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(54) **AUXILIARY IMAGE DISPLAY AND MANIPULATION ON A COMPUTER DISPLAY IN A MEDICAL ROBOTIC SYSTEM**

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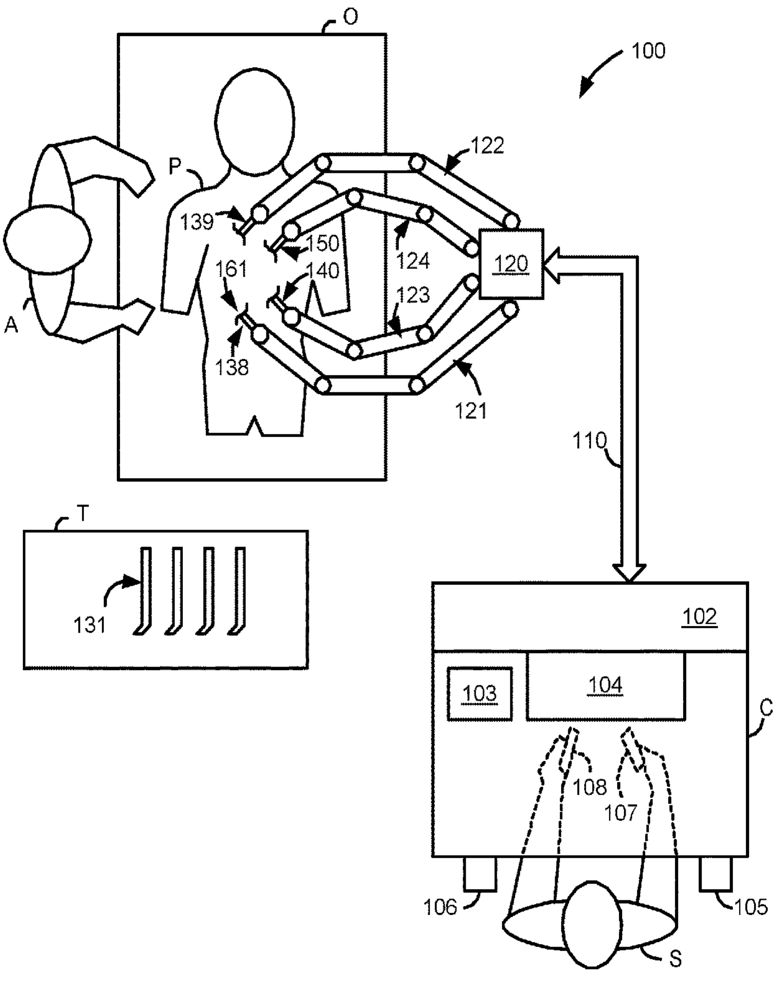
(57) **ABSTRACT**

To assist a surgeon performing a medical procedure, auxiliary images generally indicating internal details of an anatomic structure being treated are displayed and manipulated by the surgeon on a computer display screen to supplement primary images generally of an external view of the anatomic structure. A master input device controlling a robotic arm in a first mode may be switched by the surgeon to a second mode in order to function instead as a mouse-like pointing device to facilitate the surgeon performing such auxiliary information display and manipulation.



