imaging system of claim **1**, wherein the controller is further configured to automatically adjust direction or orientation of the transducer array with respect to the hand or foot based on the 3D image of the hand or foot, such that ultrasound beam emitted by the transducer array is perpendicular to the hand or foot surface during a scanning process.

4. The ultrasound imaging system of claim **1**, wherein the 3D image acquisition device comprises a 3D camera or a 3D coordinate measuring device.

5. The ultrasound imaging system of claim **1**, wherein the controller is further configured to automatically adjust the location or position of the transducer array with respect to the hand or foot based on the 3D image of the hand or foot, such that the transducer array is in close proximity to the hand or foot but without touching the hand or foot during scanning processes.

6. The ultrasound imaging system of claim **1**, wherein the controller is further configured to automatically adjust location or position of the transducer array with respect to the hand or foot based on the 3D image of the hand or foot, such that a distance between the transducer array and the hand or foot is equal to a constant value during scanning processes.

7. The ultrasound imaging system of claim **1**, further comprising:
- one or more guide rails; and
- one or more rotational motors for controlling the transducer array to rotate around the one or more guide rails;
- wherein the controller is further configured to control at least one of the rotational motors to automatically adjust movement of the transducer array with respect to the hand or foot based on the 3D image of the hand or foot.

8. The ultrasound imaging system of claim **7**, further comprising:
- one or more linear motors for controlling the transducer array to move along the one or more guide rails;
- wherein the controller is further configured to control at least one of the rotational motors and the linear motors to automatically adjust movement of the transducer array with respect to the hand or foot based on the 3D image of the hand or foot.

9. The ultrasound imaging system of claim **7**, wherein the one or more guide rails comprise a horizontal rail, a lateral rail perpendicular to the horizontal rail, and a vertical rail perpendicular to the horizontal rail and the lateral rail; and
- wherein the one or more rotational motors comprise a motor for controlling the transducer array to rotate around the horizontal rail, a motor for controlling the

transducer array to rotate around the lateral rail, and a motor for controlling the transducer array to rotate around the vertical rail.

10. The ultrasound imaging system of claim **8**, wherein the one or more linear motors comprise a motor for controlling the transducer array to move along the horizontal rail, a motor for controlling the transducer array to move along the lateral rail, and a motor for controlling the transducer array to move along the vertical rail.

11. The ultrasound imaging system of claim **1**, wherein the controller is configured to identify location of joints based on the 3D image of the hand or foot, control the transducer array to scan the plurality of joints in a first imaging mode and in a second imaging mode based on the identified location of the joints, and generate ultrasound images of the joints in the first imaging mode and generate ultrasound images of blood flow in the joints in the second imaging mode.

12. The ultrasound imaging system of claim **11**, wherein the ultrasound images of the joints comprise b-mode ultrasound images of the joints, the ultrasound images of blood flow in the joints comprise Power Doppler Imaging (PDI) images or high resolution PDI images of the joints.

13. A method of acquiring ultrasound images for a hand or foot examination, the method comprising:

receiving a hand or foot in a scanning assembly including a transducer array and a fluid for providing an acoustic coupling between the transducer array and the hand or foot;

obtaining a 3D image of the hand or foot using a three-dimensional (3D) image acquisition device;

automatically adjusting direction or orientation of the transducer array with respect to the hand or foot based on the 3D image of the hand or foot.

14. The method of claim **13**, further comprising:

automatically adjusting direction or orientation of the transducer array with respect to the hand or foot based on the 3D image of the hand or foot, such that the transducer array is perpendicular to a tangent plane of the hand or foot surface during a scanning process.

15. The method of claim **13**, further comprising:

automatically adjusting direction or orientation of the transducer array with respect to the hand or foot based on the 3D image of the hand or foot, such that ultrasound beam emitted by the transducer array is perpendicular to the hand or foot surface during a scanning process.

16. The method of claim **13**, further comprising:

automatically adjusting the location or position of the transducer array with respect to the hand or foot based on the 3D image of the hand or foot, such that the transducer array is in close proximity to the hand or foot but without touching the hand or foot during scanning processes.

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

automatically adjusting the location or position of the transducer array with respect to the hand or foot based on the 3D image of the hand or foot, such that a distance between the transducer array and the hand or foot is equal to a constant value during scanning processes.

18. The method of claim **13**, further comprising:

controlling the transducer array to rotate around one or more guide rails using one or more rotational motors; and

controlling at least one of the rotational motors to automatically adjust movement of the transducer array with respect to the hand or foot based on the 3D image of the hand or foot.

19. The method of claim **18**, further comprising:

controlling the transducer array to move along the one or more guide rails using one or more linear motors; and

controlling at least one of the rotational motors and the linear motors to automatically adjust movement of the transducer array with respect to the hand or foot based on the 3D image of the hand or foot.

20. The method of claim **18**, wherein the one or more guide rails comprise a horizontal rail, a lateral rail perpendicular to the horizontal rail, and a vertical rail perpendicular to the horizontal rail and the lateral rail; and

wherein the one or more rotational motors comprise a motor for controlling the transducer array to rotate around the horizontal rail, a motor for controlling the transducer array to rotate around the lateral rail, and a motor for controlling the transducer array to rotate around the vertical rail.

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专利名称(译)	联合超声成像系统和方法		
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当前申请(专利权)人(译)	通用电气公司		
[标]发明人	HAN XIAODONG HALMANN MENACHEM TAO KUN LIU ZHENYU CHENG GANG CHEN DONGQING WANG HONG		
发明人	HAN, XIAODONG HALMANN, MENACHEM TAO, KUN LIU, ZHENYU CHENG, GANG CHEN, DONGQING WANG, HONG		
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摘要(译)

超声成像系统包括扫描组件，三维（3D）图像采集设备和控制器。扫描组件被配置为接收手或脚并且包括换能器阵列和声学耦合流体。 3D图像采集设备被配置用于获得手或脚的3D图像。控制器被配置为基于手或脚的3D图像自动调节换能器阵列相对于手或脚的方向或取向。