US 20080283771A1

(19) **United States**

(12) **Patent Application Publication**

Li

(10) **Pub. No.: US 2008/0283771 A1**

(43) **Pub. Date: Nov. 20, 2008**

(54) **SYSTEM AND METHOD OF COMBINING ULTRASOUND IMAGE ACQUISITION WITH FLUOROSCOPIC IMAGE ACQUISITION**

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(21) Appl. No.: **12/060,698**

(22) Filed: **Apr. 1, 2008**

Related U.S. Application Data

(60) Provisional application No. 60/938,602, filed on May 17, 2007.

Publication Classification

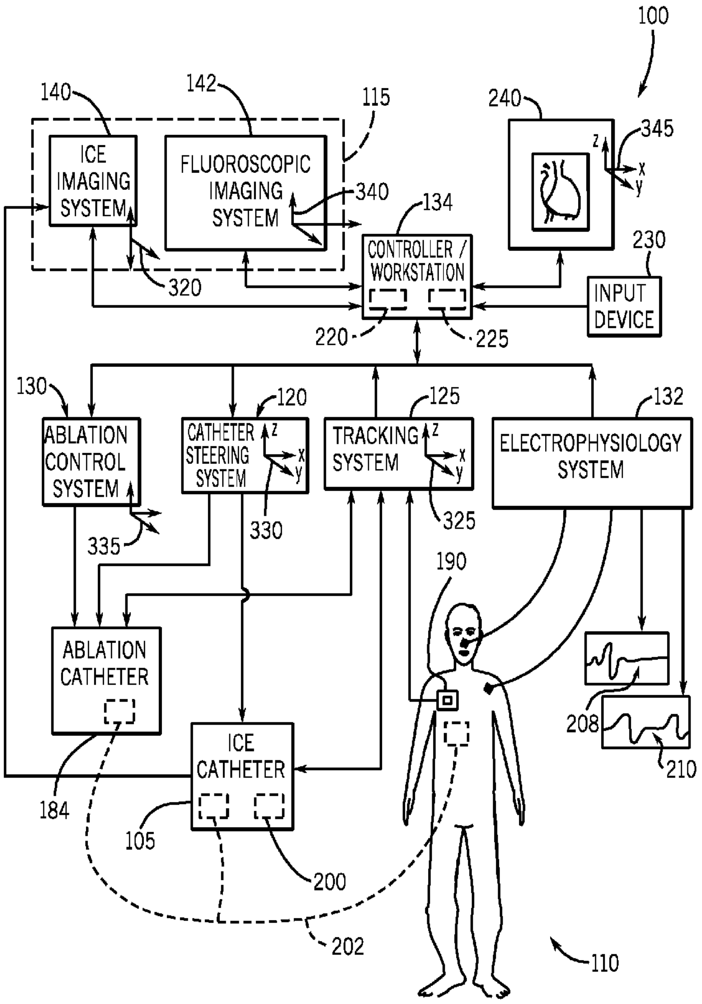
(51) **Int. Cl.**

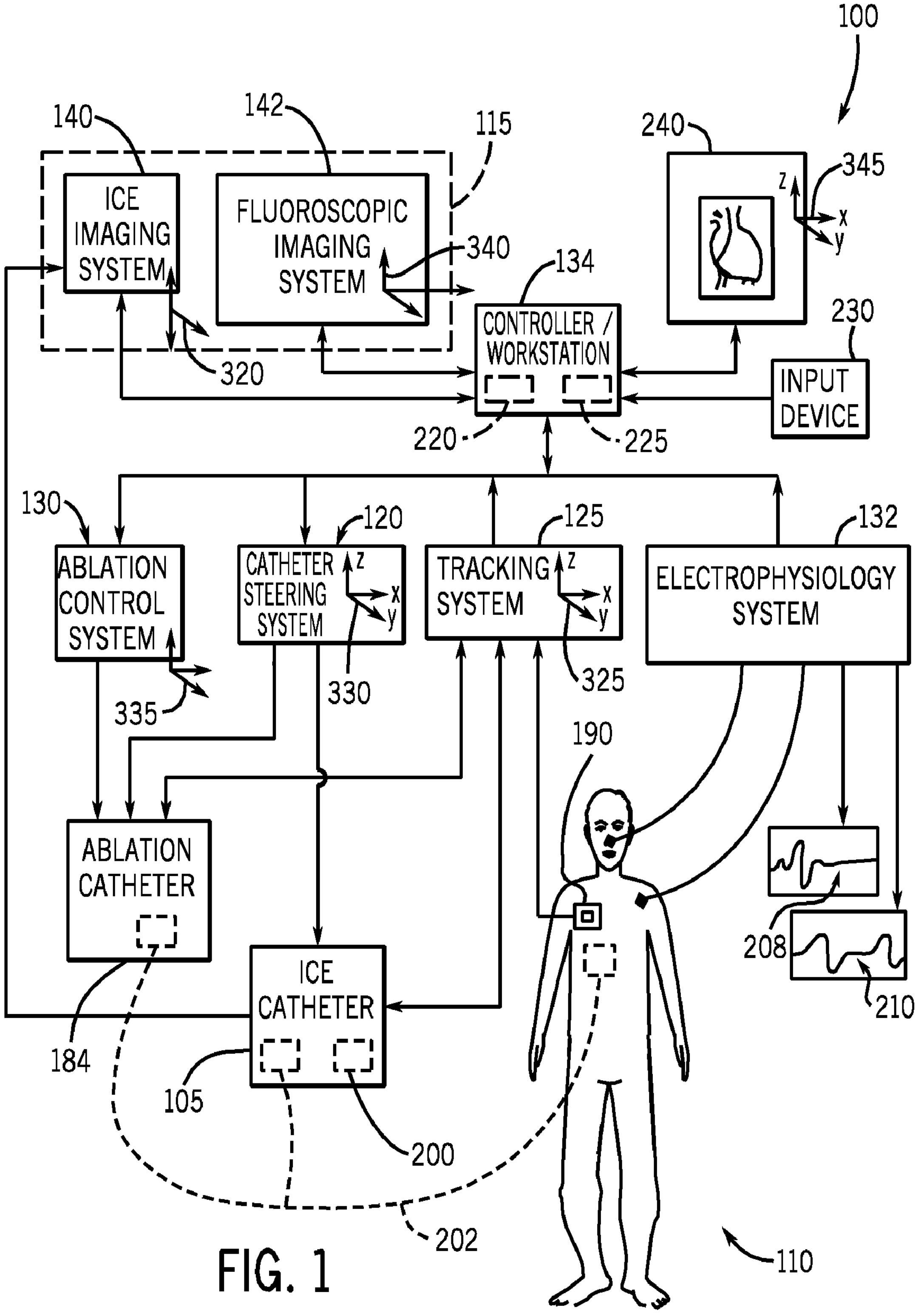
G01J 1/58	(2006.01)
A61B 18/12	(2006.01)
A61B 8/00	(2006.01)
A61B 6/00	(2006.01)

(52) **U.S. Cl.** **250/459.1**; 606/34; 600/439; 600/424; 250/458.1

(57) **ABSTRACT**

A system and method to image an imaged subject is provided. The system comprises an ultrasound imaging system including an imaging probe operable to move internally and acquire ultrasound image data of the imaged subject, a fluoroscopic imaging system operable to acquire fluoroscopic image data of the imaged subject during image acquisition by the ultrasound imaging system, and a controller in communication with the ultrasound imaging system and the fluoroscopic imaging system. A display can be illustrative of the ultrasound image data acquired with the imaging probe in combination with a fluoroscopic imaging data acquired by the fluoroscopic imaging system.





