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(54) **IMAGE ORIENTATION IDENTIFICATION FOR AN EXTERNAL MICROCONVEX-LINEAR ULTRASOUND PROBE**

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(57) **ABSTRACT**

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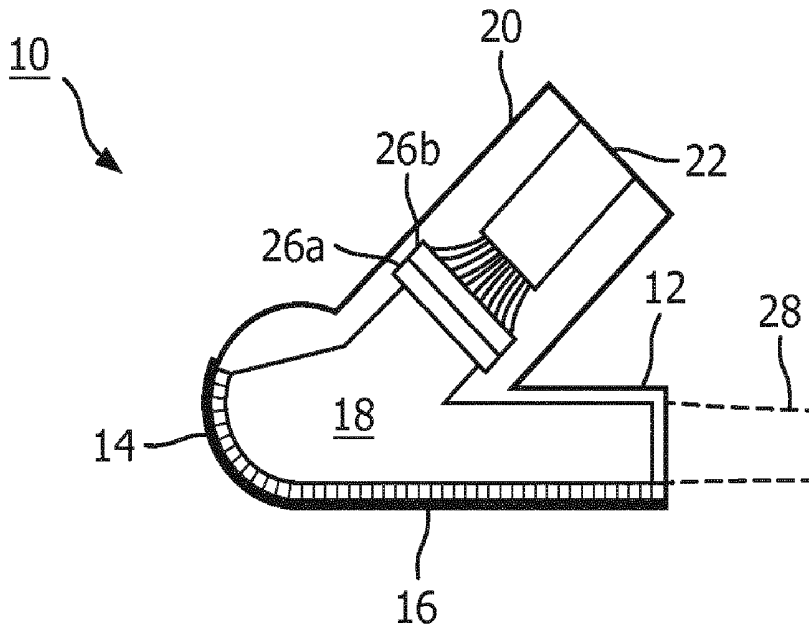
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A microconvex-linear ultrasound probe is used to image the insertion of a needle into a subject with a microconvex portion of a transducer array of the probe, then image penetration of the needle toward target anatomy with a linear portion of the transducer array by rotation of the probe against the subject. Ultrasound images produced by the probe are consistently displayed by control of a scan converter with an orientation signal. The orientation signal results from the processing of accelerometer signals from the probe, the identification of a portion of the transducer array which is in acoustic contact with the subject, and/or the identification or tracking of a feature in the ultrasound images such as the target anatomy.



