US 20140187946A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2014/0187946 A1
(43) Pub. Date: Jul. 3, 2014
Miller et al.

(54) **ACTIVE ULTRASOUND IMAGING FOR INTERVENTIONAL PROCEDURES**

(71) Applicant: **GENERAL ELECTRIC COMPANY**, Schenectady, NY (US)

(72) Inventors: **James Vradenburg Miller**, Niskayuna, NY (US); **Kedar Anil Patwardhan**, Niskayuna, NY (US)

(73) Assignee: **GENERAL ELECTRIC COMPANY**, Schenectady, NY (US)

(21) Appl. No.: **13/731,213**

(22) Filed: **Dec. 31, 2012**

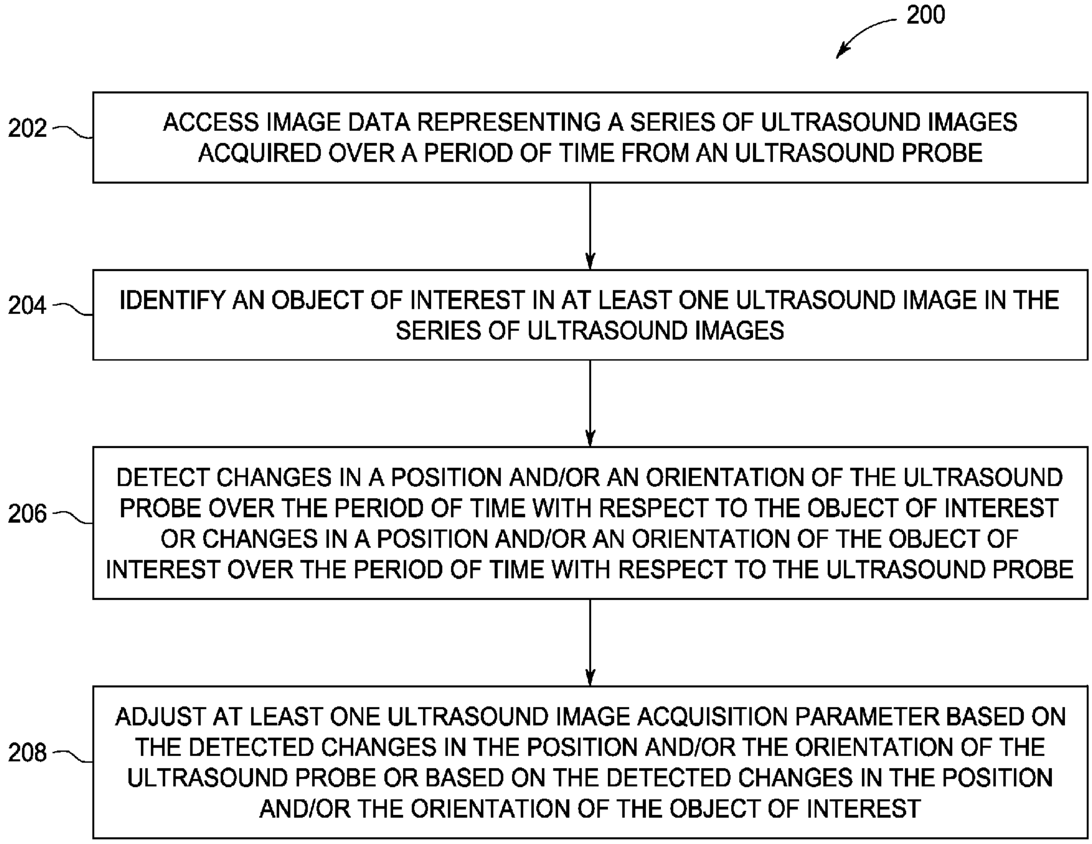
Publication Classification

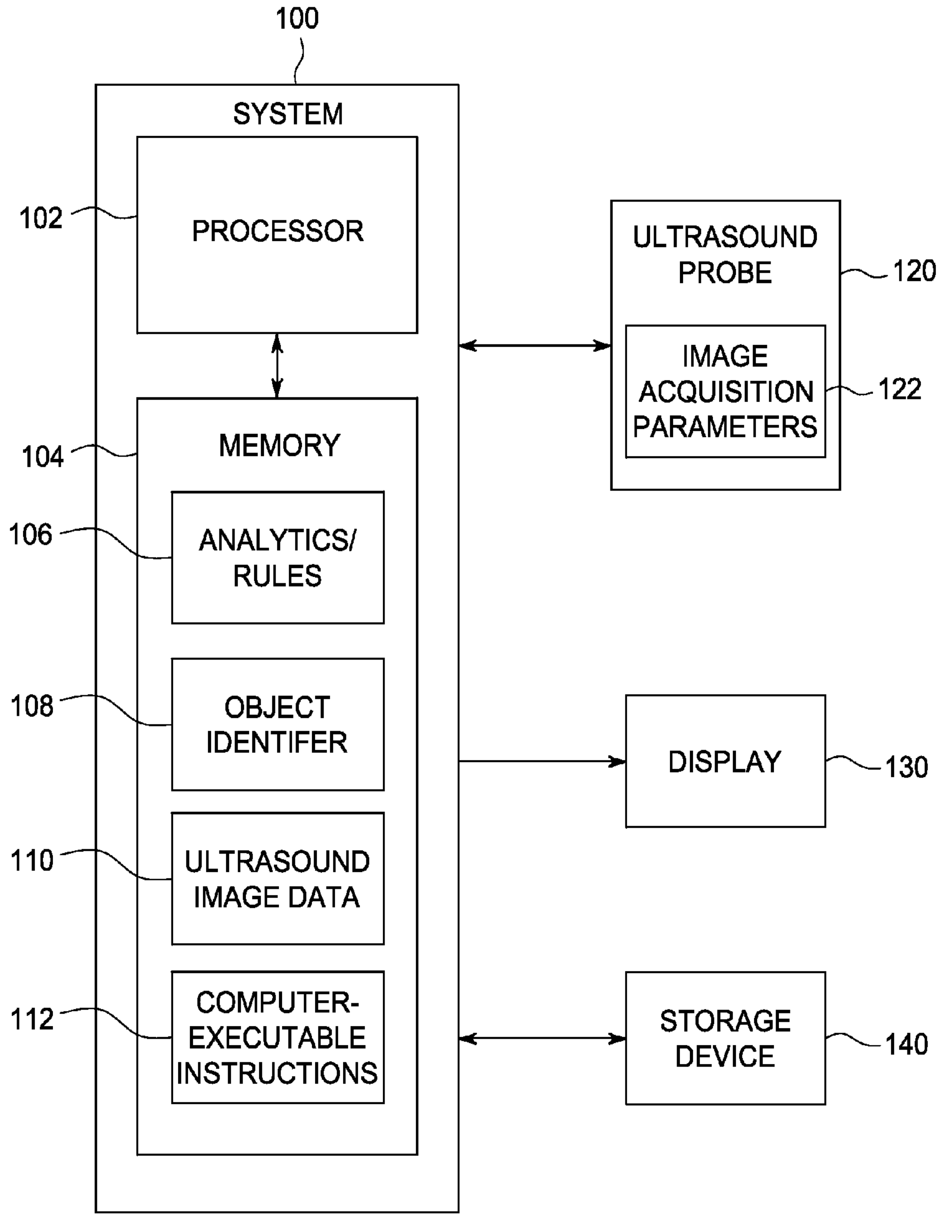
(51) **Int. Cl.**
A61B 8/08 (2006.01)
A61B 8/00 (2006.01)

(52) **U.S. Cl.**
CPC *A61B 8/5207* (2013.01); *A61B 8/0833* (2013.01); *A61B 8/4245* (2013.01); *A61B 8/463* (2013.01)
USPC **600/440**; 600/443

(57) **ABSTRACT**

A computer-implemented method for active control of ultrasound image acquisition includes accessing image data representing a series of ultrasound images acquired over a period of time from an ultrasound probe and identifying an object of interest in at least one of the images. The method further includes detecting changes in a position of the ultrasound probe and/or an orientation of the ultrasound probe over the period of time with respect to the object of interest, or changes in a position of the object of interest and/or an orientation of the object of interest over the period of time with respect to the ultrasound probe. The method further includes adjusting at least one ultrasound image acquisition parameter based on the detected changes in the position and/or the orientation of the ultrasound probe and/or based on the detected changes in the position and/or the orientation of the object of interest.