100
140
142
115
240
345
ICE IMAGING SYSTEM
FLUOROSCOPIC IMAGING SYSTEM
340
134
CONTROLLER / WORKSTATION
230
INPUT DEVICE
320
220
225
130
120
125
132
ABLATION CONTROL SYSTEM
CATHETER STEERING SYSTEM
TRACKING SYSTEM
ELECTROPHYSIOLOGY SYSTEM
335
330
325
190
ABLATION CATHETER
ICE CATHETER
184
105
200
208
210
202
110

FIG. 1

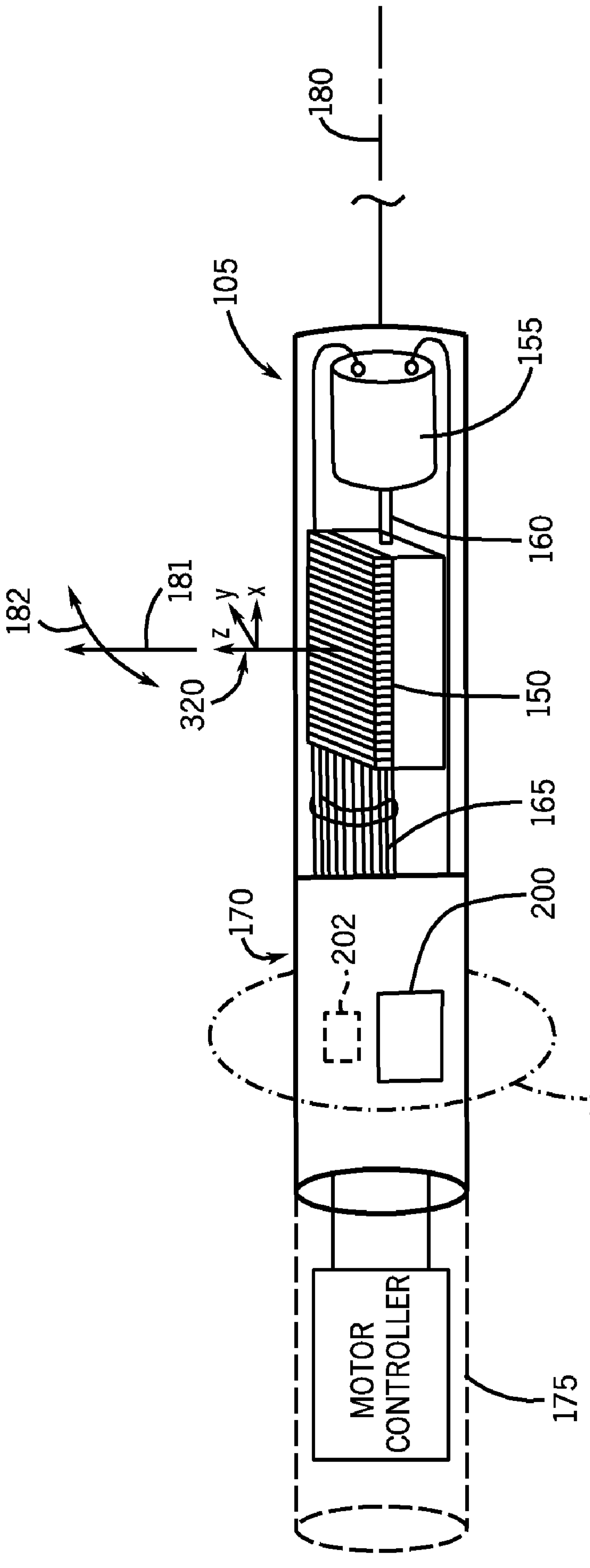

180
105
155
160
182
181
y
x
z
320
150
165
170
202
200
205
MOTOR
CONTROLLER
175

FIG. 2

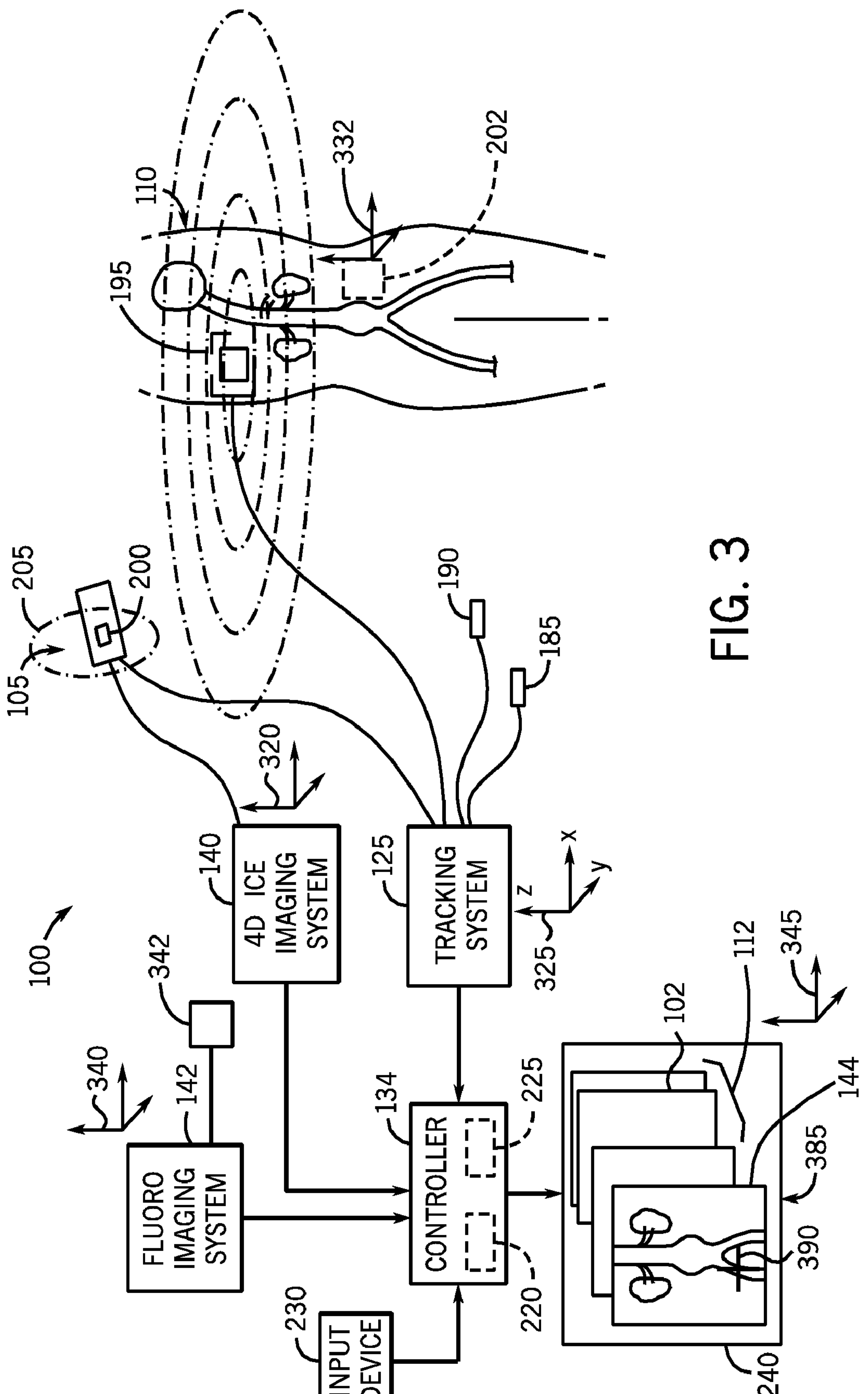

100
FLUORO IMAGING SYSTEM
4D ICE IMAGING SYSTEM
TRACKING SYSTEM
CONTROLLER
INPUT DEVICE
x
y
z
105
110
112
125
134
140
142
144
185
190
195
200
202
205
220
225
230
240
320
325
332
340
342
345
385
390