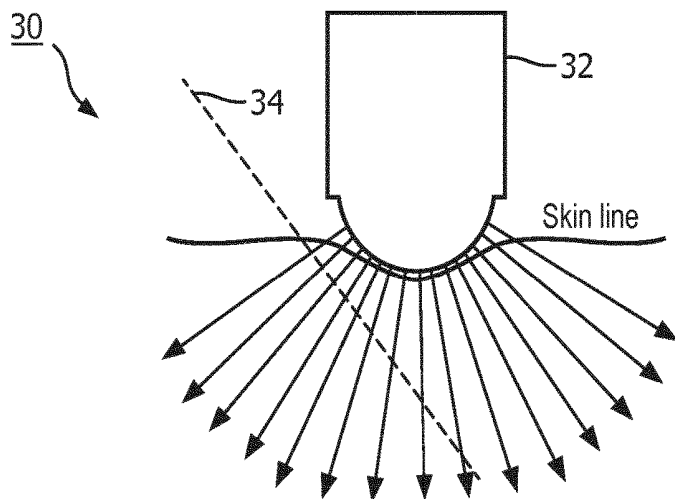


FIG. 1

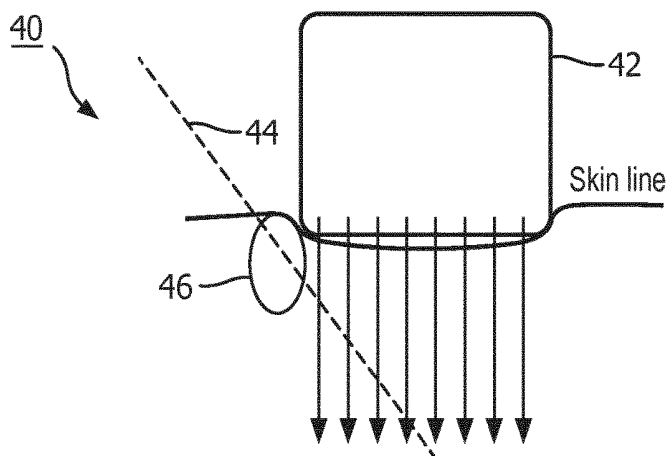


FIG. 2

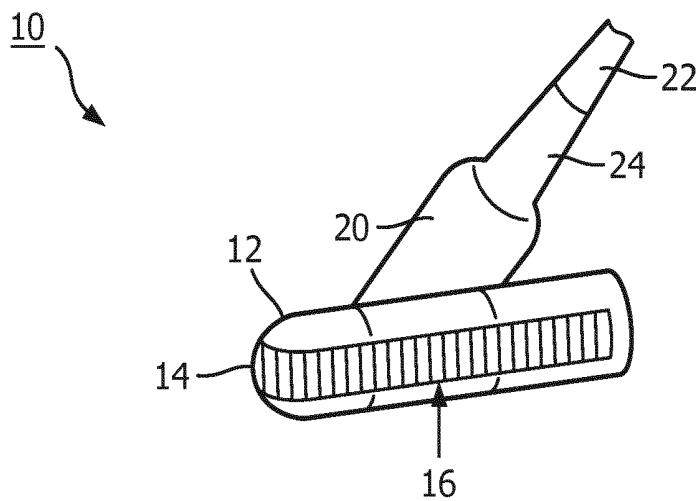


FIG. 3

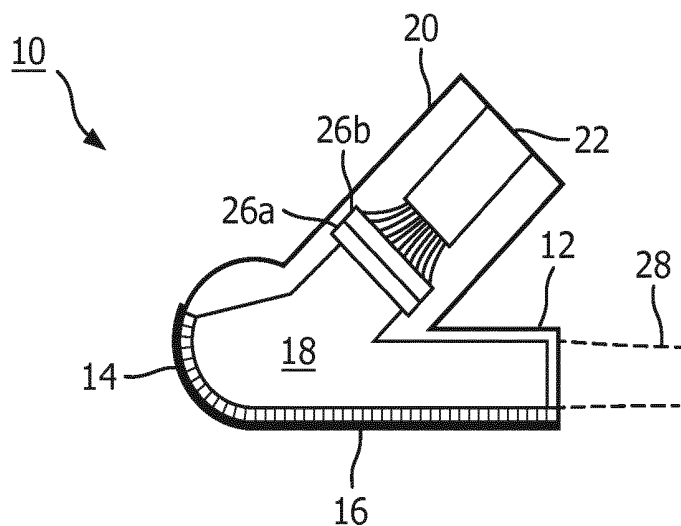


FIG. 4

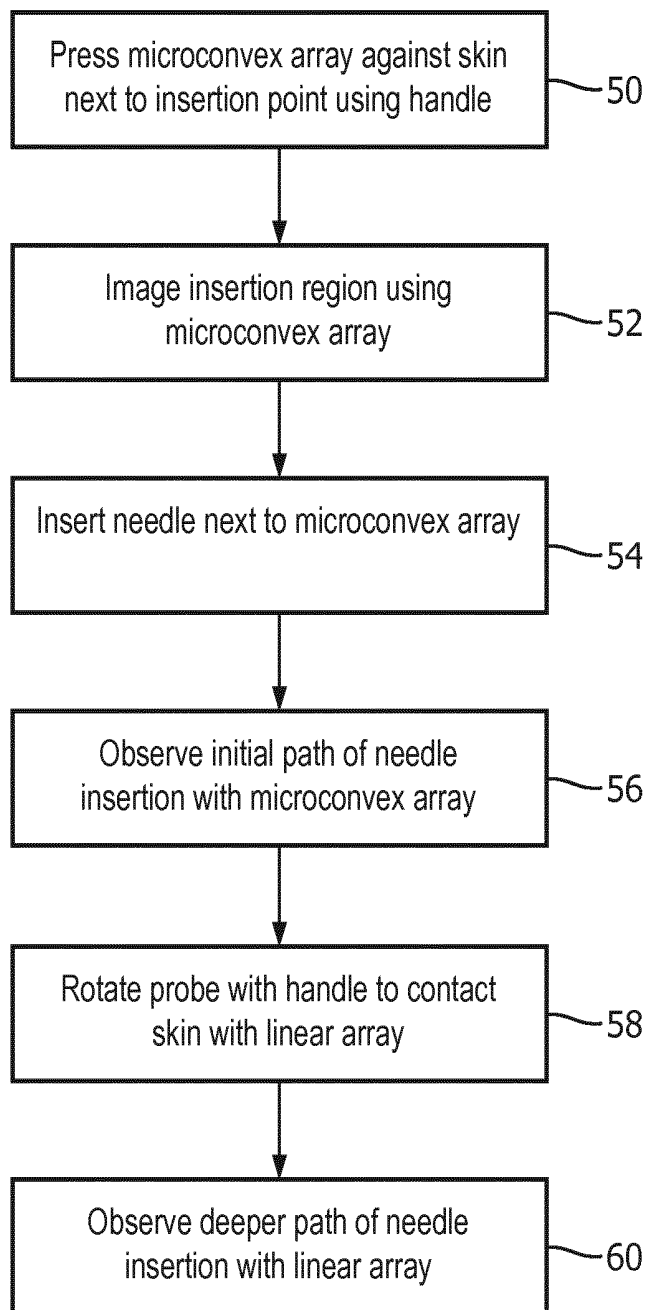


FIG. 5

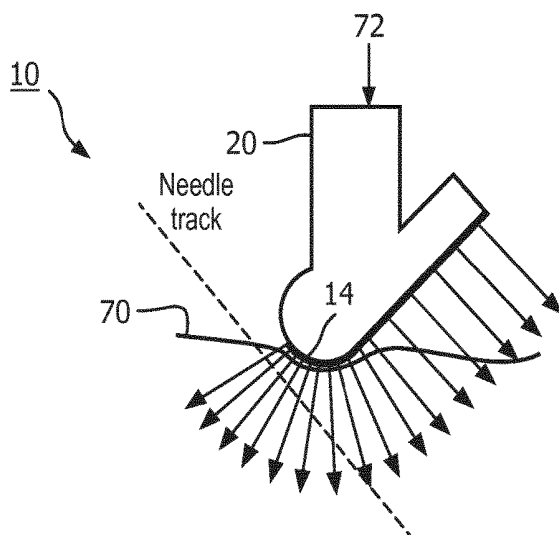


FIG. 6

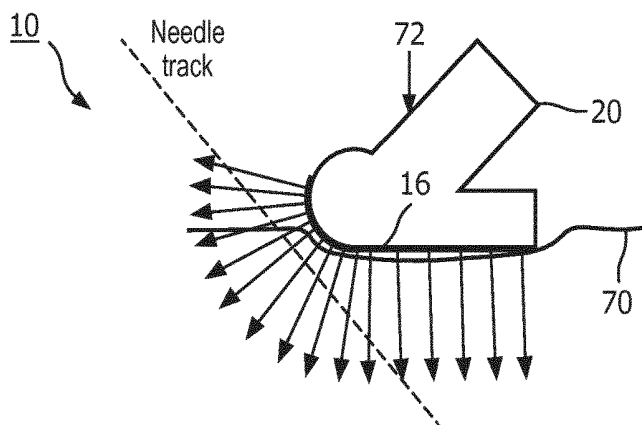


FIG. 7

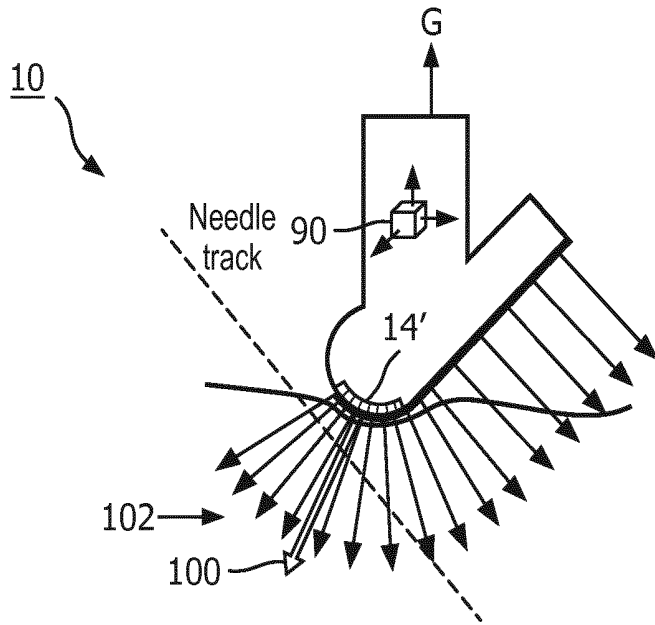


FIG. 8a

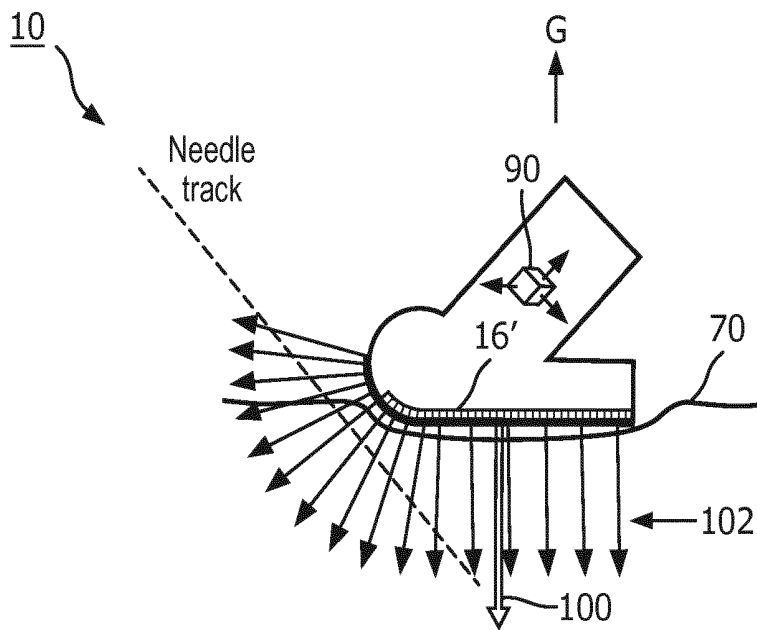


FIG. 8b

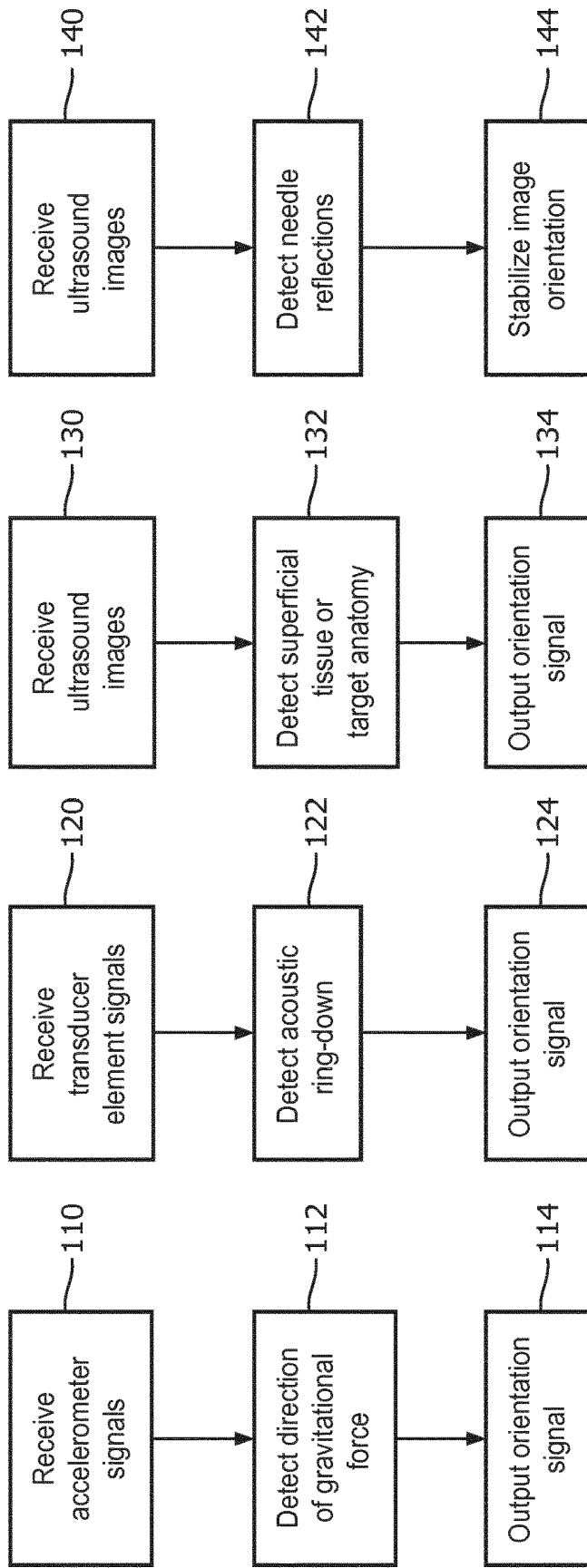


FIG. 9d

FIG. 9c

FIG. 9b

FIG. 9a

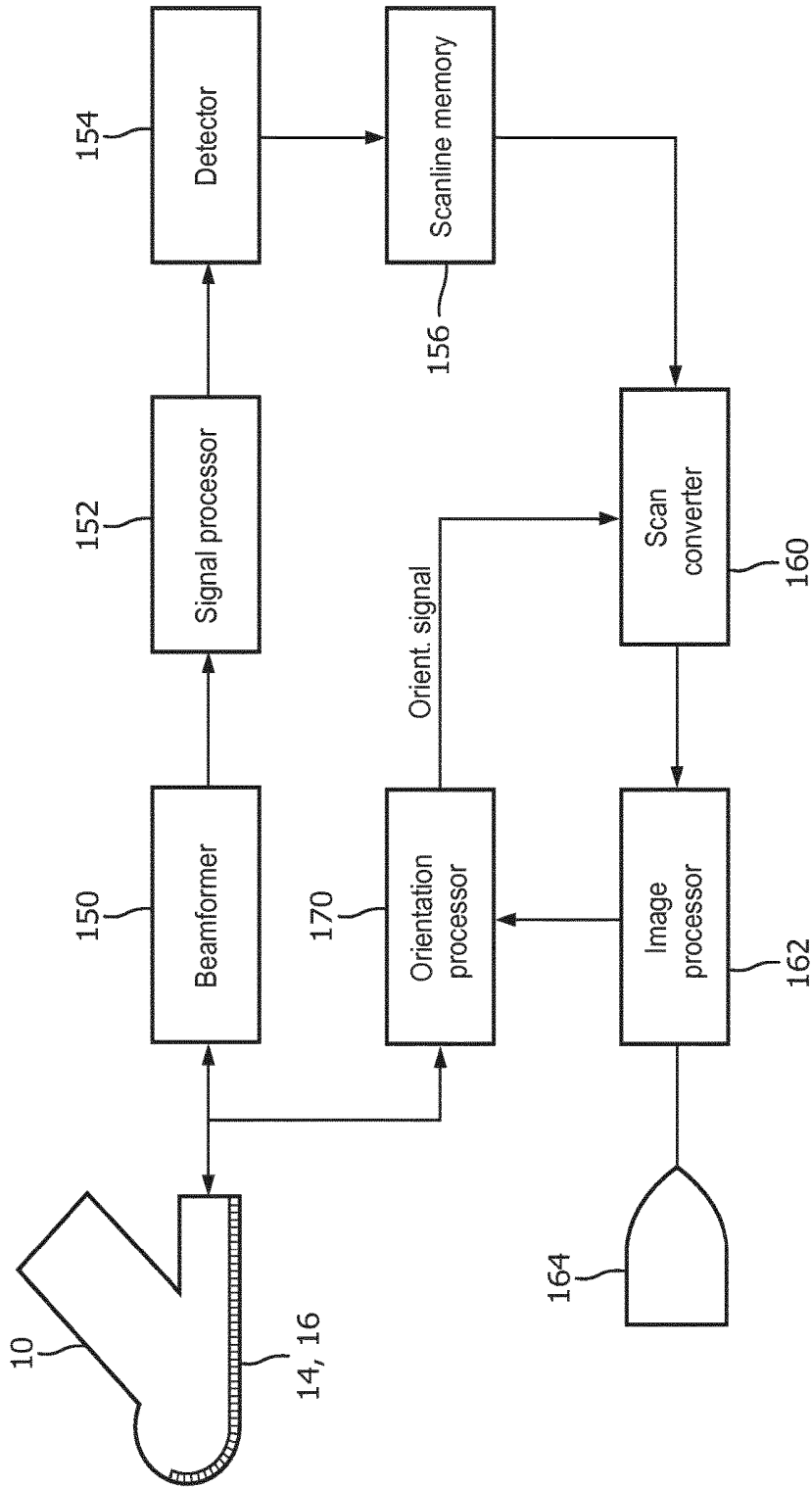


FIG. 10

**IMAGE ORIENTATION IDENTIFICATION
FOR AN EXTERNAL
MICROCONVEX-LINEAR ULTRASOUND
PROBE**

[0001] This invention relates to medical diagnostic ultrasonic systems and, in particular, to microconvex-linear ultrasound probes for biopsy procedures.

[0002] Ultrasonic image guidance is frequently used to guide biopsies and other needle procedures by which a needle is introduced into the body to biopsy or aspirate or ablate material inside the body. A familiar problem occurs at the beginning of the procedure, where it is desired to image the needle as soon as it penetrates the skin surface so that the path of the needle to the target can be guided and observed. It is desirable to be able to visualize and avoid penetrating superficial blood vessels and nerves to as great a degree as possible. Furthermore, the presence of dense subcutaneous tissues can cause the needle to bend or deflect and vary from its intended path of travel. It is therefore desirable to begin imaging the needle as soon as it enters the body so that these potential problems can be immediately observed and overcome.