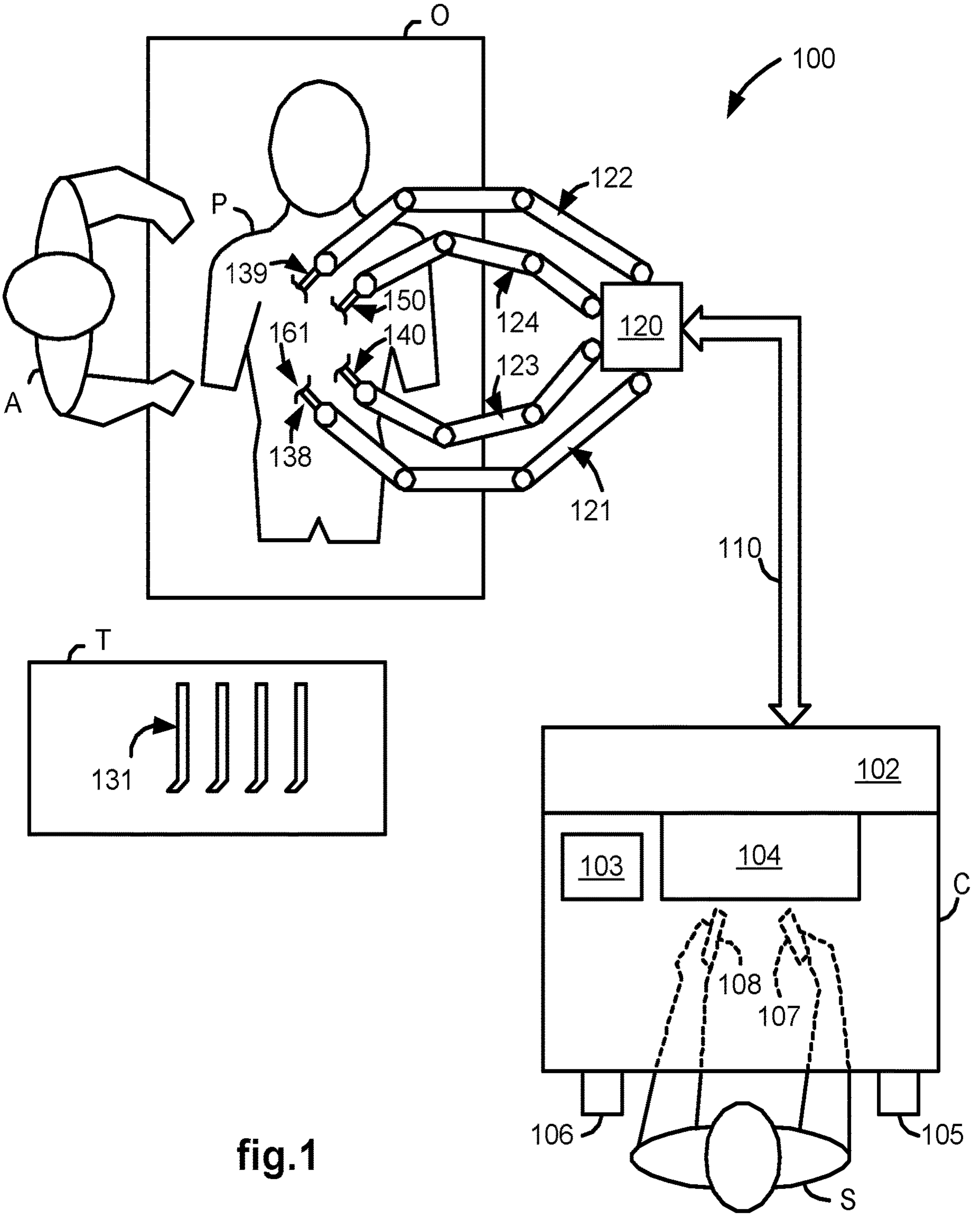