FIG. 3

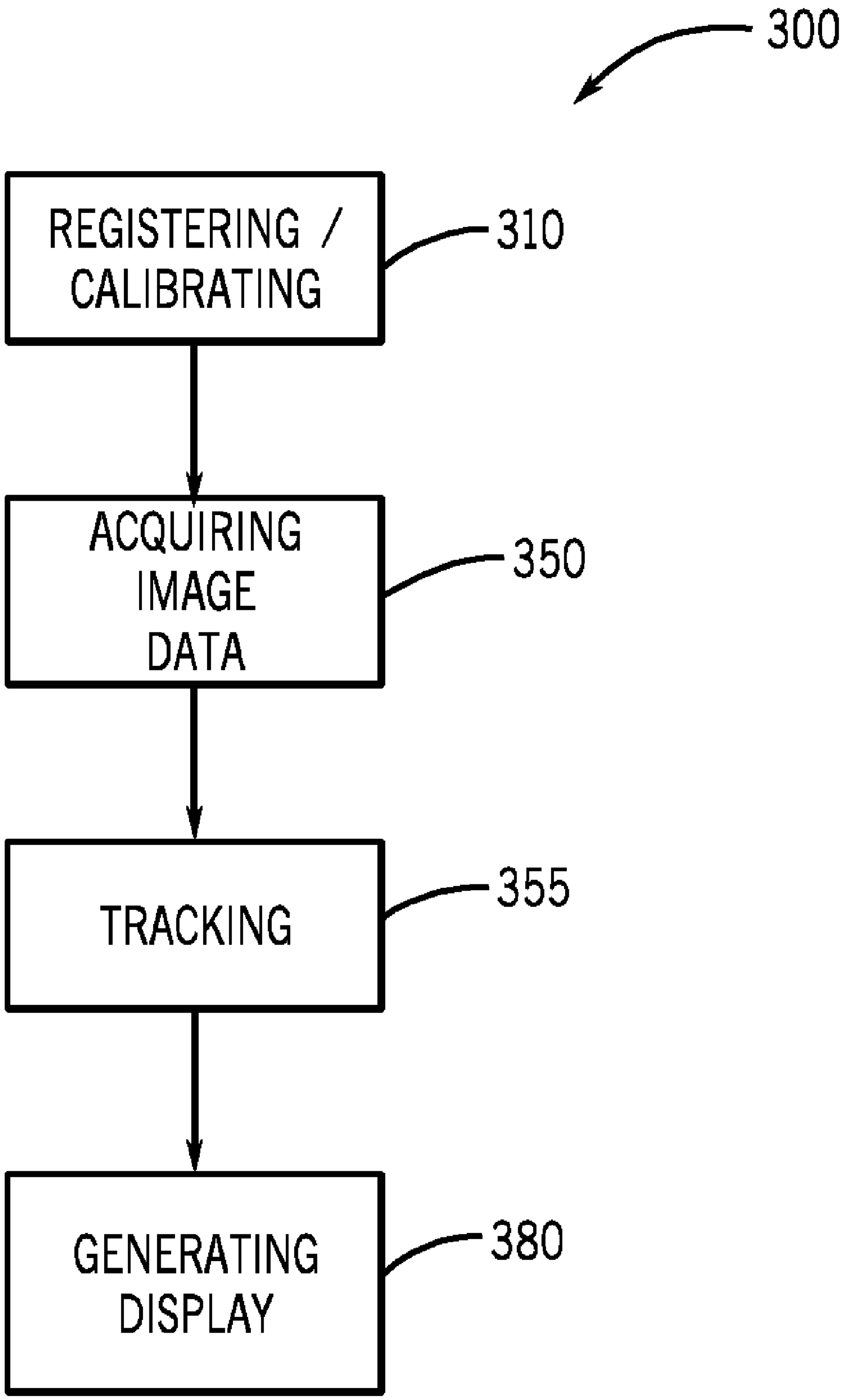

300
REGISTERING / CALIBRATING
310
ACQUIRING IMAGE DATA
350
TRACKING
355
GENERATING DISPLAY
380

FIG. 4

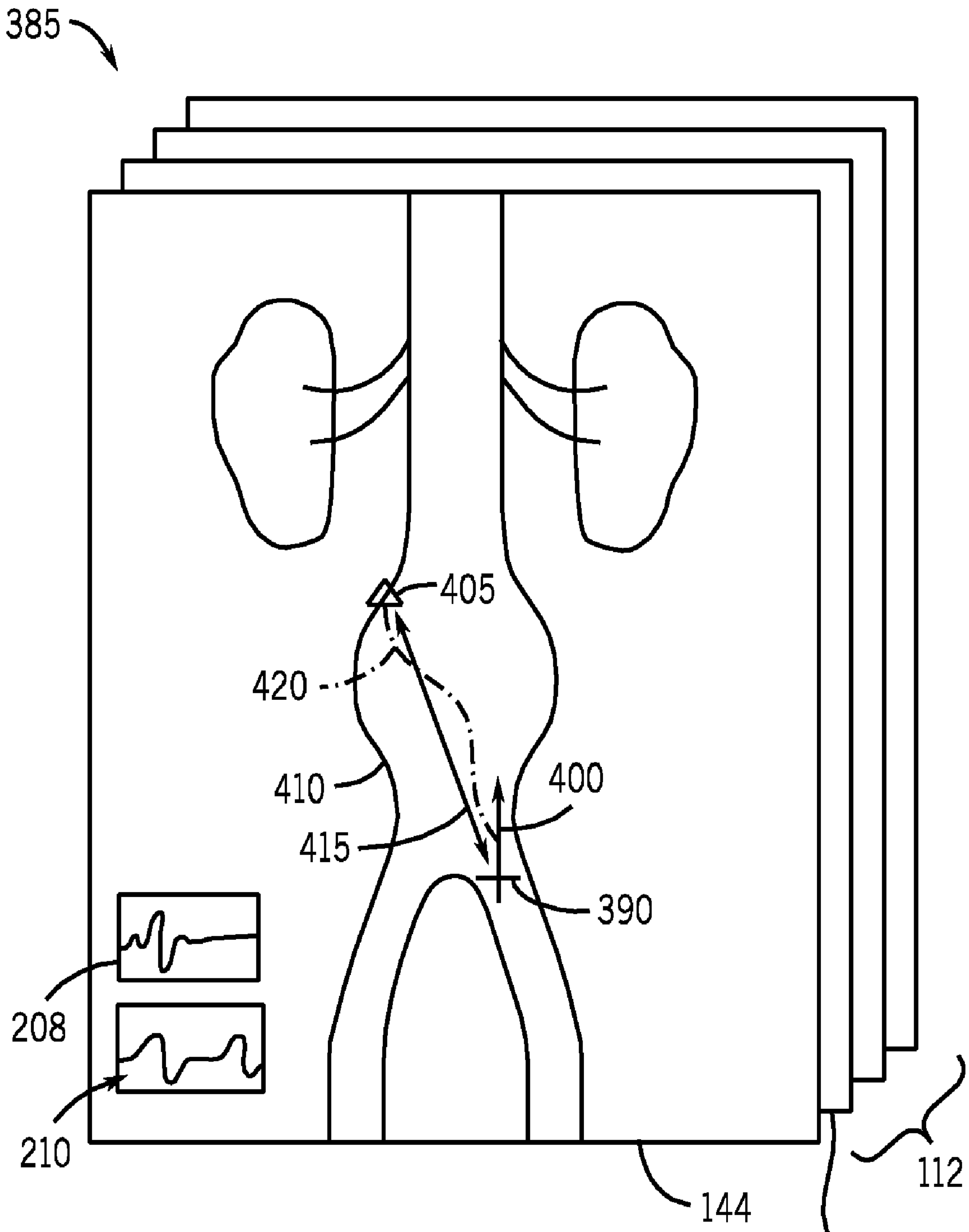


FIG. 5

SYSTEM AND METHOD OF COMBINING ULTRASOUND IMAGE ACQUISITION WITH FLUOROSCOPIC IMAGE ACQUISITION

RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application No. 60/938,602 filed on May 17, 2007, and is hereby incorporated herein by reference in its entirety.

BACKGROUND

[0002] The subject matter herein generally relates to tracking or delivery of medical instruments, and in particular, systems and methods to track and deliver medical instruments using ultrasound.

[0003] Image-guided surgery is a developing technology that generally provides a surgeon with a virtual roadmap into a patient's anatomy. This virtual roadmap allows the surgeon to reduce the size of entry or incision into the patient, which can minimize pain and trauma to the patient and result in shorter hospital stays. Examples of image-guided procedures include laparoscopic surgery, thorasoscopic surgery, endoscopic surgery, etc. Types of medical imaging systems, for example, computerized tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET), ultrasound (US), radiological machines, etc., can be useful in providing static image guiding assistance to medical procedures. The above-described imaging systems can provide two-dimensional or three-dimensional images that can be displayed to provide a surgeon or clinician with an illustrative map to guide a tool (e.g., a catheter) through an area of interest of a patient's body.