100
SYSTEM
102
PROCESSOR
104
MEMORY
106
ANALYTICS/ RULES
108
OBJECT IDENTIFER
110
ULTRASOUND IMAGE DATA
112
COMPUTER-EXECUTABLE INSTRUCTIONS
ULTRASOUND PROBE
120
IMAGE ACQUISITION PARAMETERS
122
DISPLAY
130
STORAGE DEVICE
140

FIG. 1

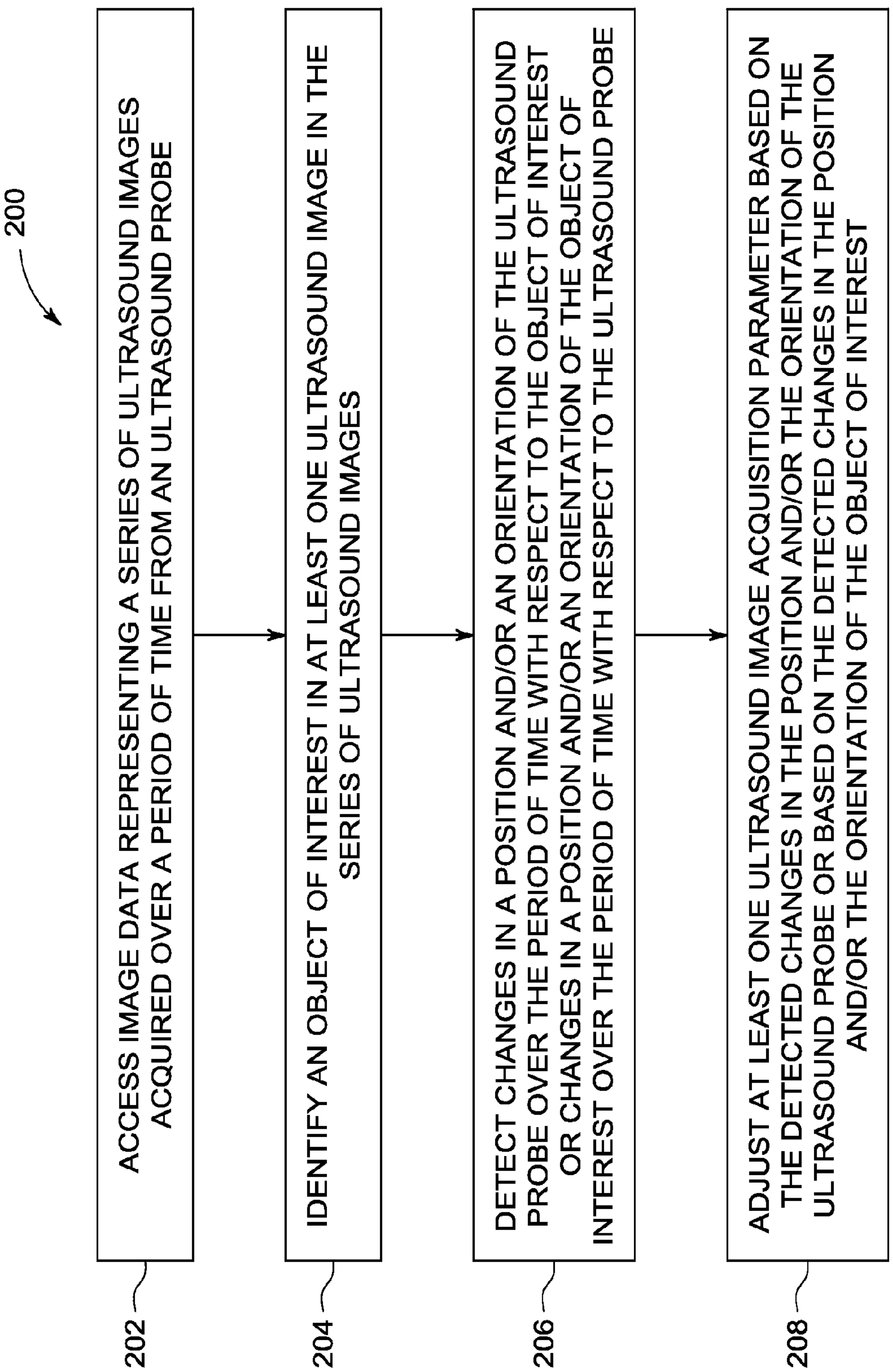

200
202
ACCESS IMAGE DATA REPRESENTING A SERIES OF ULTRASOUND IMAGES ACQUIRED OVER A PERIOD OF TIME FROM AN ULTRASOUND PROBE
204
IDENTIFY AN OBJECT OF INTEREST IN AT LEAST ONE ULTRASOUND IMAGE IN THE SERIES OF ULTRASOUND IMAGES
206
DETECT CHANGES IN A POSITION AND/OR AN ORIENTATION OF THE ULTRASOUND PROBE OVER THE PERIOD OF TIME WITH RESPECT TO THE OBJECT OF INTEREST OR CHANGES IN A POSITION AND/OR AN ORIENTATION OF THE OBJECT OF INTEREST OVER THE PERIOD OF TIME WITH RESPECT TO THE ULTRASOUND PROBE
208
ADJUST AT LEAST ONE ULTRASOUND IMAGE ACQUISITION PARAMETER BASED ON THE DETECTED CHANGES IN THE POSITION AND/OR THE ORIENTATION OF THE ULTRASOUND PROBE OR BASED ON THE DETECTED CHANGES IN THE POSITION AND/OR THE ORIENTATION OF THE OBJECT OF INTEREST