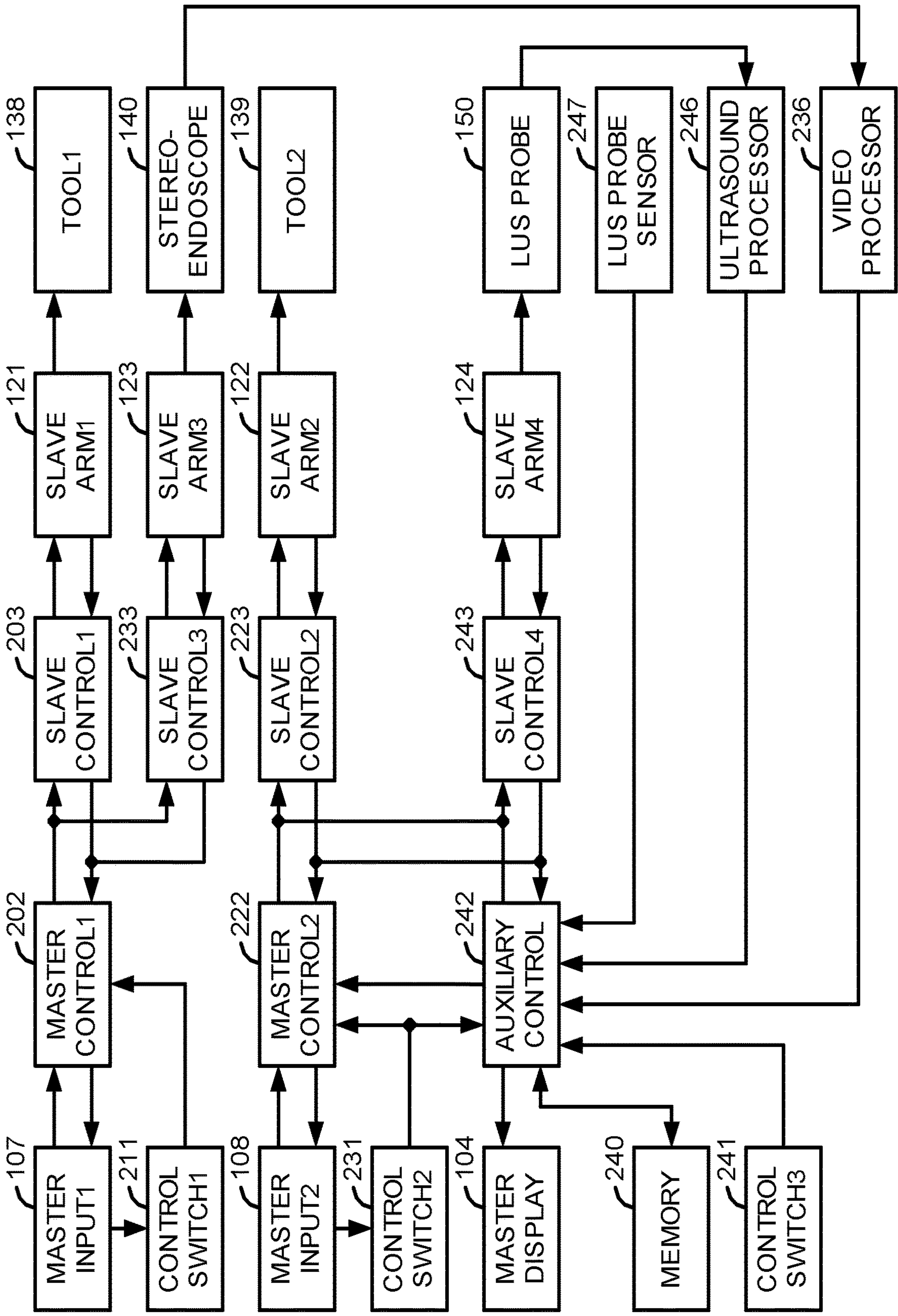