[0004] One example of application of image-guided surgery is to perform an intervention procedure to treat cardiac disorders or arrhythmias. Heart rhythm disorders or cardiac arrhythmias are a major cause of mortality and morbidity. Atrial fibrillation is one of the most common sustained cardiac arrhythmia encountered in clinical practice. Cardiac electrophysiology has evolved into a clinical tool to diagnose these cardiac arrhythmias. As will be appreciated, during electrophysiological studies, probes, such as catheters, are positioned inside the anatomy, such as the heart, and electrical recordings are made from the different chambers of the heart.

[0005] A certain conventional image-guided surgery technique used in interventional procedures includes inserting a probe, such as an imaging catheter, into a vein, such as the femoral vein. The catheter is operable to acquire image data to monitor or treat the patient. Precise guidance of the imaging catheter from the point of entry and through the vascular structure of the patient to a desired anatomical location is progressively becoming more important. Current techniques typically employ fluoroscopic imaging to monitor and guide the imaging catheter within the vascular structure of the patient.

BRIEF SUMMARY

[0006] A technical effect of the embodiments of the system and method described herein includes enhancement in monitoring and/or treating regions of interest. Another technical effect of the subject matter described herein includes enhancement of placement and guidance of probes (e.g., catheters) traveling through an imaged subject. Yet, another technical effect of the system and method described herein includes reducing manpower, expense, and time to perform interventional procedures, thereby reducing health risks associated with long-term exposure of the subject to radiation.

[0007] According to one embodiment, a system to image an imaged subject is provided. The system comprises an ultrasound imaging system including an imaging probe operable to move internally and acquire ultrasound image data of the imaged subject, a fluoroscopic imaging system operable to acquire fluoroscopic image data of the imaged subject during image acquisition by the ultrasound imaging system, and a controller in communication with the ultrasound imaging system and the fluoroscopic imaging system. A display can be illustrative of the ultrasound image data acquired with the imaging probe in combination with a fluoroscopic imaging data acquired by the fluoroscopic imaging system.

[0008] According to another embodiment of the subject matter described herein, a method of image acquisition of an imaged subject is provided. The method comprises the steps of providing an ultrasound imaging system including an imaging probe in communication with a controller; providing a fluoroscopic imaging system operable to acquire fluoroscopic image data of the imaged subject; acquiring the ultrasound image data simultaneously with acquiring fluoroscopic image data of the imaged subject; and displaying a combination of the ultrasound image data and the fluoroscopic image data.

[0009] Systems and methods of varying scope are described herein. In addition to the aspects of the subject matter described in this summary, further aspects of the subject matter will become apparent by reference to the drawings and with reference to the detailed description that follows.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. **1** illustrates a schematic diagram of an embodiment of a system of the subject matter described herein to perform imaged guided medical procedures on an imaged subject.

[0011] FIG. **2** illustrates a picture of a tool to travel through the imaged subject.

[0012] FIG. **3** illustrates a more detailed schematic diagram of a tracking system in combination with an imaging system as part of the system described in FIG. **1**.

[0013] FIG. **4** shows an embodiment of a method of performing an image-guided procedure via the system of FIG. **1**.

[0014] FIG. **5** shows an embodiment of an illustration of a display created with the system of FIG. **1**.

DETAILED DESCRIPTION

[0015] In the following detailed description, reference is made to the accompanying drawings that form a part hereof, and in which is shown by way of illustration specific embodiments, which may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the embodiments, and it is to be understood that other embodiments may be utilized and that logical, mechanical, electrical and other changes may be made without departing from the scope of the embodiments. The following detailed description is, therefore, not to be taken in a limiting sense.

[0016] FIG. **1** illustrates an embodiment of a system **100** operable to create a full-view three- or four-dimensional (3D or 4D) image or model from a series of generally real-time, acquired 3D or 4D image data **102** relative to a tracked position information of a probe (e.g., an imaging catheter **105**) traveling through the imaged subject **110**. According to one embodiment, the system **100** can be operable to acquire a series of general real-time, partial view, 3D or 4D image data **102** while simultaneously rotating and tracking a position and orientation of the catheter **105** through the imaged subject

110. From the acquired general real-time, partial views of 3D or 4D image data **102**, a technical effect of the system **100** includes creating an illustration of a general real-time 3D or 4D model **112** of a region of interest (e.g., a beating heart) so as to guide a surgical procedure.

[0017] An embodiment of the system **100** generally includes an image acquisition system **115**, a steering system **120**, a tracking system **125**, an ablation system **130**, and an electrophysiology system **132** (e.g., a cardiac monitor, respiratory monitor, pulse monitor, etc. or combination thereof), and a controller or workstation **134**.

[0018] The image acquisition system **115** is generally operable to generate the 3D or 4D image or model **112** corresponding to an area of interest of the imaged subject **110**. Examples of the image acquisition system **115** can include, but is not limited to, computed tomography (CT), magnetic resonance imaging (MRI), x-ray or radiation, positron emission tomography (PET), computerized tomosynthesis (CT), ultrasound (US), angiographic, fluoroscopic, and the like or combination thereof. The image acquisition system **115** can be operable to generate static images acquired by static imaging detectors (e.g., CT systems, MRI systems, etc.) prior to a medical procedure, or real-time images acquired with real-time imaging detectors (e.g., angioplastic systems, laparoscopic systems, endoscopic systems, etc.) during the medical procedure. Thus, the types of images acquired by the acquisition system **115** can be diagnostic or interventional.

[0019] One embodiment of the image acquisition system **115** includes a general real-time, intracardiac echocardiography (ICE) imaging system **140** that employs ultrasound to acquire general real-time, 3D or 4D ultrasound image data of the patient's anatomy and to merge the acquired image data to generate a 3D or 4D model **112** of the patient's anatomy relative to time, generating herein referred to as the 4D model or image **112**. In accordance with another embodiment, the image acquisition system **115** is operable to fuse or combine acquired ultrasound image data **102** or model **112** using above-described ICE imaging system **140** with an intra-operative image data or image models (e.g., 2D image data) generated by a fluoroscopic imaging system **142**. One embodiment of the fluoroscopic imaging system **142** generally includes an X-ray source in combination with an image intensifier to acquire fluoroscopic image data **144** of the imaged subject **110**. The acquired image data **102**, **112**, or **144** can be further combined with other pre-operative or intra-operative image data (e.g., MRI, PET, endoscopic, CT, etc.) and is not limiting on the invention.

[0020] FIG. **2** illustrates one embodiment of the catheter **105**, herein referred to as an ICE catheter **105**. The illustrated embodiment of the ICE catheter **105** includes a transducer array **150**, a micromotor **155**, a drive shaft or other mechanical connection **160** between the micromotor **155** and the transducer array **150**, an interconnect **165**, and a catheter housing **170**.

[0021] According to the illustrated embodiment in FIG. **3**, the micromotor **155** via the drive shaft **160** generally rotates the transducer array **150**. The rotational motion of the transducer array **150** is controlled by a motor control **175** of the micromotor **155**. The interconnect **165** generally refers to, for example, cables and other connections coupling so as to receive and/or transmit signals between the transducer array **150** with the ICE imaging system (shown in FIG. **1**) **105**. An embodiment of the interconnect **165** is configured to reduce its respective torque load on the transducer array **150** and the micromotor **155**.

[0022] Still referring to FIG. **2**, an embodiment of the catheter housing **170** generally encloses the transducer array **150**, the micromotor **155**, the drive shaft **160**, and the interconnect **165**. The catheter housing **170** may further enclose the motor control **175** (illustrated in dashed line). The catheter housing is generally of a material, size, and shape adaptable to internal imaging applications and insertion into regions of interest of the imaged subject **110**. At least a portion of the catheter housing **170** that intersects the ultrasound imaging volume or scanning direction is comprised of acoustically transparent (e.g., low attenuation and scattering, acoustic impedance near that of the blood and tissue (Z~1.5M Rayl) material. An embodiment of the space between the transducer array **150** and the housing **170** is filled with acoustic coupling fluid (e.g., water) having an acoustic impedance and sound velocity near those of blood and tissue (e.g., Z~1.5M Rayl, V~1540 m/sec).