FIG. 2

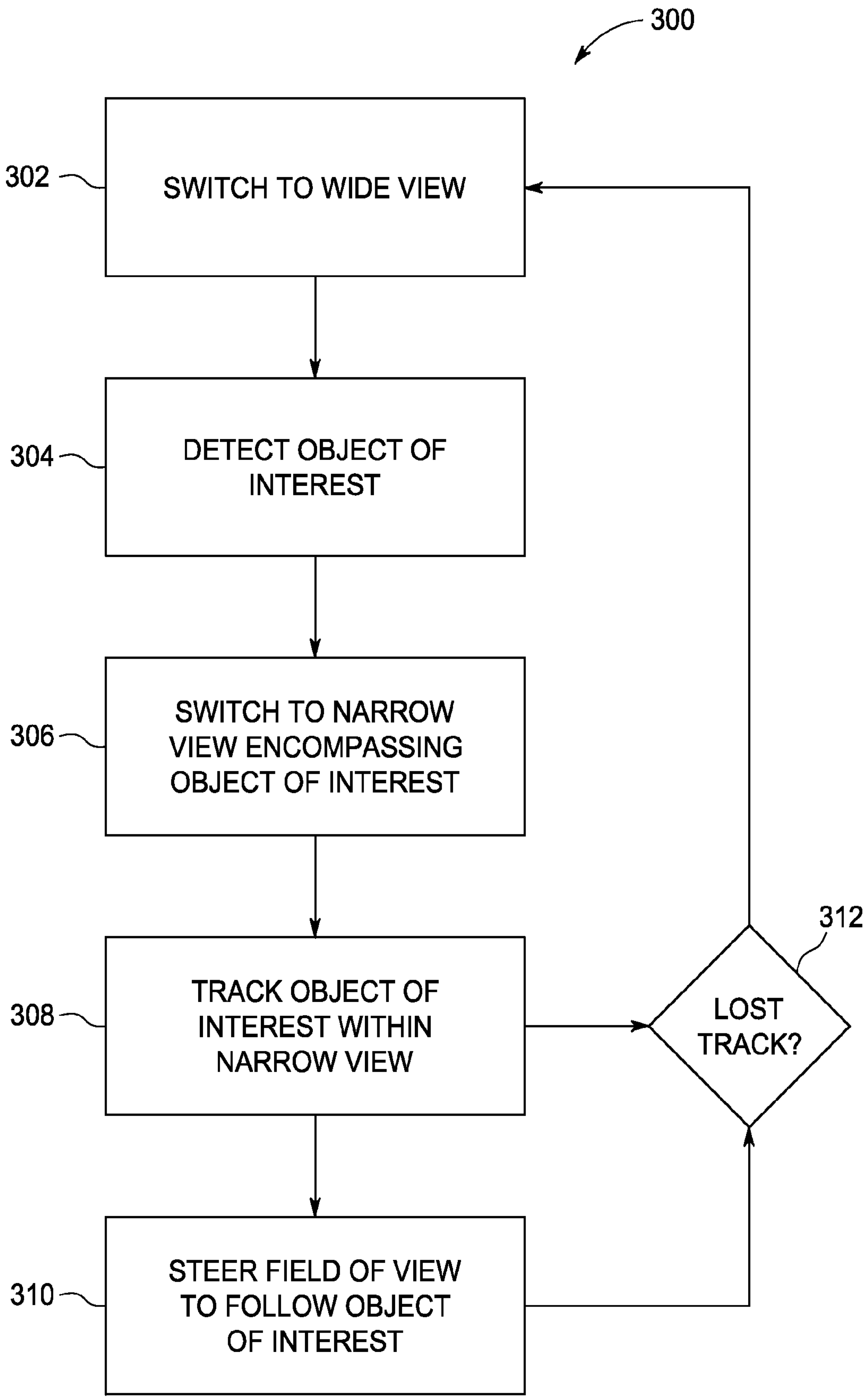

300
302
SWITCH TO WIDE VIEW
304
DETECT OBJECT OF INTEREST
306
SWITCH TO NARROW VIEW ENCOMPASSING OBJECT OF INTEREST
308
TRACK OBJECT OF INTEREST WITHIN NARROW VIEW
310
STEER FIELD OF VIEW TO FOLLOW OBJECT OF INTEREST
312
LOST TRACK?