[0003] A common aid in handling the needle is to use a biopsy guide. This is a bracket that fastens around the ultrasound probe and holds the needle in-line for its intended path of travel. Unfortunately the biopsy guide worsens the problem of initial visualization of the needle, as it usually holds the needle outward from the side of the probe and away from the acoustic window of the probe. Other approaches have been tried to reduce this problem, such as manufacturing slots in the probe face next to the array transducer and sometimes even between elements of the array. However these approaches in specialized probe construction are expensive, such probes are difficult to clean, and are limited to the specific needle access of the particular design. Accordingly, many experienced clinicians prefer to use a standard imaging probe with no biopsy guide so that they can insert the needle into the skin of the patient as close to the probe and its acoustic window as possible. Accordingly it is desirable to facilitate both unaided and biopsy guide assisted biopsies with good image guidance.

[0004] It is a further objective of the present invention to improve visual guidance of needle insertion by providing a wide lateral field of view near the skin surface for needle insertion, and well resolved images at deeper depths of field as the needle approaches the target pathology inside the body.

[0005] In accordance with the principles of the present invention, an external probe for image guidance of needle insertion procedures has a combined microconvex array and linear array construction. The probe has a handle by which a user can press the microconvex array section against the skin of the patient at the beginning of the procedure to visualize needle insertion, then can rotate the probe to bring the linear array section into good acoustic contact with the skin of the patient to observe the needle as it penetrates to deeper depths of the body. A method of using the probe in a needle procedure comprises pressing the microconvex array section against the subject to image with the microconvex array; inserting a needle adjacent to the microconvex array section and observing its initial penetration; rotating the probe to bring the linear array section into good acoustic contact with the subject; and observing deeper penetration of the needle with the linear array section.

[0006] In accordance with a further aspect of the present invention, an orientation processor circuit controls the display of the ultrasonic image so that the skin line of the patient is always located at the top of the display while the probe is rotated during needle insertion and depth penetration. The orientation processor may utilize an accelerometer producing signals which are processed to determine the direction of the force of gravity, image processing, or acoustic contact to determine the desired image orientation.

[0007] In the drawings:

[0008] FIG. 1 illustrates needle insertion visually guided by a microconvex array probe.

[0009] FIG. 2 illustrates needle insertion visually guided by a linear array probe.

[0010] FIG. 3 illustrates the microconvex and linear acoustic apertures of an external ultrasound probe constructed in accordance with the principles of the present invention.

[0011] FIG. 4 is a schematic illustration of the internal construction of an external ultrasound probe of the present invention.

[0012] FIG. 5 is a flowchart of the steps of an invasive needle procedure conducted in accordance with the present invention.

[0013] FIG. 6 illustrates initial needle insertion guidance using a microconvex-linear array probe of the present invention.

[0014] FIG. 7 illustrates guidance of deeper needle insertion using a microconvex-linear array probe of the present invention.

[0015] FIGS. 8a and 8b illustrate the change in image orientation which occurs as a microconvex-linear array probe of the present invention is rotated to follow needle insertion.

[0016] FIGS. 9a, 9b, 9c, and 9d illustrate algorithms executed by an orientation processor in accordance with the present invention to determine image orientation.

[0017] FIG. 10 illustrates an ultrasound system in block diagram with an image orientation processor in accordance with the present invention.

[0018] FIG. 1 illustrates a needle insertion procedure with visual guidance provided by a microconvex transducer array probe 30 having a microconvex array 32 at its distal tip. The term "microconvex" is applied to curved array transducers that are tightly curved with a relatively small radius of curvature. Microconvex arrays are generally used in delicate procedures when a small probe with a wide field of view is needed. Microconvex ultrasound transducers provide a wide field of view immediately beneath the skin line and thus are desirable for needle interventions. The procedure is performed by pressing the microconvex array aperture of the probe 30 against the skin surface as shown in the drawing, and inserting a needle adjacent to the probe and, for a two-dimensional imaging probe, in line with the plane of the image. The needle is inserted into the body at an angle as indicated by needle path 34. The arrows inside the body indicate the beam directions from the microconvex array 32. Although the needle can be followed visually almost immediately after penetrating the skin line, the limited active aperture of the microconvex array due to element directivity and the array curvature limits the resolution of the image at depth. Thus, linear array probes are frequently used for needle guidance because they provide better penetration and resolution at deeper depth than microconvex probes. FIG. 2

illustrates a linear array transducer probe **40** with a linear array transducer **42** at its distal end. A linear array is generally able to visually follow the path **44** of the needle to a considerable depth in the body, as indicated by the arrows extending from the array aperture into the body. But with a standard linear array probe, some of the needle path **46** at the initial point of entry adjacent to the probe **40** is not visualized at all and the beams of a linear array produce poorer resolution at the edge of the array.

[0019] FIG. 3 illustrates a microconvex-linear array transducer probe **10** constructed in accordance with the principles of the present invention. The probe **10** has a main body **12** with an active aperture of transducer elements extending from a straight edge of the main body, down to and around a distal tip of the main body. The transducer elements thus comprise a linear array **16** where the section of elements is in a straight line, transitioning to a microconvex array **14** where the elements curve around the distal tip of the probe. With beamforming that transmits and receives beams normal to the active aperture surface all along the array of elements, a continuous image field can be scanned and imaged in front of the entire section of microconvex and linear elements. On the opposite side of the main body **12** from the linear array section is a handle **20** which extends from the main body at an oblique angle and is used to hold the probe **10** in contact with the skin surface during a needle procedure. In this example a cable **22** which connects the probe **10** to an ultrasound imaging system exits the probe through the end of the handle **20**. The cable is protected at its point of attachment to the handle with a cable strain relief **24**.