[0023] An embodiment of the transducer array **150** is a 64-element one-dimensional array having 0.110 mm azimuth pitch, 2.5 mm elevation, and 6.5 MHz center frequency. The elements of the transducer array **150** are electronically phased in order to acquire a sector image generally parallel to a longitudinal axis **180** of the catheter housing **170**. In operation, the micromotor **155** mechanically rotates the transducer array **150** about the longitudinal axis **180**. The rotating transducer array **150** captures a plurality of two-dimensional images for transmission to the ICE imaging system **140** (shown in FIG. **1**). The ICE imaging system **140** is generally operable to assemble the sequence or succession of acquired 2D images so as to generally produce or generate 3D image or reconstructed model **112** of the imaged subject **110**.

[0024] The motor control **175** via the micromotor **155** generally regulates or controls the rate of rotation of the transducer array **150** about the longitudinal axis **180** of the ICE catheter **105**. For example, the motor control **175** can instruct the micromotor **155** to rotate the transducer array **150** relatively slowly to produce the 3D reconstructed image or model **112**. Also, the motor control **175** can instruct the micromotor **155** to rotate the transducer array **150** relatively faster to produce the general real-time, 3D or 4D reconstructed image or model. The 4D reconstructed image or model **112** can be defined to include a 3D reconstructed image or model correlated relative to an instant or instantaneous time of image acquisition. The motor control **175** is also generally operable to vary the direction of rotation so as to generally create an oscillatory motion of the transducer array **150**. By varying the direction of rotation, the motor control **175** is operable to reduce the torque load associated with the interconnect **165**, thereby enhancing the performance of the transducer array **150** to focus imaging on specific regions within the range of motion of the transducer array **150** about the longitudinal axis **180**.

[0025] Referring back to FIG. **1**, an embodiment of the steering system **120** is generally coupled in communication to control maneuvering (including the position or the orientation) of the ICE catheter **105**. The embodiment of the system **100** can include synchronizing the steering system **120** with gated image acquisition by the ICE imaging system **140**. The steering system **120** may be provided with a manual catheter steering function or an automatic catheter steering function or combination thereof. With selection of the manual steering function, the controller **134** and/or steering system **120** aligns an imaging plane vector **181** relative to the ICE catheter **105** shown on the 3D ICE reconstructed image or model **112** per received instructions from the user, as well as directs the ICE catheter **105** to a target anatomical site. An embodiment of the imaging plane vector **181** represents a central direction of the plane that the transducer array **150** travels, moves or rotates through relative to the longitudinal axis **180**. With selection of the automatic steering function, the controller **134** and/or steering system **120** or combination thereof estimates a displacement or a rotation angle **182** at or less than maximum (See FIG. **2**) relative to a reference (e.g., imaging plane vector **181**), passes position information of the ICE catheter **105** to the steering system **120**, and automatically drives or positions the ICE catheter **105** to continuously follow movement of a second object (e.g., delivery of an ablation catheter **184** of the ablation system **130**, moving anatomy, etc.). The reference (e.g., imaging plane vector **181**) can vary.

[0026] Referring to FIGS. **1** and **3**, the tracking system **125** is generally operable to track or detect the position of the tool or ICE catheter **105** relative to the acquired image data or 3D or 4D reconstructed image or model **112** generated by the image acquisition system **115**, or relative to delivery of a second instrument or tool (e.g., ablation system **130**, electrophysiology system **132**).

[0027] As illustrated in FIG. **3**, an embodiment of the tracking system **125** includes an array or series of microsensors or tracking elements **185**, **190**, **195**, **200** connected (e.g., via a hard-wired or wireless connection) to communicate position data to the controller **134** (See FIG. **1**). Yet, it should be understood that the number of tracking elements **185**, **190**, **195**, **200** can vary. An embodiment of the system **100** includes intraoperative tracking and guidance in the delivery of the at least one catheter **184** of the ablation system **130** by employing a hybrid electromagnetic and ultrasound positioning technique.

[0028] An embodiment of the hybrid electromagnetic/ultrasound positioning technique can facilitate dynamic tracking by locating tracking elements or dynamic references **185**, **190**, **195**, **200**, alone in combination with ultrasound markers **202** (e.g., comprised of metallic objects such brass balls, wire, etc. arranged in unique patterns for identification purposes). The ultrasonic markers **202** may be active (e.g., illustrated in dashed line located at catheters **105** and **184**) or passive targets (e.g., illustrated in dashed line at imaged anatomy of subject **110**). An embodiment of the ultrasound markers **202** can be located at the ICE catheter **105** and/or ablation catheter **184** so as to be identified or detected in acquired image data by supplemental imaging system **142** and/or the ICE imaging system **140** or controller **134** or combination thereof. As image data is acquired via the ICE catheter **105**, an image-processing program stored at the controller **134** or other component of the system **100** can extract or calculate a voxel position of the ultrasonic markers **202** in the image data. In this way, the controller **134** or tracking system **125** or combination thereof can track a position of the ultrasonic markers **202** with respect to the ICE catheter **105**, or vice versa. The tracking system **125** can be configured to selectively switch between tracking relative to electromagnetic tracking elements **185**, **190**, **195**, **200** or ultrasound markers **202** or simultaneously track both.

[0029] For sake of example, assume the series of tracking elements **185**, **190**, **195**, **200** includes a combination of transmitters or dynamic references **185** and **190** in communication or coupled (e.g., RF signal, optically, electromagnetically, etc.) with one or more receivers **195** and **200**. The number and type transmitters in combination with receivers can vary. Either the transmitters **185** and **190** or the receivers **195** and **200** can define the reference of the spatial relation of the tracking elements **185**, **190**, **195**, **200** relative to one another. An embodiment of one of the receivers **195** represents a dynamic reference at the imaged anatomy of the subject **110**. An embodiment of the system **100** is operable to register or calibrate the location (e.g., position and/or orientation) of the tracking elements **185**, **190**, **195**, **200** relative to the acquired imaging data by the image acquisition system **115**, and operable to generate a graphic representation suitable to visualize the location of the tracking elements **185**, **190**, **195**, **200** relative to the acquired image data.

[0030] The tracking elements **185**, **190**, **195**, **200** generally enable a surgeon to continually track the position and orientation of the catheters **105** or **182** during surgery. The tracking elements **185**, **190**, **195** may be passively powered, powered by an external power source, or powered by an internal battery. One embodiment of one or more of the tracking elements or microsensors **185**, **190**, **195** include electromagnetic (EM) field generators having microcoils operable to generate a magnetic field, and one or more of the tracking elements **185**, **190**, **195**, **200** include an EM field sensor operable to detect an EM field. For example, assume tracking elements **185** and **190** include a EM field sensor operable such that when positioned into proximity within the EM field generated by the other tracking elements **195** or **200** is operable to calculate or measure the position and orientation of the tracking elements **195** or **200** in real-time (e.g., continuously), or vice versa, calculate the position and orientation of the tracking elements **185** or **190**.

[0031] For example, tracking elements **185** and **190** can include EM field generators attached to the subject **110** and operable to generate an EM field, and assume that tracking element **195** or **200** includes an EM sensor or array operable in combination with the EM generators **185** and **190** to generate tracking data of the tracking elements **185**, **190** attached to the patient **110** relative to the microsensor **195** or **200** in real-time (e.g., continuously). According to one embodiment of the series of tracking elements **185**, **190**, **195**, **200**, one is an EM field receiver and a remainder are EM field generators. The EM field receiver may include an array having at least one coil or at least one coil pair and electronics for digitizing magnetic field measurements detected by the receiver array. It should, however, be understood that according to alternate embodiments, the number of combination of EM field receivers and EM field generators can vary.

[0032] The field measurements generated or tracked by the tracking elements **185**, **190**, **195**, **200** can be used to calculate the position and orientation of one another and attached instruments (e.g., catheters **105** or **184**) according to any suitable method or technique. An embodiment of the field measurements tracked by the combination of tracking elements **185**, **190**, **195**, **200** are digitized into signals for transmission (e.g., wireless, or wired) to the tracking system **125** or controller **134**. The controller **134** is generally operable to register the position and orientation information of the one or more tracking elements **185**, **190**, **195**, **200** relative to the acquired imaging data from ICE imaging system **140** or other supplemental imaging system **142**. Thereby, the system **100** is operable to visualized or illustrate the location of the one or more tracking elements **185**, **190**, **195**, **200** or attached catheters **105** or **184** relative to pre-acquired image data or real-time image data acquired by the image acquisition system **115**.