FIG. 3

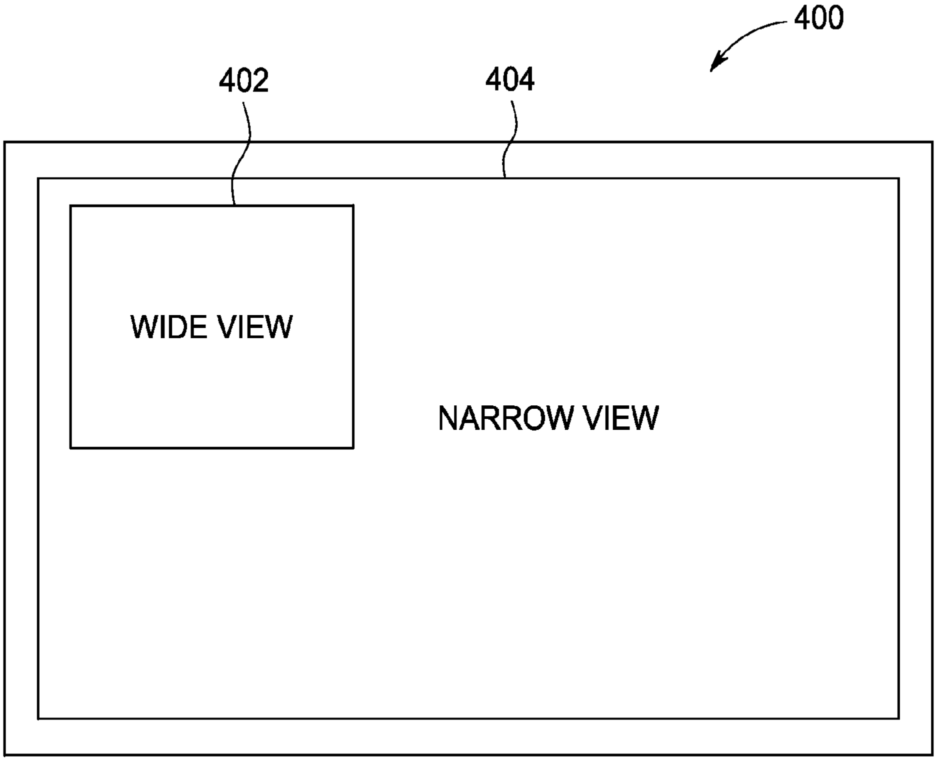

400
402
404
WIDE VIEW
NARROW VIEW

FIG. 4A

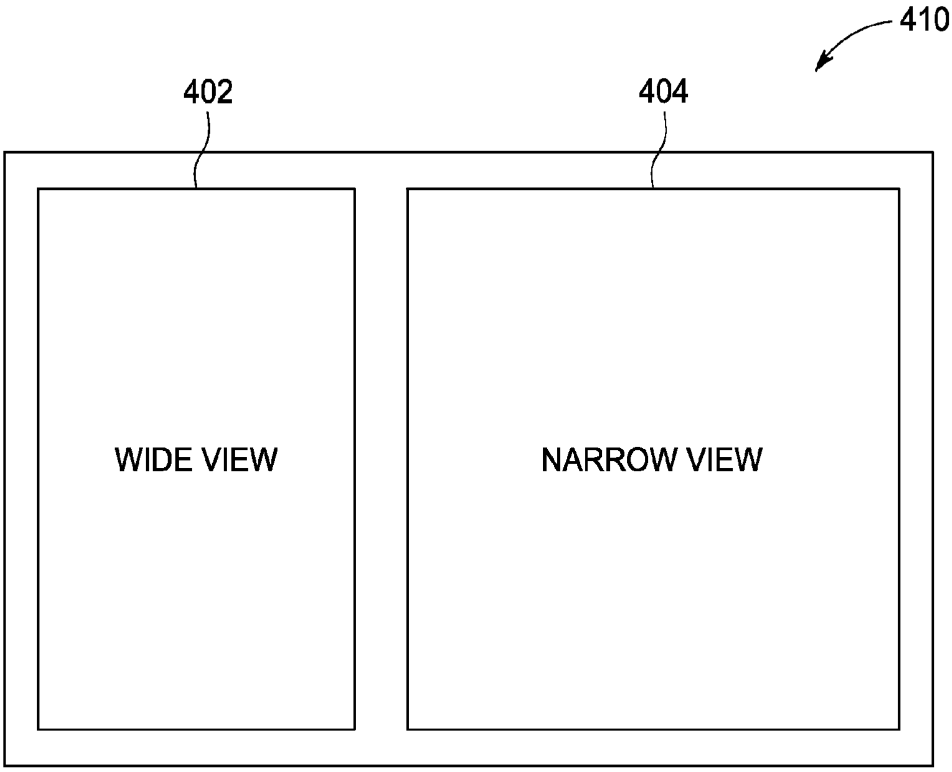

410
402
404
WIDE VIEW
NARROW VIEW

FIG. 4B

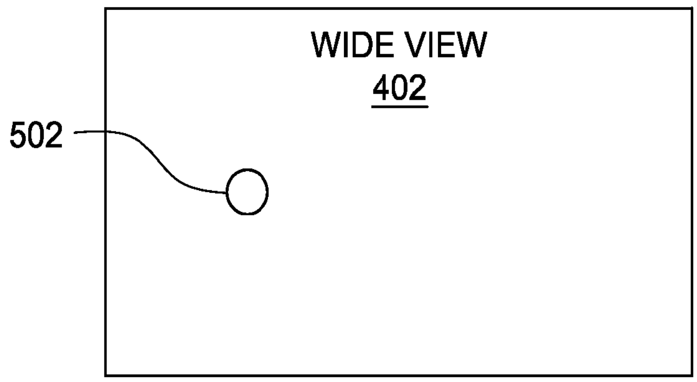


FIG. 5A

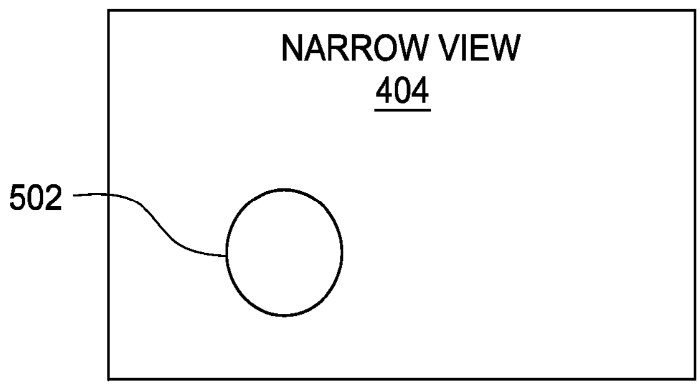


FIG. 5B

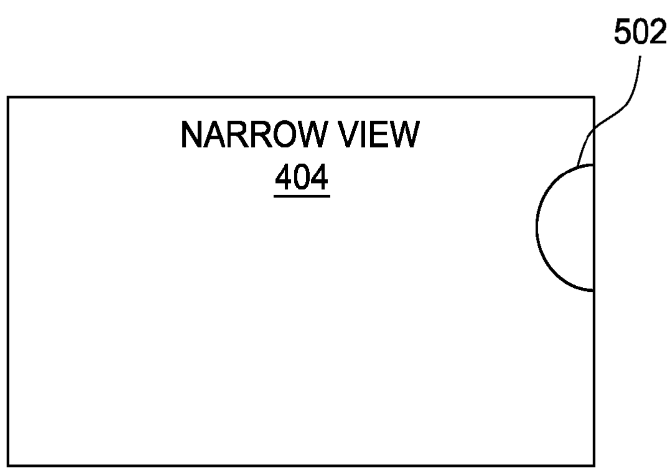


FIG. 5C

ACTIVE ULTRASOUND IMAGING FOR INTERVENTIONAL PROCEDURES

FIELD

[0001] This disclosure relates generally to medical imaging, and more particularly, to systems and methods of active ultrasound imaging for interventional procedures.

BACKGROUND

[0002] Some conventional ultrasound probes have several adjustable image acquisition parameters, including, for example, spatial resolution, field of view, frame rate, and depth and frequency of the ultrasound signal. These parameters can be adjusted manually by a physician or clinician during an interventional procedure as needed. However, adjusting or changing one image acquisition parameter can affect other image acquisition parameters due to certain performance limitations of the ultrasound probe. For instance, widening the field of view may require decreasing the resolution, while increasing the spatial resolution may require narrowing the field of view.

[0003] While performing an interventional ultrasound scanning procedure, initially the user may manually select a wide field of view, at a low resolution, for locating and identifying an object of interest in the patient, and then manually switch to a narrower field of view encompassing the object of interest at a higher resolution. In addition to positioning and orienting the ultrasound probe, the manual switching of parameters involves additional inputs from the user. Thus, it can be difficult to manually adjust various image acquisition parameters, such as spatial resolution, field of view, frame rate, depth and frequency, while simultaneously manipulating the position and orientation of the ultrasound probe.

SUMMARY

[0004] According to one embodiment, a computer includes a processor and a memory operatively coupled to the processor. A computer-implemented method for active control of ultrasound image acquisition using the computer includes accessing, by the processor, image data representing a series of ultrasound images acquired over a period of time from an ultrasound probe operatively coupled to the processor. The method further includes identifying, by the processor, an object of interest in at least one ultrasound image in the series of ultrasound images, and detecting, by the processor, changes in a position of the ultrasound probe and/or an orientation of the ultrasound probe over the period of time with respect to the object of interest, and/or detecting changes in a position of the object of interest and/or an orientation of the object of interest over the period of time with respect to the ultrasound probe. The method further includes adjusting, by the processor, at least one ultrasound image acquisition parameter for acquiring at least one additional ultrasound image using the ultrasound probe based on the detected changes in the position and/or the orientation of the ultrasound probe, and/or at least one ultrasound image acquisition parameter for acquiring at least one additional ultrasound image using the ultrasound probe based on the detected changes in the position and/or the orientation of the object of interest.

[0005] In some embodiments, at least one of the ultrasound image acquisition parameters may include a depth of a signal emitted by the ultrasound probe, a frequency of the signal emitted by the ultrasound probe, a spatial resolution of the ultrasound image, a field of view of the ultrasound image, and/or an acquisition frame rate of the ultrasound image.

[0006] In some embodiments, the step of adjusting may include increasing or decreasing the spatial resolution such that the object of interest is visible within the at least one additional ultrasound image based on a set of predefined rules, increasing or decreasing the field of view such that the object of interest appears in the at least one additional ultrasound image based on the set of predefined rules, increasing or decreasing the acquisition frame rate based on the set of predefined rules, increasing or decreasing the depth of the signal based on the set of predefined rules, and/or increasing or decreasing the frequency of the signal based on the set of predefined rules.

[0007] In some embodiments, the step of adjusting may include automatically steering the field of view based on the detected changes in the position and/or the orientation of the ultrasound probe and/or the object of interest such that the object of interest remains substantially encompassed within the field of view.

[0008] In some embodiments, the method may further include simultaneously displaying a wide field of view and a narrow field of view via a user interface operatively coupled to the processor.

[0009] In some embodiments, the object of interest may include an anatomical structure in a patient, a surgical instrument inserted into the patient, a device, and/or a marker placed into the patient. In some embodiments, the step of identifying the object of interest may include using one or more image analysis techniques including low level feature detection, statistical model fitting, machine learning, and/or image and model registration. In some embodiments, at least one of the steps of identifying, detecting and adjusting may be further based at least in part on concurrent multimodal input information (e.g., ultrasound and X-ray inputs).

[0010] According to one embodiment, a non-transitory computer-readable medium has stored thereon computer-executable instructions that when executed by a computer cause the computer to receive data representing a series of ultrasound images acquired over a period of time from an ultrasound probe operatively coupled to the processor, identify an object of interest in at least one ultrasound image in the series of ultrasound images, detect changes in a position of the ultrasound probe and/or an orientation of the ultrasound probe over the period of time with respect to the object of interest, and/or detect changes in a position of the object of interest and/or an orientation of the object of interest over the period of time with respect to the ultrasound probe, and adjust at least one ultrasound image acquisition parameter for acquiring at least one additional ultrasound image using the ultrasound probe based on the detected changes in the position and/or the orientation of the ultrasound probe, and/or at least one ultrasound image acquisition parameter for acquiring at least one additional ultrasound image using the ultrasound probe based on the detected changes in the position and/or the orientation of the object of interest.