[0020] The internal components of the probe **10** are shown in the cross sectional view of FIG. 4. In this view the microconvex elements **14** curve around the distal tip of the probe on the left side and transition into a linear array of elements **16**. Attached to the back of the array is a flex circuit **18** with conductors attached to the array elements. The conductors of the flex circuit terminate at a connector **26a** inside the handle portion **20** of the probe. The cable **22** entering the end of the handle has conductors terminating in a connector **26b**, which mates with connector **26a** to electrically couple the array elements to the conductors of the cable and ultimately to the beamformer of the ultrasound system. While the cable **22** is shown attached at the end of the handle **20** in this example, it could alternately be attached to the probe at the proximal end of the main body **12** as indicated by the dashed lines **28** in the drawing.

[0021] FIG. 5 is a flowchart illustrating the steps in a typical needle insertion procedure in accordance with the present invention. In the first step **50** a clinician grasps the handle **20** of the probe and presses the microconvex array **14** into good acoustic contact with the skin of the patient. When the probe is held in this way it appears as shown in FIG. 6. In this position the clinician is able to assert contact force in the direction of the axis of the handle and directly in line with the microconvex array **14** as shown at **72** in the drawing. The force of the probe against the skin **70** of the patient will not only assure good acoustic contact between the microconvex array and the skin, it also will widen the contact area due to depression of the skin. This enables scanning in a wider sector by reason of the improved contact at the edge of the probe, a sector which is able to image the initial penetration of the needle into the body as indicated by the dashed needle track shown in the drawing, which is step

52 in FIG. 5. In step **54** the clinician inserts the needle next to the microconvex array **14** as shown in FIG. 6, and in step **56** the clinician observes the initial path of needle insertion in the image field scanned by the microconvex array. As the clinician advances the needle, the next step **58** is to rotate the probe with the handle **20**, bringing the linear array **16** into acoustic contact with the skin **70** as shown in FIG. 7. This rotation also is seen to bring the far end of the microconvex array out of acoustic contact with the skin. This may be done without losing the view of the needle, as at least a portion of the aperture of the microconvex and linear array elements is always in acoustic contact with the skin as the probe is rotated. The handle **20** is now above the linear array **16** as FIG. 7 shows, enabling the clinician to press down with a force **72** to firmly press the linear array aperture into good acoustic contact with the skin **70**. The continued insertion of the needle is beneath the linear array section of the probe aperture, enabling the linear array **16** to visualize continued insertion of the needle deeper into the body with good resolution and clarity until the tip of the needle reaches its intended target, as stated by step **60**.

[0022] Due to the fact that the probe is intended to be rotated during the needle insertion procedure, and also the fact that the microconvex-linear array transmits and receives beams in directions spanning over 1000, an ambiguity arises during imaging: how should the image be displayed? Ultrasound images are normally displayed in a fixed orientation to the probe, with the shallowest beam depths at the top of the image and extending to deeper beam depths at the bottom. But when the probe is rotated during the procedure as illustrated in FIGS. 6 and 7, the display becomes disorienting as the needle position appears to move on the screen. Since the clinician is intently focused on the needle position to guide the needle tip to its target tissue in the body, it is desirable to prevent this disorientation. In accordance with a further aspect of the present invention, the display format is dynamically adjusted during rotation of the probe so that greater tissue depths are always at the bottom of the display, thereby giving the clinician a consistent frame of reference. Preferably this is done by control of the manner in which the scan converter renders the image. In a conventional ultrasound system the purpose of the scan converter is to convert the $r-\theta$ coordinates of the receive beam scanlines into an image with $x-y$ coordinates suitable for a raster display and in the appropriate sector, linear, or curved linear scan format. In an implementation of the present invention, the scan converter is further controlled by an orientation signal which identifies the vertical orientation (up, down direction) of the image. There are several ways to accomplish this. One is by use of an accelerometer **90** located in the probe **10** as shown in FIGS. 8a and 8b, which produces signals that measure a constant orientation direction such as the direction of gravitational force. The scan converter then renders the ultrasound image with its vertical direction aligned with the measured orientation direction. Conventionally accelerometers have been used in ultrasound probes to measure displacement for the reconstruction of 3D images, as described in U.S. Pat. No. 5,529,070 (Augustine et al.) In the probe described in this patent, signals from accelerometers are processed over time to measure probe displacement, which is the second derivative of the acceleration signals. For this dynamic acceleration measurement, the gravitational force vectors are canceled in the processing algorithms. But it is the static gravitational force vector alone

which can be used as an orientation signal in an implementation of the present invention.

[0023] A second way to produce an orientation signal is by detection of the portion of the array **14**, **16** which is acoustically coupled to the skinline at any point in time. The vertical image direction is then taken as a vector **100** normal to the center of the acoustically coupled portion of the array. For instance, FIG. **8a** shows the probe **10** being held at the time of needle insertion with most of the elements **14'** of the microconvex array in contact with the skin. The elements of the linear array **16** are not in contact with the skinline at this time. A vector arrow **100** is shown drawn normal to the center of the microconvex array portion **14'**, and this vector direction is used for the image orientation signal. At a later point in the procedure, when the linear array portion **16'** of the probe has been rotated into acoustic contact with the skinline **70**, the vector arrow **100** normal to the center of the acoustically coupled portion **16'** of the array appears as shown in FIG. **8b**. Scanlines **102** which are parallel to the vector arrow direction will be rendered vertically in the scan converted image, with scanlines at other angles oriented in accordance with their angular offset from the direction of the vector arrow direction of the orientation signal.