[0033] Referring now to FIG. 3, an embodiment of the tracking system 125 includes the tracking element 200 located at the ICE catheter 105. The tracking element 200 is in communication with the receiver 195. This embodiment of the tracking element 200 includes a transmitter that comprises a series of coils that define the orientation or alignment of the ICE catheter 105 about the rotational axis (generally aligned along the longitudinal axis 180) of the ICE catheter 105. Referring to FIG. 2, the tracking element 200 can be located integrally with the ICE catheter 105 and can be generally operable to generate or transmit a magnetic field 205 to be detected by the receiver 195 of the tracking system 125. In response to passing through the magnetic field 205, the receiver 195 generates a signal representative of a spatial relation and orientation of the receiver 195 or other reference relative to the transmitter 200. Yet, it should be understood that the type or mode of coupling, link or communication (e.g., RF signal, infrared light, magnetic field, etc.) operable to measure the spatial relation varies. The spatial relation and orientation of the tracking element 200 is mechanically predefined or measured in relation relative to a feature (e.g., a tip) of the ICE catheter 105. Thereby, the tracking system 125 is operable to track the position and orientation of the ICE catheter 105 navigating through the imaged subject 110.

[0034] An embodiment of the tracking elements 185, 190, or 200 can include a plurality of coils (e.g., Hemholtz coils) operable to generate a magnetic gradient field to be detected by the receiver 195 of the tracking system 125 and which defines an orientation of the ICE catheter 105. The receiver 195 can include at least one conductive loop operable to generate an electric signal indicative of spatial relation and orientation relative to the magnetic field generated by the tracking elements 185, 190 and 200.

[0035] Referring back to FIG. 1, an embodiment of the ablation system 130 includes the ablation catheter 184 that is operable to work in combination with the ICE catheter 105 of the ICE imaging system 140 to delivery ablation energy to ablate or end electrical activity of tissue of the imaged subject 110. An embodiment of the ICE catheter 105 can include or be integrated with the ablation catheter 184 or be independent thereof. An embodiment of the ablation catheter 184 can include one of the tracking elements 185, 190 of the tracking system 125 described above to track or guide intra-operative delivery of ablation energy to the imaged subject 110. Alternatively or in addition, the ablation catheter 184 can include ultrasound markers 202 (illustrated in dashed line in FIG. 1) operable to be detected from the acquired ultrasound image data generated by the ICE imaging system 140. The ablation system 130 is generally operable to manage the ablation energy delivery to an ablation catheter 184 relative to the acquired image data and tracked position data.

[0036] An embodiment of an electrophysiological system (s) 132 is connected in communication with the ICE imaging system 140, and is generally operable to track or monitor or acquire data of the cardiac cycle 208 or respiratory cycle 210 of imaged subject 110. Data acquisition can be correlated to the gated acquisition or otherwise acquired image data, or correlated relative to generated 3D or 4D models 112 created by the image acquisition system 115.

[0037] Still referring FIG. 1, the controller or workstation computer 134 is generally connected in communication with and controls the image acquisition system 115 (e.g., the ICE imaging system 140 or supplemental imaging system 142), the steering system 120, the tracking system 125, the ablation system 130, and the electrophysiology system 132 so as to enable each to be in synchronization with one another and to enable the data acquired therefrom to produce or generate a full-view 3D or 4D ICE model 112 of the imaged anatomy.

[0038] An embodiment of the controller 134 includes a processor 220 in communication with a memory 225. The processor 220 can be arranged independent of or integrated with the memory 225. Although the processor 220 and memory 225 is described located the controller 134, it should be understood that the processor 220 or memory 225 or portion thereof can be located at image acquisition system 115, the steering system 120, the tracking system 125, the ablation system 130 or the electrophysiology system 132 or combination thereof.

[0039] The processor 220 is generally operable to execute the program instructions representative of acts or steps described herein and stored in the memory 225. The processor 220 can also be capable of receiving input data or information or communicating output data. Examples of the processor 220 can include a central processing unit of a desktop computer, a microprocessor, a microcontroller, or programmable logic controller (PLC), or the like or combination thereof.

[0040] An embodiment of the memory 225 generally comprises one or more computer-readable media operable to store a plurality of computer-readable program instructions for execution by the processor 220. The memory 225 can also operable to store data generated or received by the controller 134. By way of example, such media may comprise RAM, ROM, PROM, EPROM, EEPROM, Flash, CD-ROM, DVD, or other known computer-readable media or combinations thereof which can be used to carry or store desired program code in the form of instructions or data structures and which can be accessed by a general purpose or special purpose computer or other machine with a processor. When information is transferred or provided over a network or another communications connection (either hardwired, wireless, or a combination of hardwired or wireless) to a machine or remote computer, remote computer properly views the connection as a computer-readable medium. Thus, any such a connection is properly termed a computer-readable medium.

[0041] The controller 134 further includes or is in communication with an input device 230 and an output device 240. The input device 230 can be generally operable to receive and communicate information or data from user to the controller 210. The input device 230 can include a mouse device, pointer, keyboard, touch screen, microphone, or other like device or combination thereof capable of receiving a user directive. The output device 240 is generally operable to illustrate output data for viewing by the user. An embodiment of the output device 240 can be operable to simultaneously illustrate or fuse static or real-time image data generated by the image acquisition system 115 (e.g., the ICE imaging system 140 or supplemental imaging system 142) with tracking data generated by the tracking system 125. The output device 240 is capable of illustrating two-dimensional, three-dimensional image and/or four-dimensional image data or combination thereof through shading, coloring, and/or the like. Examples of the output device 240 include a cathode ray monitor, a liquid crystal display (LCD) monitor, a touch-screen monitor, a plasma monitor, or the like or combination thereof.

[0042] Having provided a description of the general construction of the system 100, the following is a description of a method 300 (see FIG. 4) of operation of the system 100 in relation to the imaged subject 110. Although an exemplary embodiment of the method 300 is discussed below, it should be understood that one or more acts or steps comprising the method **300** could be omitted or added. It should also be understood that one or more of the acts can be performed simultaneously or at least substantially simultaneously, and the sequence of the acts can vary. Furthermore, it is embodied that at least several of the following steps or acts can be represented as a series of computer-readable program instructions to be stored in the memory **225** of the controller **210** for execution by the processor **220** or one or more of the image acquisition system **115**, the steering system **120**, the tracking system **125**, the ablation system **130**, the electrophysiology system **132**, or a remote computer station connected thereto via a network (wireless or wired).

[0043] The controller **134** via communication with the tracking system **125** is operable to track movement of the ICE catheter **105** in accordance with known mathematical algorithms programmed as program instructions of software for execution by the processor **220** of the controller **134** or by the tracking system **125**. An exemplary navigation software is INSTATRAK® as manufactured by the GENERAL ELECTRIC® Corporation, NAVIVISION® as manufactured by SIEMENS®, and BRAINLAB®.

[0044] The method **300** includes a step of registering **310** a reference frame **320** of the ICE imaging system **140** with one or more of the group comprising: a reference frame **325** of the tracking system **125**, a reference frame **330** of the steering system **120**, a reference frame **335** of the ablation system **130**, or a reference time frame of the electrophysiological system (s) (e.g., cardiac monitoring system, respiratory monitoring system, etc.) **132**.

[0045] The registering step **310** can further include registering the reference frame **320** of the ICE imaging system with a reference frame or coordinate system **340** that defines a spatial distribution of image data acquired by the fluoroscopic imaging system **142**. The fluoroscopic system **142** can include a navigation calibration target **342** comprising an array of radio-opaque fiducials and one or more of the tracking elements **185**, **190** of the tracking system **125**.