[0011] In some embodiments, the computer-readable medium may further include computer-executable instructions that when executed by the computer cause the computer to increase or decrease the spatial resolution such that the object of interest is visible within the at least one additional ultrasound image based on a set of predefined rules, increase or decrease the field of view such that the object of interest appears in the at least one additional ultrasound image based on the set of predefined rules, increase or decrease the acquisition frame rate based on the set of predefined rules, increase or decrease the depth of the signal based on the set of predefined rules, and/or increase or decrease the frequency of the signal based on the set of predefined rules.

[0012] In some embodiments, the computer-readable medium may further include computer-executable instructions that when executed by the computer cause the computer to automatically steer the field of view based on the detected changes in the position and/or the orientation of the ultrasound probe and/or the object of interest such that the object of interest remains substantially encompassed within the field of view.

[0013] In some embodiments, the computer-readable medium may further include computer-executable instructions that when executed by the computer cause the computer to simultaneously display a wide field of view and a narrow field of view via a user interface operatively coupled to the processor.

[0014] In some embodiments, the computer-readable medium may further include computer-executable instructions that when executed by the computer cause the computer to identify the object of interest by using one or more image analysis techniques including low level feature detection, statistical model fitting, machine learning, and image and model registration.

[0015] According to one embodiment, a system for active control of ultrasound image acquisition includes a processor, an input operatively coupled to the processor and configured to receive data representing a series of ultrasound images, and a memory operatively coupled to the processor. The memory includes computer-executable instructions that when executed by the processor cause the processor to receive data representing a series of ultrasound images acquired over a period of time from an ultrasound probe operatively coupled to the processor, identify an object of interest in at least one ultrasound image in the series of ultrasound images, detect changes in a position of the ultrasound probe and/or an orientation of the ultrasound probe over the period of time with respect to the object of interest, and/or detect changes in a position of the object of interest and/or an orientation of the object of interest over the period of time with respect to the ultrasound probe, and adjust at least one ultrasound image acquisition parameter for acquiring at least one additional ultrasound image using the ultrasound probe based on the detected changes in the position and/or the orientation of the ultrasound probe, and/or at least one ultrasound image acquisition parameter for acquiring at least one additional ultrasound image using the ultrasound probe based on the detected changes in the position and/or the orientation of the object of interest.

[0016] In some embodiments, the memory may further include computer-executable instructions that when executed by the processor cause the processor to increase or decrease the spatial resolution such that the object of interest is visible within the at least one additional ultrasound image based on a set of predefined rules, increase or decrease the field of view such that the object of interest appears in the at least one additional ultrasound image based on the set of predefined rules, increase or decrease the acquisition frame rate based on the set of predefined rules, increase or decrease the depth of the signal based on the set of predefined rules, and/or increase or decrease the frequency of the signal based on the set of predefined rules.

[0017] In some embodiments, the memory may further include computer-executable instructions that when executed by the processor cause the processor to automatically steer the field of view based on the detected changes in the position and/or the orientation of the ultrasound probe and/or the object of interest such that the object of interest remains substantially encompassed within the field of view.

[0018] In some embodiments, the memory may further include computer-executable instructions that when executed by the computer cause the computer to simultaneously display a wide field of view and a narrow field of view via a user interface operatively coupled to the processor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Features and aspects of embodiments are described below with reference to the accompanying drawings, in which elements are not necessarily depicted to scale.

[0020] FIG. **1** is a block diagram of an example of a system for analyzing an ultrasound image, in accordance with an embodiment.

[0021] FIG. **2** is a flow diagram of an example of a process for analyzing an ultrasound image, in accordance with an embodiment.

[0022] FIG. **3** is a flow diagram of an example of a process for analyzing an ultrasound image, in accordance with an embodiment.

[0023] FIGS. **4**A and **4**B depict examples of a display interface for displaying ultrasound images, in accordance with some embodiments.

[0024] FIGS. **5**A, **5**B and **5**C depict examples of various fields of view of ultrasound images, in accordance with some embodiments.

DETAILED DESCRIPTION

[0025] Various embodiments of the present disclosure are directed to active ultrasound imaging for interventional procedures. In some embodiments, one or more ultrasound image acquisition parameters can be automatically controlled based on a context in which the user is using an ultrasonic probe.

[0026] According to some embodiments, a computer-implemented image processing method, which may be performed in real-time (e.g., contemporaneously), provides active control of one or more image acquisition parameters during the scan process by detecting an object of interest in the ultrasound image and tracking changes in the position and/or the orientation of the object of interest, or by tracking changes in the position and/or the orientation of the ultrasound probe. Such changes may be indicative of a context in which the user is operating the ultrasound probe. The context can be used as a basis for selecting individual image acquisition parameters or combinations of parameters that provide the most advantageous visualizations within the context. For example, while the user is guiding a surgical instrument into position within a patient, the ultrasound imaging can automatically be switched from a wide field of view for providing a broad anatomical context at a low spatial resolution and frame rate, to a narrow field of view for providing a detailed, high resolution view of the tool at a high frame rate. The former provides the user with a broad anatomical context, while the latter provides the user with a detailed view for precisely manipulating the tool or other device into position. In another example, if the surgical instrument disappears from the narrow field of view, or if the user displaces the position and/or orientation of the ultrasound probe such that the instrument is no longer within the field of view, the ultrasound imaging can automatically be switched back from the narrow field of view to the wide field of view to permit the user to re-locate the instrument in the broad anatomical view.

[0027] FIG. **1** is a block diagram of an example of a system **100** for analyzing an ultrasound image, according to an embodiment. The system **100** includes a computer having a processor **102** and a memory **104** operatively coupled to the processor **102**. The memory is configured to store data representing analytics and/or rules **106** for processing an ultrasound image and an object identifier **108**. The memory is further configured to store ultrasound image data **110** representing the ultrasound image, and computer-executable instructions **112** that can be executed by the processor **102** to implement, for example, detection and tracking of an object of interest in the ultrasound image and for displaying the ultrasound image. The system **100** may be operatively coupled to an ultrasound probe **120** for receiving the ultrasound image data **110** therefrom and sending image acquisition parameters **122** thereto. The system **100** may be operatively coupled to a display **130** for displaying ultrasound images. The system **100** may be operatively coupled to a storage device **140** for storing and/or retrieving, for example, data representing image data, training data, statistical model data and/or computer-executable instructions.

[0028] FIG. **2** is a flow diagram of an example of a process **200** for analyzing an ultrasound image, according to an embodiment. At step **202**, image data representing a series of ultrasound images acquired over a period of time from an ultrasound probe is accessed. For example, the series of ultrasound images may be generated as an user manipulates the ultrasound probe. The images can be accessed at substantially the same time as the ultrasound probe is acquiring image data (e.g., in real-time or contemporaneously). At step **204**, an object of interest in at least one in the series of ultrasound images is identified. The object of interest may include, for example, an anatomical structure in a patient (e.g., an organ, tissue, bone, etc.), a surgical instrument inserted into the patient, a device (e.g., a valve, a pacemaker lead, a cathode ray tube (CRT) lead, a plug, etc.), or a marker placed into the patient. In some embodiments, a portion of a tool, such as the tip, can be the object of interest.

[0029] The object identifier **108** of FIG. **1** can be used to identify the object of interest. For example, the object identifier **108** may include a statistical model representing an image of a known object. The object of interest may be identified by comparison to the statistical model. Other techniques known in the art may be utilized, including low level feature detection, statistical model fitting, machine learning, and image and model registration. In some embodiments, the object of interest can be identified based on inputs received from one or more modalities other than ultrasound images (e.g., X-ray images).