[0024] A third way to produce a suitable orientation signal is by image analysis, also known in the art as feature tracking. For instance the layers of skin, fat, and striated muscle immediately beneath the skin can be identified in the image and the horizontal orientation set to be in general alignment with these layers by an orientation signal. A second image analysis technique is to identify the pathological target of the needle procedure in the image, which may be done either manually or automatically. For example, the clinician can click on the target in the image prior to commencing needle insertion. The target anatomy is then rendered in the same location in each successive image frame, which may be done using image stabilization techniques. Ultrasonic image stabilization is well known, as described in U.S. Pat. No. 6,589,176 (Jago et al.) The image stabilization in an implementation of the present invention is preferably not done rigorously enough to preclude rotation, as that is the expected result of the probe motion. Center-to-center stabilization will be sufficient to produce a sequence of consistently useful images as the probe is rotated. Alternatively, the speckle characteristic of the identified target anatomy can be tracked from frame to frame to maintain the anatomy in the same location from frame to frame.

[0025] FIGS. **9a**, **9b**, **9c**, and **9d** illustrate a number of methods for generating an orientation signal. FIG. **9a** illustrates a technique using an accelerometer in the probe. A suitable accelerometer for this purpose is a three-axis accelerometer such as those of the ADXL300 series of MEMS (micro electro-mechanical system) accelerometers available from Analog Devices, Inc. of Boston, Mass. The signals of the three axes are received by an orientation processor in step **110**. Samples of these three signals are respectively averaged over a sampling interval such as a few seconds to produce values v_x , v_y , and v_z from the three axes. The three values are vectorially combined to produce the vertical acceleration vector v corresponding to gravity, which is nominally 9.81 meters/second and is in a direction straight up as shown in step **112**. The vector direction of gravitational force, indicated by arrow G in FIGS. **8a** and **8b**, is then used in the output orientation signal, step **114**, to cause the scan

converter to render the image with the indicated direction G as the vertical direction. Thus, the direction commonly referred to as "up" will always be at the top of the displayed image.

[0026] FIG. **9b** illustrates an orientation signal identification process using acoustic contact between elements of the transducer array **14**, **16** and the skin of the patient. Signals from all of the elements of the array are coupled to an orientation processor in step **120** where they are analyzed for acoustic ring-down in step **122**. When an ultrasound transducer element is not acoustically coupled to the skin, its echo response exhibits a distinctive ring-down artifact. A typical ring-down signal from an uncoupled transducer element is shown in FIG. 6 of U.S. Pat. No. 5,517,994 (Burke et al.) for instance. Elements acoustically coupled to the subject will in contradistinction receive a sequence of echo signals from tissue. The orientation processor algorithm identifies those elements which are acoustically coupled to the patient, identifies the center of the sequence of acoustically coupled elements and, from knowledge of the geometry of the array, then identifies the direction normal to this center. The orientation signal communicates this direction (arrow **100** in FIGS. **8a** and **8b**) to the scan converter in step **124**, which uses this direction as the vertical direction in the rendered images. The element coupling and arrow direction are constantly updated so that the vertical direction of the image is constantly refined during the needle insertion procedure.

[0027] FIG. **9c** illustrates the production of an image orientation signal by image processing and feature tracking. In step **130** a sequence of ultrasound images is received by the orientation processor which in this instance is an image processor. Analysis is performed in step **132** to locate known image features, such as the previously described superficial layers immediately beneath the skin or the target anatomy. Alternatively these image characteristics may be manually identified in an image. An identified characteristic is tracked and its orientation or image location is communicated to the scan converter in step **134**, which renders the image characteristic consistently from image frame to image frame.

[0028] A specific image analysis technique is illustrated in FIG. **9d**. During needle insertion the clinician will be closely watching the position of the needle as it enters the body and particularly its inclination toward the target anatomy. The method of FIG. **9d** assists the clinician in this effort by stabilizing the position of the needle in the images. Ultrasound images are received by an orientation processor at step **140**, which detects echo signal reflections from a needle. Such echo signals are very distinctive as a needle is a highly specular reflector of ultrasound and the echo signals from a needle are very strong. See, e.g., U.S. Pat. No. 6,951,542 (Greppi et al.) When these distinctive echoes are detected by the orientation processor in step **142**, their image locations are communicated to the scan converter in the orientation signal, which responds by rendering the needle in a consistent position from frame to frame. Image stabilization techniques can be used to render a sequence of images with a stable needle location. See, e.g., U.S. Pat. No. 6,589,176 (Jago et al.)

[0029] An ultrasound system constructed in accordance with the principles of the present invention is shown in block diagram form in FIG. **10**. The microconvex-linear array **14**, **16** of a probe **10** is coupled to a beamformer **150**, which causes elements of the array to transmit ultrasound waves

and receive echo signals in response. The received echo signal are beamformed into scanlines of coherent echo signals by the beamformer. The echo signals are processed by a signal processor 152 which performs functions such as filtering, frequency or spatial compounding, harmonic separation, and quadrature demodulation. A detector 154 performs signal detection, amplitude detection in the case of B mode images and Doppler detection in the case of Doppler signals. The scanlines of echo signals are stored in a scanline memory 156 which may be a conventional digital memory device. The scanlines of echo signals are rendered in a desired image format of Cartesian coordinates by a scan converter 160, with the vertical axis of the image or the location of a specific image object determined by an orientation signal as described previously. The orientation signal is produced as described above by an orientation processor 170, which may comprise electronic hardware components, hardware controlled by software, or a microprocessor executing signal and/or image processing algorithms as described in conjunction with FIGS. 9a-9d. The orientation processor 170 is shown coupled to receive accelerometer signals and/or echo signals from the probe 10 for vertical vector analysis and/or acoustic coupling analysis as described in FIGS. 9a and 9b. The orientation processor 170 is also shown coupled to receive ultrasound images from an image processor 162 for execution of the image processing techniques for orientation signal production as described in conjunction with FIGS. 9c and 9d. The image processor 162 receives rendered ultrasound images from the scan converter 160 and applies the images to a monitor or display 164 for viewing by the clinician.