[0046] According to one embodiment, the fluoroscopic imaging system **142** can acquire image data of a navigation calibration target to define the fluoroscopic reference frame **340** relative thereto. The ICE imaging system **140** can acquire ultrasound image data of the navigation calibration target **342** to define the imaging reference frame **320** relative thereto. By comparison to the same calibration target **342**, mathematical modeling can be used to transform or register the fluoroscopic reference frame **340** relative to the imaging reference frame **320** (as well as one or more of the reference frames **325**, **330**, and **335** described above). Once reference frames **320** and **340** are registered relative to one another, the 4D ultrasound image data **102** and models **112** generated by the ICE imaging system **140** can be projected onto or combined with 2D generally real-time acquired fluoroscopic imaging data.

[0047] All reference frames **320**, **325**, **330**, **335**, and **340** can be registered to a common or world coordinate reference frame **345**. One embodiment of the world reference frame **345** can be defined as a dynamic reference that includes one of the tracking elements **195** or an ultrasound marker **202** or both located at (e.g., rigidly attached with internally to the heart or externally to the chest) the imaged subject **110**.

[0048] One embodiment of calibrating can include acquiring at least one fluoroscopic image containing both the fiducial markers (not shown) at the target **142** in combination with the position of the tracking elements **185**, **190** at one or more of the fiducials markers at the target **142**. The calibration estimates the intrinsic (or projection) fluoroscopic imaging parameters including focal length, piercing points, and 2D image scaling factor. The calibration step can also include calculating the extrinsic camera parameters including the calibration target fiducial positions relative to the fluoroscopic coordinate system **340**. The fluoroscopic imaging parameters may be defined or transformed to any preferable coordinate reference frame. For example, given extrinsic fluoroscopic imaging parameter information and the calibration target sensor position information, a first transformation may be from the fluoroscopic image data defined in the intrinsic fluoroscopic imaging reference frame **340** relative to the sensor array coordinate reference frame **325**, and then to the world coordinate system **345** as the dynamic reference at the imaged subject **110**. Correspondingly, the 2D fluoroscopic reference frame **340** may be transformed to the world coordinate reference frame **345**.

[0049] In another embodiment, the registering step **310** can further include registering a pre-operative 4D CT, MR, or PET image with the fluoroscopic reference frame **340** or one or more of the reference frames **320**, **325**, **330**, and **335** described above.

[0050] An embodiment of the method **300** further includes a step **350** of acquiring image data (e.g., scan) of the anatomy of interest of the imaged subject **110**. An embodiment of the step of acquiring image data includes acquiring the series of partial-views **102** of 3D or 4D image data while rotating the ICE catheter **105** around the longitudinal axis **180**. The image acquisition step **350** can include synchronizing or gating a sequence of image acquisition relative to cardiac and respiratory cycle information **208**, **210** measured by the electrophysiology system **132**. One embodiment of the image acquiring step **350** can also include extracting a surface model of the imaged anatomy from the generated 4D ICE model according to the cardiac timing sequence, which may be denoted as [T(ice.3D.surf ->wcs)].t**1**, [T(ice.3D.surf->wcs)].t**2**, . . . , and [T(ice.3D.surf->wcs)].tn.

[0051] The embodiment of step **350** can further include acquiring fluoroscopic imaging data of the imaged subject **110** during acquisition of the image data by the ICE catheter **105** of the ICE imaging system **140**. The simultaneous acquisition of image data by the ICE imaging system **140** and the fluoroscopic imaging system **142** can be gated according to, or referenced to, the same time reference frame of the cardiac cycle or respiratory cycle information **208** and **210** acquired by the electrophysiology system **132**. The illustration of the surface of the general real-time 4D ICE model **112** may be projected in combination with (e.g., overlapping) the two-dimensional (2D) fluoroscopic imaging data **144** at any given cardiac phase. Alternatively, projected general real-time 2D ultrasound image may be superimposed on the 2D fluoroscopic image data **144**.

[0052] The embodiment of the method **300** further includes a step **355** of tracking a position or location of the at least one catheter **105** or **184** relative to the acquired image data. According to one embodiment of the method **300**, at least one catheter **105** or **184** can be integrated with one or more ultrasonic markers **202** indicative of a unique identifier. The ultrasonic markers **202** can both be located and rigidly mounted on the at least one instrument catheter **105** or **184**. A computer image-processing program is operable to detect and mark positions of the ultrasonic markers **202** relative to the generated 3D or 4D ICE image model **112**.

[0053] The controller **134** can be generally operable to align positions of the ultrasonic markers **202** with a tracking coordinate reference frame or coordinate system **325**. This registration information may be used for the alignment (calibration) between the tracking reference frame or coordinate system **325** relative to the imaging reference frame or coordinate system **320**. This information may also be used for detecting the presence of electromagnetic distortion or tracking inaccuracy.

[0054] According to one embodiment, the controller **134** can process acquired partial views of 3D or 4D image data of the catheter **105** or **184** to extract the voxel positions of the ultrasonic markers **202**. The controller **134** can also process the acquired partial views of 3D or 4D image data to extract or delineate a surface model of the imaged anatomy.

[0055] The embodiment of the ICE catheter **105** can include the tracking element **200** (e.g., electromagnetic coils or electrodes or other tracking technology) or ultrasound marker **202** operable such that the tracking system **125** can calculate the position and orientation (about six degrees of freedom) of the catheter **105**. The tracking information may be used in combination with the registering step **310** described above to align the series of partial view 3D or 4D images **102** to create the larger 3D or 4D image or model **112** with an extended or larger FOV.

[0056] According to another embodiment, the tracking system **125** may not track the position or orientation of the ICE catheter **105**. The controller **134** can assemble the series of acquired partial view 3D or 4D image data **102** by matching of speckle, boundaries, and other features identified in the image data.

[0057] An embodiment of step **380** can include creating a display **385** of the acquired real-time, partial views of 3D or 4D ultrasound image data **102** of the anatomical structure acquired by the ICE imaging system **140** in combination with the fluoroscopic image data **144** acquired with the fluoroscopic imaging system **142**. One embodiment of step **380** includes combining the general-real-time 4D ultrasound surface model **112** generated by the ICE imaging system **140** in fused or superimposed relation with general real-time 2D fluoroscopic image data **144** acquired by the fluoroscopic imaging system **142** during movement of the catheter **105** or ablation catheter **184** through the imaged subject **110**. The combination (e.g., overlapping, fusing, superposition, etc. or combination thereof) and order of combination (e.g., on top, on bottom, intermediate) can vary.

[0058] The above-described display **385** can further include one or more of the following: graphic representation (s) **390** of the locations (e.g., historical, present or future or combination thereof) and identifications of the ICE catheter **105** or ablation catheter **184** relative to the acquired 3D or 4D image data or 3D or 4D models **112** generated therefrom of the imaged anatomy; a graphic representation **400** of the imaging plane vector **181** representative of a general direction of the field of view (FOV) of the ICE catheter **105**; selection of a target anatomical site **405** (e.g., via input instructions from the user) at the graphically illustrated surface **410** of the generated 3D or 4D model **390** of the imaged anatomy. An embodiment of step **380** can further include creating a graphic illustration of a distance **415** between the catheter **105** (or component thereof) relative to the illustrated anatomical surface **410**, or a graphic illustration of a path **420** of the ICE catheter **105** or ablation catheter **184** delivery to the target anatomical site **405**.

[0059] An embodiment of the displaying step **380** can also include illustrating the cardiac and respiratory cycles **208**, **210** synchronized relative to point of time of acquisition or time of update of the displayed fluoroscopic and ultrasound image data **102**, **112**. One embodiment of the step **380** includes displaying of the 4D ICE model **112** synchronized with the cardiac or respiratory signals **208** and **210** can be represented as the following sequence of image frames [T(ice.3D->wcs)].t**1**, [T(ice.3D->wcs)].t**2**, . . . , and [T(ice.3D->wcs)].tn according to a cardiac phase t**1**, t**2**, . . . , and tn.