[0030] At step **206**, changes in a position of the ultrasound probe and/or an orientation of the ultrasound probe over the period of time with respect to the object of interest are detected. In some embodiments, changes in a position of the object of interest and/or an orientation of the object of interest over the period of time with respect to the ultrasound probe are detected. In some embodiments, a combination of changes in the position and/or orientation of the object of interest and the ultrasound probe are detected. The detected changes can be applied to a set of analytics or predefined rules (e.g., the analytics **106** of FIG. **1**) for determining a context in which the user is using the ultrasound probe. For example, rapid or large changes to the position and/or orientation of the ultrasound probe may indicate that the user is searching for the object of interest, where a broad anatomical view is advantageous. In another example, small or incremental changes to the position and/or orientation of the ultrasound probe may indicate that the user has located the object of interest and is attempting to obtain more precise or detailed images of it, where a narrower, more detailed view is advantageous. Thus, depending on the context, the ultrasound image acquisition parameters can be changed to accommodate the context, such as discussed below with respect to step **208**.

[0031] At step **208**, at least one ultrasound image acquisition parameter for acquiring at least one additional ultrasound image using the ultrasound probe based on the detected changes in the position and/or the orientation of the ultrasound probe is adjusted. In some embodiments, at least one ultrasound image acquisition parameter for acquiring at least one additional ultrasound image using the ultrasound probe based on the detected changes in the position and/or the orientation of the object of interest is adjusted. In some embodiments, at least one ultrasound image acquisition parameter for acquiring at least one additional ultrasound image using the ultrasound probe based on the detected changes in the position and/or the orientation of the object of interest and the ultrasound probe is adjusted. The ultrasound image acquisition parameter can include a spatial resolution of the ultrasound image, a field of view of the ultrasound image, a depth of the ultrasound signal, a frequency of the ultrasound signal, and/or an acquisition frame rate of the ultrasound image. The field of view can include a direction (e.g., in three-dimensional image acquisition, the field of view is defined by the angles or direction of multiple ultrasonic signals) and/or an angular aperture of the ultrasound signal emitted by the ultrasound probe. In one example, adjusting the field of view includes increasing (e.g., widening) the field of view or decreasing (e.g., narrowing) the field of view. In another example, adjusting the field of view includes steering or shifting the field of view such that the object of interest remains substantially encompassed within the field of view as the object of interest moves with respect to the ultrasound probe and/or as the ultrasound probe moves with respect to the object of interest. In another example, adjusting the spatial resolution includes increasing or decreasing the spatial resolution of the ultrasound image acquired by the ultrasound probe. In yet another example, adjusting the frame rate includes increasing or decreasing the rate at which frames of the ultrasound image are acquired by the ultrasound probe. In yet another example, acquisition of the ultrasound image can be automatically switched between two- and three-dimensional views and/or single or multiple scan planes.

[0032] Computer-executable instructions (e.g., the computer-executable instructions **112** of FIG. **1**) may, for example, be executed by a processor (e.g., the processor **102**) to perform steps **202-208** in accordance with one or more embodiments described herein.

[0033] FIG. **3** is a flow diagram of an example of a process **300** for adjusting image acquisition parameters of an ultrasound image, according to an embodiment. At step **302**, the field of view is switched to a wide view. As discussed above, a wide field of view may be useful when the user is attempting to locate the object of interest within a patient. For example, the wide view may provide an ultrasound image that covers a relatively large anatomical region, which may be useful while the user is attempting to locate the object of interest (e.g., surgical tool, anatomical structure, etc.). Depending on the configuration of the ultrasound probe, it may be necessary, for example, to reduce the spatial resolution of the ultrasound image and/or decrease the image acquisition frame rate while acquiring a wide field of view.

[0034] At step **304**, the object of interest is identified using, for example, the object identifier **108** of FIG. **1**. The object of interest may include, for example, an anatomical structure in a patient (e.g., an organ, tissue, bone, etc.), a surgical instrument inserted into the patient, a device (e.g., a valve, a pacemaker lead, a cardiac resynchronization therapy device (CRT) lead, a plug, etc.), or a marker placed into the patient. In some embodiments, a portion of a tool, such as the tip, can be the object of interest. The object of interest may, for example, be identified and detected by comparison with a statistical model (e.g., acquired from training data representing known objects) or by using other medical image analysis techniques, as will be understood by one of skill in the art.

[0035] Once the object of interest has been detected, at step **306**, the field of view is automatically switched to a narrow view. For example, the narrow view may provide an ultrasound image that covers a relatively small anatomical region. As discussed above, a narrow field of view may be useful when the user is attempting to observe the object of interest in greater detail. Depending on the configuration of the ultrasound probe, it may be possible, for example, to increase the spatial resolution of the ultrasound image and/or increase the image acquisition frame rate while acquiring a narrow field of view so as to provide greater detail in the ultrasound image.

[0036] In some embodiments, at step **308**, the object of interest can be tracked automatically. For example, if the object of interest and/or the ultrasound probe moves with respect to the other, the image acquisition parameters can be automatically adjusted to maintain the object of interest within the field of view. At step **310**, the field of view is automatically steered or adjusted to follow certain motion of the object of interest and/or the ultrasound probe so as to maintain the object of interest within the field of view. Such steering may be obtained, for example, by adjusting the depth and/or frequency of the ultrasound probe. In some embodiments, annotations can be provided within the visualization that direct the user to manipulate the ultrasound probe in a manner that places or maintains the object of interest within the field of view. In some embodiments, the annotations direct the user to manipulate the device or tool to place or maintain the device or tool within the field of view. It will be understood, however, that beyond a certain limit of motion of the object of interest and/or the ultrasound probe (e.g., within the tolerances and capabilities of the ultrasound probe and/or the image analysis and processing algorithms), the object of interest can no longer be tracked (i.e., the tracking is lost). At step **312**, if tracking of the object of interest is lost (i.e., no longer obtainable), then process **300** returns to step **302**, where the field of view is automatically switched to a wide view. This enables the user to re-locate the object of interest, as described above.

[0037] Computer-executable instructions (e.g., the computer-executable instructions **112** of FIG. **1**) may, for example, be executed by a processor (e.g., the processor **102**) to perform steps **302**-**312** in accordance with one or more embodiments described herein.

[0038] FIG. **4**A depicts one example of a user interface display **400** for displaying one or more ultrasound images, according to an embodiment. In the user interface display **400**, both a wide field of view **402** and a narrow field of view **404** can be displayed concurrently, with the wide field of view **402** overlaying a portion of the narrow field of view **404**. In this manner both the detailed, narrow field of view **404** and the less detailed, wide field of view may be observed simultaneously in the same user interface display **400**. In some embodiments, the wide field of view **402** and/or the narrow field of view **404** includes a two- or three-dimensional image. In some embodiments, the wide field of view **402** and/or the narrow field of view **404** includes a multi-planar ultrasound image.

[0039] FIG. **4**B depicts another example of a user interface display **410** for displaying one or more ultrasound images, according to an embodiment. The user interface display **410** is substantially similar to the user interface display **400** of FIG. **4**A, except that the wide field of view **402** and the narrow field of view **404** can be displayed side-by-side. It will be understood that the user interface displays **400**, **410** are exemplary and that other configurations and arrangements of the wide and narrow fields of view **402** and **404** can be utilized in conjunction with various embodiments.

[0040] FIG. **5**A depicts one example of the wide field of view **402** encompassing an object of interest **502**. In some embodiments, after the object of interest **502** is detected, the field of view can automatically switch to the narrow field of view **404** such as depicted, for example, in FIG. **5**B, in which the object of interest **502** can be displayed at a larger scale than in the wide field of view **402**. If the object of interest **502** subsequently changes positions such that at least a portion of the object of interest **502** is no longer encompassed within the narrow field of view **404**, such as depicted, for example, in FIG. **5**C, the field of view can automatically switch back to the wide field of view **402** as depicted in the example of FIG. **5**A.