[0030] It should be noted that the various embodiments described above and illustrated herein may be implemented in hardware, software or a combination thereof. The various embodiments and/or components, for example, the modules, or components and controllers therein, also may be implemented as part of one or more computers or microprocessors. The computer or processor may include a computing device, an input device, a display unit and an interface, for example, for accessing the Internet. The computer or processor may include a microprocessor. The microprocessor may be connected to a communication bus, for example, to access a PACS system. The computer or processor may also include a memory. The memory may include Random Access Memory (RAM) and Read Only Memory (ROM). The computer or processor further may include a storage device, which may be a hard disk drive or a removable storage drive such as a floppy disk drive, optical disk drive, solid-state thumb drive, and the like. The storage device may also be other similar means for loading computer programs or other instructions into the computer or processor.

[0031] As used herein, the term “computer” or “module” or “processor” may include any processor-based or microprocessor-based system including systems using microcontrollers, reduced instruction set computers (RISC), ASICs, logic circuits, and any other circuit or processor capable of executing the functions described herein. The above examples are exemplary only, and are thus not intended to limit in any way the definition and/or meaning of these terms. The computer or processor executes a set of instructions that are stored in one or more storage elements, in order to process input data. The storage elements may also store data or other information as desired or needed. The storage

element may be in the form of an information source or a physical memory element within a processing machine.

[0032] The set of instructions may include various commands that instruct the computer or processor as a processing machine to perform specific operations such as the methods and processes of the various embodiments of the invention. The set of instructions may be in the form of a software program. The software may be in various forms such as system software or application software and which may be embodied as a tangible and non-transitory computer readable medium. Further, the software may be in the form of a collection of separate programs or modules, a program module within a larger program or a portion of a program module. The software also may include modular programming in the form of object-oriented programming. The processing of input data by the processing machine may be in response to operator commands, or in response to results of previous processing, or in response to a request made by another processing machine.

[0033] Furthermore, the limitations of the following claims are not written in means-plus-function format and are not intended to be interpreted based on 35 U.S.C. 112, sixth paragraph, unless and until such claim limitations expressly use the phrase “means for” followed by a statement of function devoid of further structure.

1. An ultrasound system comprising:

an array of microconvex ultrasound elements and linear ultrasound elements;

a scan converter, coupled to receive echo signals from the array and render ultrasound images in a desired image format, wherein the echo signals form beams normal to active aperture surfaces along the entire array of microconvex elements and linear elements such that a continuous image field is scanned along the entire array of microconvex elements and linear elements;

an orientation processor, coupled to at least one of the array or the scan converter to produce an image orientation signal which is coupled to the scan converter; and

an ultrasound image display coupled to display images produced by the scan converter in a desired image orientation.

2. The ultrasound system of claim 1, wherein the system further comprises an accelerometer,

wherein the orientation processor is further coupled to receive signals from the accelerometer.

3. The ultrasound system of claim 2, wherein the orientation processor is further configured to detect a direction of gravitational force.

4. The ultrasound system of claim 1,

wherein the orientation processor is further coupled to receive echo signals from the ultrasound elements.

5. The ultrasound system of claim 4, wherein the orientation processor is further configured to identify ring-down signals from ultrasound elements which are not acoustically coupled to a subject.

6. The ultrasound system of claim 1, wherein the orientation processor further comprises an ultrasound image processor.

7. The ultrasound system of claim 6, wherein the orientation processor is further configured to identify a specific feature in an ultrasound image.

8. The ultrasound system of claim 7, wherein the orientation processor is further configured to track a specific feature in a sequence of ultrasound images.

9. The ultrasound system of claim 8, wherein the orientation processor is further configured to track the specific feature in a sequence of ultrasound images by speckle tracking.

10. The ultrasound system of claim 8, wherein the orientation processor is further configured to stabilize a location of the specific feature in the sequence of ultrasound images.

11. The ultrasound system of claim 7, wherein the orientation processor is further configured to identify echo signals returned from a needle.

12. The ultrasound system of claim 11, wherein the orientation processor is further configured to stabilize a location of the needle in a sequence of ultrasound images.

13. The ultrasound system of claim 1, further comprising a beamformer coupled to receive echo signals from ultrasound elements.

14. The ultrasound system of claim 13, further comprising a detector coupled to the beamformer.

15. The ultrasound system of claim 14, further comprising a scanline memory coupled to the detector.

* * * * *

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|----------------|--|---------|------------|
| 专利名称(译) | 外部微型线性超声探头的图像方向识别 | | |
| 公开(公告)号 | US20190223831A1 | 公开(公告)日 | 2019-07-25 |
| 申请号 | US16/306963 | 申请日 | 2017-06-12 |
| [标]申请(专利权)人(译) | 皇家飞利浦电子股份有限公司 | | |
| 申请(专利权)人(译) | 皇家飞利浦N.V. | | |
| 当前申请(专利权)人(译) | 皇家飞利浦N.V. | | |
| [标]发明人 | FREEMAN STEVEN RUSSELL | | |
| 发明人 | FREEMAN, STEVEN RUSSELL | | |
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摘要(译)

使用微型线性超声探头将针插入到具有探针的换能器阵列的微凸部分的受试者中的成像，然后通过旋转使用换能器阵列的线性部分将针朝向目标解剖结构穿透图像。对这个问题的探索。通过用定向信号控制扫描转换器，一致地显示由探头产生的超声图像。取向信号来自对来自探头的加速度计信号的处理，对与对象声学接触的换能器阵列的一部分的识别，和/或对诸如目标的超声图像中的特征的认识或跟踪。解剖学。