[0060] The technical effect of the subject matter described herein is to enable intraoperative tracking and guidance in the delivery of at least one instrument (e.g., ICE catheter **105** or ablation catheter **184**) through an imaged subject **110** based on acquisition of ultrasound imaging information in combination with fluoroscopic imaging information. By integrating the 4D ICE ultrasound image data with the tracking system **125**, the field of view of image data acquired by the imaging catheter **105** is enhanced. The subject matter described herein can accelerate the 4D ICE registration process with other pre-operative and intraoperative images, and can enable pre-operative surgical planning and intraoperative instrument catheter guidance. The hybrid of electromagnetic and ultrasound tracking system **125** described above can further improve reliability, usability, and accuracy. The system **100** can also provide the 4D view of anatomical structures, fast registration with other pre-operative and intraoperative images, surgical planning capability, and intraoperative surgical device guidance.

[0061] Embodiments of the subject matter described herein include method steps which can be implemented in one embodiment by a program product including machine-executable instructions, such as program code, for example in the form of program modules executed by machines in networked environments. Generally, program modules include routines, programs, objects, components, data structures, etc. that perform particular tasks or implement particular abstract data types. Machine-executable instructions, associated data structures, and program modules represent examples of computer program code for executing steps of the methods disclosed herein. The particular sequence of such computer- or processor-executable instructions or associated data structures represent examples of corresponding acts for implementing the functions described in such steps.

[0062] Embodiments of the subject matter described herein may be practiced in a networked environment using logical connections to one or more remote computers having processors. Logical connections may include a local area network (LAN) and a wide area network (WAN) that are presented here by way of example and not limitation. Such networking environments are commonplace in office-wide or enterprise-wide computer networks, intranets and the Internet and may use a wide variety of different communication protocols. Those skilled in the art will appreciate that such network computing environments will typically encompass many types of computer system configurations, including personal computers, hand-held devices, multi-processor systems, microprocessor-based or programmable consumer electronics, network PCs, minicomputers, mainframe computers, and the like. Embodiments of the subject matter described herein may also be practiced in distributed computing environments where tasks are performed by local and remote processing devices that are linked (either by hardwired links, wireless links, or by a combination of hardwired or wireless links) through a communications network. In a distributed computing environment, program modules may be located in both local and remote memory storage devices.

[0063] This written description uses examples to disclose the subject matter, including the best mode, and also to enable any person skilled in the art to make and use the subject matter described herein. Accordingly, the foregoing description has been presented for purposes of illustration and description, and is not intended to be exhaustive or to limit the subject matter to the precise form disclosed, and modifications and variations are possible in light of the above teachings or may be acquired from practice of the subject matter described herein. The patentable scope of the subject matter is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. A system to image an imaged subject, comprising:

an ultrasound imaging system including an imaging probe operable to move internally and acquire ultrasound image data of the imaged subject;

a fluoroscopic imaging system operable to acquire fluoroscopic image data of the imaged subject during image acquisition by the ultrasound imaging system;

a controller in communication with the ultrasound imaging system and the fluoroscopic imaging system; and

a display in communication with the controller, the display illustrative of the ultrasound imaged data acquired with the imaging probe in combination with a fluoroscopic imaging data acquired by the fluoroscopic imaging system.

2. The system of claim **1**, wherein the imaging probe includes an intracardiac echocardiography (ICE) catheter having a transducer array rotational about a longitudinal axis and operable to acquire the ultrasound image data of the imaged subject.

3. The system of claim **2**, wherein the display includes a graphic representation of a location of a target site relative to the image data per instructions received at the controller **134**.

4. The system of claim **3**, wherein the display includes a graphical illustration of a path of the imaging probe that leads to the target site of the imaged subject.

5. The system of claim **2**, wherein the controller is operable to identify a location and an identification of a marker in the acquired ultrasound image data, the marker attached at an ablation catheter, and to generate a graphic representation of the identification and the location of the ablation catheter relative to the acquired fluoroscopic image data for illustration in the display.

6. The system of claim **5**, wherein the display further includes a graphic illustration of a distance between the imaging probe relative to the anatomical surface of the imaged anatomy of the imaged subject.

7. The system of claim **6**, wherein the display further includes an illustration of the cardiac cycle or the respiratory cycle synchronized relative to a point of time of acquisition of updates the ultrasound and fluoroscopic image data of the imaged anatomy continuously or periodically acquired and combined in the display.

8. The system of claim **7**, wherein the marker is integrated in a construction of the imaging probe, and wherein the marker includes a metallic object representative of a unique identifier detectable in the fluoroscopic image data acquired by the fluoroscopic image system.

9. The system of claim **1**, wherein an ultrasound reference frame defines a spatial relation of the ultrasound image data, and a fluoroscopic reference frame defines a spatial relation of the fluoroscopic image data, and the controller registers the ultrasound reference frame relative to fluoroscopic reference frame.

10. A method of image acquisition of an imaged subject, the method comprising the steps of:

providing an ultrasound imaging system including an imaging probe in communication with a controller;

providing a fluoroscopic imaging system operable to acquire fluoroscopic image data of the imaged subject;

acquiring the ultrasound image data simultaneously with acquiring fluoroscopic image data of the imaged subject; and

displaying a combination of the ultrasound image data and the fluoroscopic image data.

11. The method of claim **10**, wherein the step of acquiring the ultrasound image data includes rotating a transducer array rotational about a longitudinal axis of the imaging probe, the imaging probe operable to acquire an ultrasound image data of the imaged subject.

12. The method of claim **11**, wherein step of displaying includes creating a graphic representation of a location of a target site relative to the image data per instructions received at the controller.

13. The method of claim **12**, wherein the step of displaying includes creating a graphical illustration of a path of the imaging probe that leads to the target site of the imaged subject.

14. The method of claim **11**, wherein the controller is operable to identify a location and an identification of a marker attached at an ablation catheter in the acquired ultrasound image data, and to generate a graphic representation of the identification and the location of the ablation catheter relative to acquired fluoroscopic image data for illustration in the display.

15. The method of claim **14**, wherein the step of displaying further includes creating a graphic illustration of a distance between the imaging probe relative to the anatomical surface of the imaged anatomy of the imaged subject.

16. The method of claim **14**, wherein the step of displaying further includes creating an illustration of a cardiac cycle or a respiratory cycle synchronized relative to a point of time of acquisition of updates continuously or periodically acquired and combined with the fluoroscopic image data of the imaged subject.

17. The method of claim **14**, wherein the marker is integrated in a construction of the imaging probe, and wherein the marker includes a metallic object representative of a unique identifier detectable in the fluoroscopic image data acquired by the fluoroscopic imaging system.

18. The method of claim **10**, wherein an ultrasound reference frame defines a spatial relation of the ultrasound image data, and wherein a fluoroscopic reference frame defines a spatial relation of the fluoroscopic image data, and further comprising the step of registering the ultrasound reference frame relative to fluoroscopic reference frame.

* * * * *

专利名称(译)	将超声图像采集与荧光图像采集相结合的系统和方法		
公开(公告)号	[US20080283771A1](US20080283771A1)	公开(公告)日	2008-11-20
申请号	US12/060698	申请日	2008-04-01
[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	LI DUN ALEX		
发明人	LI, DUN ALEX		
IPC分类号	G01J1/58 A61B18/12 A61B8/00 A61B6/00		
CPC分类号	A61B5/06 A61B8/445 A61B6/463 A61B6/503 A61B6/541 A61B6/547 A61B8/0883 A61B8/12 A61B8/4254 A61B8/4461 A61B8/463 A61B8/5238 A61B18/1492 A61B19/52 A61B2019/5238 A61B2019/5278 A61B2019/5289 A61B2019/5425 A61B6/5247 A61B5/7285 A61B5/062 A61B8/4245 A61B90/36 A61B2090/364 A61B2090/376 A61B2090/3782 A61B2090/3925		
优先权	60/938602 2007-05-17 US		
其他公开文献	US8364242		
外部链接	Espacenet USPTO		

摘要(译)

提供了一种对成像对象进行成像的系统和方法。该系统包括超声成像系统，其包括可操作以在内部移动并获取被成像对象的超声图像数据的成像探头，可操作以在超声成像系统的图像获取期间获取被成像对象的荧光透视图像数据的荧光成像系统，以及控制器与超声成像系统和荧光成像系统通信。显示器可以说明利用成像探头获取的超声图像数据结合荧光透视成像系统获取的荧光透视成像数据。