[0041] Systems and methods disclosed herein may include one or more programmable processing units having associated therewith executable instructions held on one or more non-transitory computer readable medium, RAM, ROM, hard drive, and/or hardware. In exemplary embodiments, the hardware, firmware and/or executable code may be provided, for example, as upgrade module(s) for use in conjunction with existing infrastructure (for example, existing devices/processing units). Hardware may, for example, include components and/or logic circuitry for executing the embodiments taught herein as a computing process.

[0042] Displays and/or other feedback components may also be included, for example, for rendering a graphical user interface, according to the present disclosure. The display and/or other feedback components may be stand-alone equipment or may be included as one or more components/modules of the processing unit(s). In exemplary embodiments, the display and/or other feedback components may be used to simultaneously describe both morphological and statistical representations of a field-of-view of an ultrasound image.

[0043] The actual software code or control hardware which may be used to implement some of the present embodiments is not intended to limit the scope of such embodiments. For example, certain aspects of the embodiments described herein may be implemented in code using any suitable programming language type such as, for example, assembly code, C, C# or C++ using, for example, conventional or object-oriented programming techniques. Such code is stored or held on any type of suitable non-transitory computer-readable medium or media such as, for example, a magnetic or optical storage medium.

[0044] As used herein, a "processor," "processing unit," "computer" or "computer system" may be, for example, a wireless or wire line variety of a microcomputer, minicomputer, server, mainframe, laptop, personal data assistant (PDA), wireless e-mail device (for example, "BlackBerry," "Android" or "Apple," trade-designated devices), cellular phone, pager, processor, fax machine, scanner, or any other programmable device configured to transmit and receive data over a network. Computer systems disclosed herein may include memory for storing certain software applications used in obtaining, processing and communicating data. It can be appreciated that such memory may be internal or external to the disclosed embodiments. The memory may also include non-transitory storage medium for storing software, including a hard disk, an optical disk, floppy disk, ROM (read only memory), RAM (random access memory), PROM (programmable ROM), EEPROM (electrically erasable PROM), flash memory storage devices, or the like.

[0045] The system **100** of FIG. **1** may be any computer system, such as a workstation, desktop computer, server, laptop, handheld computer, tablet computer (e.g., the iPad® tablet computer), mobile computing or communication device (e.g., the iPhone® mobile communication device, the Android® mobile communication device, and the like), or other form of computing or telecommunications device that is capable of communication and that has sufficient processor power and memory capacity to perform the operations described herein. In exemplary embodiments, a distributed computational system may be provided including a plurality of such computing devices.

[0046] The system **100** may include one or more non-transitory computer-readable media having encoded thereon one or more computer-executable instructions or software for implementing the exemplary methods described herein. The non-transitory computer-readable media may include, but are not limited to, one or more types of hardware memory and other tangible media (for example, one or more magnetic storage disks, one or more optical disks, one or more USB flash drives), and the like. For example, the memory **104** included in the system **100** may store computer-readable and computer-executable instructions or software for implementing a graphical user interface as described herein. The processor **102**, and in some embodiments, one or more additional processor(s) and associated core(s) (for example, in the case of computer systems having multiple processors/cores), are configured to execute computer-readable and computer-executable instructions or software stored in the memory **104** and other programs for controlling system hardware. Processor **102** may be a single core processor or a multiple core processor.

[0047] The memory **104** may include a computer system memory or random access memory, such as DRAM, SRAM, EDO RAM, and the like. The memory **104** may include other types of memory as well, or combinations thereof.

[0048] A user may interact with the system **100** through the display **130**, which may display ultrasound images and other information in accordance with exemplary embodiments described herein. The display **130** may also display other aspects, elements and/or information or data associated with exemplary embodiments. The system **100** may include other I/O devices for receiving input from a user, for example, a keyboard or any suitable multi-point touch interface, a pointing device (e.g., a mouse, a user's finger interfacing directly with a display device, etc.). The system **100** may include other suitable conventional I/O peripherals.

[0049] The system **100** may include one or more storage devices **140**, such as a durable disk storage (which may include any suitable optical or magnetic durable storage device, e.g., RAM, ROM, Flash, USB drive, or other semiconductor-based storage medium), a hard-drive, CD-ROM, or other computer readable media, for storing data and computer-readable instructions and/or software that implement exemplary embodiments as taught herein. In exemplary embodiments, the one or more storage devices **140** may provide storage for data that may be generated by the systems and methods of the present disclosure. For example, storage device **140** may provide storage for image data and/or storage for data analysis (e.g., storage for results of parameters for any of the image or statistical analyses described herein such as image segmentation results). The one or more storage devices **140** may further provide storage for computer readable instructions relating to one or more processes as described herein. The one or more storage devices **140** may be provided on the system **100** and/or provided separately or remotely from the system **100**.

[0050] The system **100** may run any operating system, such as any of the versions of the Microsoft® Windows® operating systems, the different releases of the Unix and Linux operating systems, any version of the MacOS® for Macintosh computers, any embedded operating system, any real-time operating system, any open source operating system, any proprietary operating system, any operating systems for mobile computing devices, or any other operating system capable of running on the computing device and performing the operations described herein. In exemplary embodiments, the operating system may be run in native mode or emulated mode. In an exemplary embodiment, the operating system may be run on one or more cloud machine instances.

[0051] Having thus described several exemplary embodiments of the invention, it is to be appreciated various alterations, modifications, and improvements will readily occur to those skilled in the art. For example, while in some embodiments the object of interest can be identified and tracked as discussed above (e.g., using a single modality such as the ultrasound image input), in some embodiments, the object of interest may be identified and/or tracked, at least in part, using concurrent multimodal input information (e.g., ultrasound and X-ray inputs). In another example, the field of views of one or all modalities may be adjusted to optimize the tracking and acquisition of clinically useful objects of interest. Such alterations, modifications, and improvements are intended to be part of this disclosure, and are intended to be within the scope of the invention. Accordingly, the foregoing description and drawings are by way of example only.

What is claimed is:

1. A computer-implemented method for active control of ultrasound image acquisition, the computer including a processor and a memory operatively coupled to the processor, the method comprising:
 accessing, by the processor, image data representing a series of ultrasound images acquired over a period of time from an ultrasound probe operatively coupled to the processor;
 identifying, by the processor, an object of interest in at least one ultrasound image in the series of ultrasound images;
 detecting, by the processor, at least one of:
  changes in at least one of a position of the ultrasound probe and an orientation of the ultrasound probe over the period of time with respect to the object of interest; and
  changes in at least one of a position of the object of interest and an orientation of the object of interest over the period of time with respect to the ultrasound probe; and
 adjusting, by the processor, at least one of:
  at least one ultrasound image acquisition parameter for acquiring at least one additional ultrasound image using the ultrasound probe based on the detected changes in the position and/or the orientation of the ultrasound probe; and
  at least one ultrasound image acquisition parameter for acquiring at least one additional ultrasound image using the ultrasound probe based on the detected changes in the position and/or the orientation of the object of interest.

2. The computer-implemented method of claim **1**, wherein the at least one ultrasound image acquisition parameter comprises at least one of:
 a depth of a signal emitted by the ultrasound probe;
 a frequency of the signal emitted by the ultrasound probe;
 a spatial resolution of the ultrasound image;
 a field of view of the ultrasound image; and
 an acquisition frame rate of the ultrasound image.

3. The computer-implemented method of claim **2**, wherein the step of adjusting comprises at least one of:
 increasing or decreasing the spatial resolution such that the object of interest is visible within the at least one additional ultrasound image based on a set of predefined rules;
 increasing or decreasing the field of view such that the object of interest appears in the at least one additional ultrasound image based on the set of predefined rules;
 increasing or decreasing the acquisition frame rate based on the set of predefined rules;
 increasing or decreasing the depth of the signal based on the set of predefined rules; and
 increasing or decreasing the frequency of the signal based on the set of predefined rules.

4. The computer-implemented method of claim **2**, wherein the step of adjusting comprises automatically steering the field of view based on the detected changes in the position and/or the orientation of the ultrasound probe and/or the object of interest such that the object of interest remains substantially encompassed within the field of view.

5. The computer-implemented method of claim **2**, further comprising simultaneously displaying a wide field of view and a narrow field of view via a user interface operatively coupled to the processor.

6. The computer-implemented method of claim **1**, wherein the object of interest comprises at least one of an anatomical structure in a patient, a surgical instrument inserted into the patient, a device, and a marker placed into the patient.

7. The computer-implemented method of claim **1**, wherein the step of identifying the object of interest comprises using one or more image analysis techniques including:
 low level feature detection;
 statistical model fitting;
 machine learning; and
 image and model registration.

8. The computer-implemented method of claim **1**, wherein at least one of the steps of identifying, detecting and adjusting are further based at least in part on concurrent multimodal input information.

9. A non-transitory computer-readable medium having stored thereon computer-executable instructions that when executed by a computer cause the computer to:
 receive data representing a series of ultrasound images acquired over a period of time from an ultrasound probe operatively coupled to the processor;
 identify an object of interest in at least one ultrasound image in the series of ultrasound images;
 detect at least one of:
  changes in at least one of a position of the ultrasound probe and an orientation of the ultrasound probe over the period of time with respect to the object of interest; and
  changes in at least one of a position of the object of interest and an orientation of the object of interest over the period of time with respect to the ultrasound probe; and
 adjust at least one of:
  at least one ultrasound image acquisition parameter for acquiring at least one additional ultrasound image using the ultrasound probe based on the detected changes in the position and/or the orientation of the ultrasound probe; and
  at least one ultrasound image acquisition parameter for acquiring at least one additional ultrasound image using the ultrasound probe based on the detected changes in the position and/or the orientation of the object of interest.

10. The computer-readable medium of claim **9**, wherein the at least one ultrasound image acquisition parameter comprises at least one of:
 a depth of a signal emitted by the ultrasound probe;
 a frequency of the signal emitted by the ultrasound probe;
 a spatial resolution of the ultrasound image,
 a field of view of the ultrasound image, and
 an acquisition frame rate of the ultrasound image.

11. The computer-readable medium of claim **10**, further comprising computer-executable instructions that when executed by the computer cause the computer to at least one of:
 increase or decrease the spatial resolution such that the object of interest is visible within the at least one additional ultrasound image based on a set of predefined rules;
 increase or decrease the field of view such that the object of interest appears in the at least one additional ultrasound image based on the set of predefined rules;
 increase or decrease the acquisition frame rate based on the set of predefined rules;

increase or decrease the depth of the signal based on the set of predefined rules; and

increase or decrease the frequency of the signal based on the set of predefined rules.

12. The computer-readable medium of claim **10**, further comprising computer-executable instructions that when executed by the computer cause the computer to automatically steer the field of view based on the detected changes in the position and/or the orientation of the ultrasound probe and/or the object of interest such that the object of interest remains substantially encompassed within the field of view.

13. The computer-readable medium of claim **10**, further comprising computer-executable instructions that when executed by the computer cause the computer to simultaneously display a wide field of view and a narrow field of view via a user interface operatively coupled to the processor.

14. The computer-readable medium of claim **9**, wherein the object of interest comprises at least one of an anatomical structure in a patient, a surgical instrument inserted into the patient, a device, and a marker placed into the patient.

15. The computer-readable medium of claim **9**, further comprising computer-executable instructions that when executed by the computer cause the computer to identify the object of interest by using one or more image analysis techniques including:

low level feature detection;

statistical model fitting;

machine learning; and

image and model registration.

16. A system for active control of ultrasound image acquisition, the system comprising:

a processor;

an input operatively coupled to the processor and configured to receive data representing a series of ultrasound images; and

a memory operatively coupled to the processor, the memory comprising computer-executable instructions that when executed by the processor cause the processor to:

receive data representing a series of ultrasound images acquired over a period of time from an ultrasound probe operatively coupled to the processor;

identify an object of interest in at least one ultrasound image in the series of ultrasound images;

detect at least one of:

changes in at least one of a position of the ultrasound probe and an orientation of the ultrasound probe over the period of time with respect to the object of interest; and

changes in at least one of a position of the object of interest and an orientation of the object of interest over the period of time with respect to the ultrasound probe; and

adjust at least one of:

at least one ultrasound image acquisition parameter for acquiring at least one additional ultrasound image using the ultrasound probe based on the detected changes in the position and/or the orientation of the ultrasound probe; and

at least one ultrasound image acquisition parameter for acquiring at least one additional ultrasound image using the ultrasound probe based on the detected changes in the position and/or the orientation of the object of interest.

17. The system of claim **16**, wherein the at least one ultrasound image acquisition parameter comprises at least one of:

a depth of a signal emitted by the ultrasound probe;

a frequency of the signal emitted by the ultrasound probe;

a spatial resolution of the ultrasound image,

a field of view of the ultrasound image, and

an acquisition frame rate of the ultrasound image.

18. The system of claim **17**, wherein the memory further comprises computer-executable instructions that when executed by the processor cause the processor to at least one of:

increase or decrease the spatial resolution such that the object of interest is visible within the at least one additional ultrasound image based on a set of predefined rules;

increase or decrease the field of view such that the object of interest appears in the at least one additional ultrasound image based on the set of predefined rules;

increase or decrease the acquisition frame rate based on the set of predefined rules;

increase or decrease the depth of the signal based on the set of predefined rules; and

increase or decrease the frequency of the signal based on the set of predefined rules.

19. The system of claim **17**, wherein the memory further comprises computer-executable instructions that when executed by the processor cause the processor to automatically steer the field of view based on the detected changes in the position and/or the orientation of the ultrasound probe and/or the object of interest such that the object of interest remains substantially encompassed within the field of view.

20. The system of claim **16**, wherein the memory further comprises computer-executable instructions that when executed by the computer cause the computer to simultaneously display a wide field of view and a narrow field of view via a user interface operatively coupled to the processor.

21. The system of claim **16**, wherein the object of interest comprises at least one of an anatomical structure in a patient, a surgical instrument inserted into the patient, a device, and a marker placed into the patient.

* * * * *

专利名称(译)	介入手术的主动超声成像		
公开(公告)号	US20140187946A1	公开(公告)日	2014-07-03
申请号	US13/731213	申请日	2012-12-31
[标]申请(专利权)人(译)	通用电气公司		
申请(专利权)人(译)	通用电气公司		
当前申请(专利权)人(译)	通用电气公司		
[标]发明人	MILLER JAMES VRADENBURG PATWARDHAN KEDAR ANIL		
发明人	MILLER, JAMES VRADENBURG PATWARDHAN, KEDAR ANIL		
IPC分类号	A61B8/08 A61B8/00		
CPC分类号	A61B8/5207 A61B8/463 A61B8/4245 A61B8/0833 A61B8/469 A61B8/5215 A61B8/54 G01S7/5205 G01S7/52074		
外部链接	Espacenet USPTO		

摘要(译)

用于主动控制超声图像采集的计算机实现的方法包括访问表示在一段时间内从超声探头获取的一系列超声图像并识别至少一个图像中的感兴趣对象的图像数据。该方法还包括检测超声探头的位置的变化和/或超声探头相对于感兴趣对象的时间段的变化，或者感兴趣对象的位置和/或方向的变化。相对于超声探头，在一段时间内感兴趣的物体。该方法还包括基于检测到的超声探头的位置和/或取向的变化和/或基于检测到的感兴趣对象的位置和/或取向的变化来调整至少一个超声图像采集参数。 。