O
100
122
P
139
150
124
120
161
140
123
A
138
121
110
T
131
102
103
104
C
108
107
106
105
S

fig.1



TOOL1
138
STEREO-ENDOSCOPE
140
TOOL2
139
LUS PROBE
150
LUS PROBE SENSOR
247
ULTRASOUND PROCESSOR
246
VIDEO PROCESSOR
236
SLAVE ARM1
121
SLAVE ARM3
123
SLAVE ARM2
122
SLAVE ARM4
124
SLAVE CONTROL1
203
SLAVE CONTROL3
233
SLAVE CONTROL2
223
SLAVE CONTROL4
243
MASTER CONTROL1
202
MASTER CONTROL2
222
AUXILIARY CONTROL
242
MASTER INPUT1
107
CONTROL SWITCH1
211
MASTER INPUT2
108
CONTROL SWITCH2
231
MASTER DISPLAY
104
MEMORY
240
CONTROL SWITCH3
241

fig.2

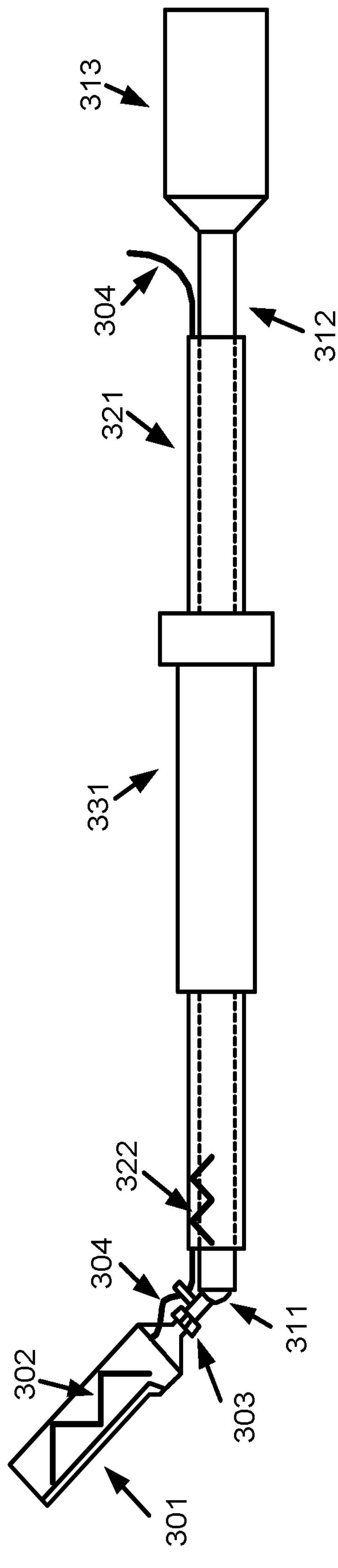


fig.3

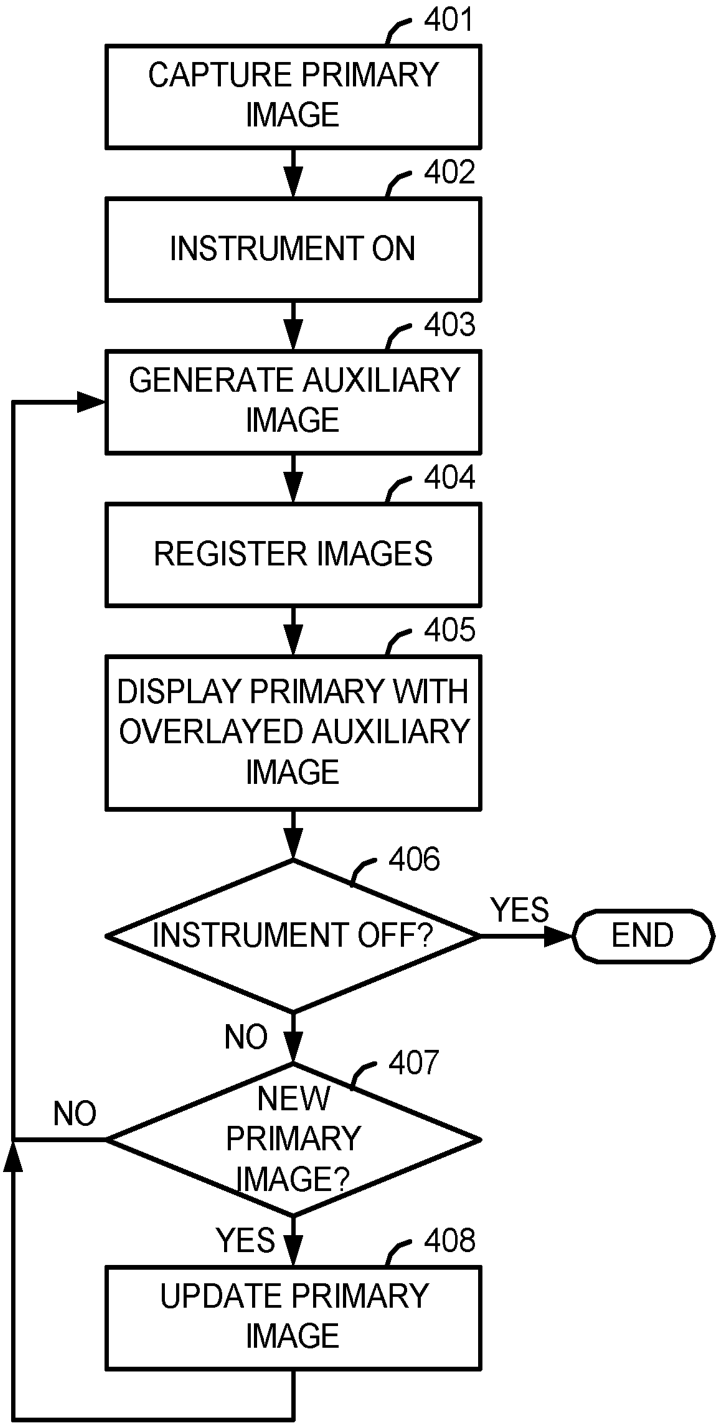

401
CAPTURE PRIMARY IMAGE
402
INSTRUMENT ON
403
GENERATE AUXILIARY IMAGE
404
REGISTER IMAGES
405
DISPLAY PRIMARY WITH OVERLAYED AUXILIARY IMAGE
406
INSTRUMENT OFF?
YES
END
NO
407
NEW PRIMARY IMAGE?
NO
YES
408
UPDATE PRIMARY IMAGE

fig.4

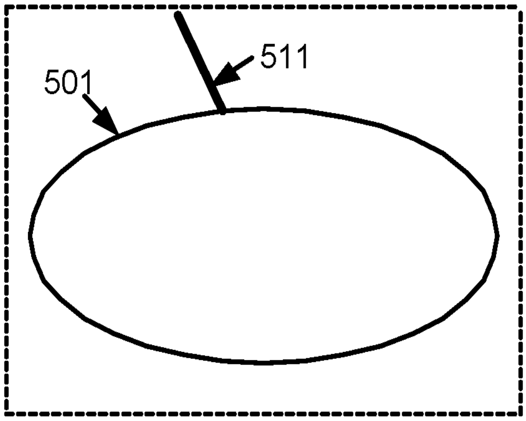


fig.5

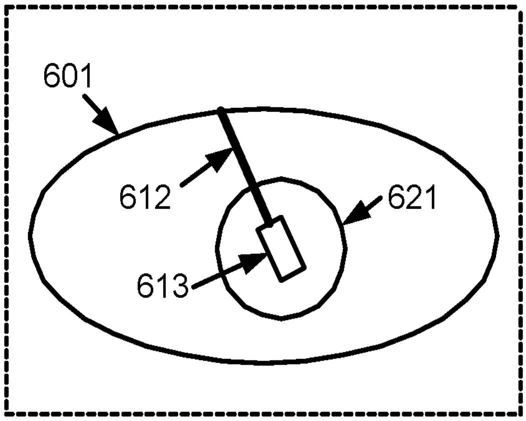


fig.6

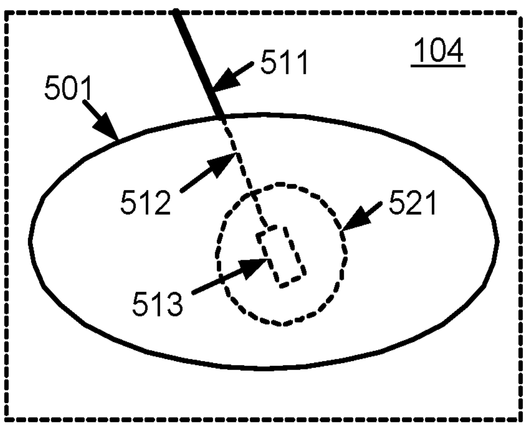


fig.7

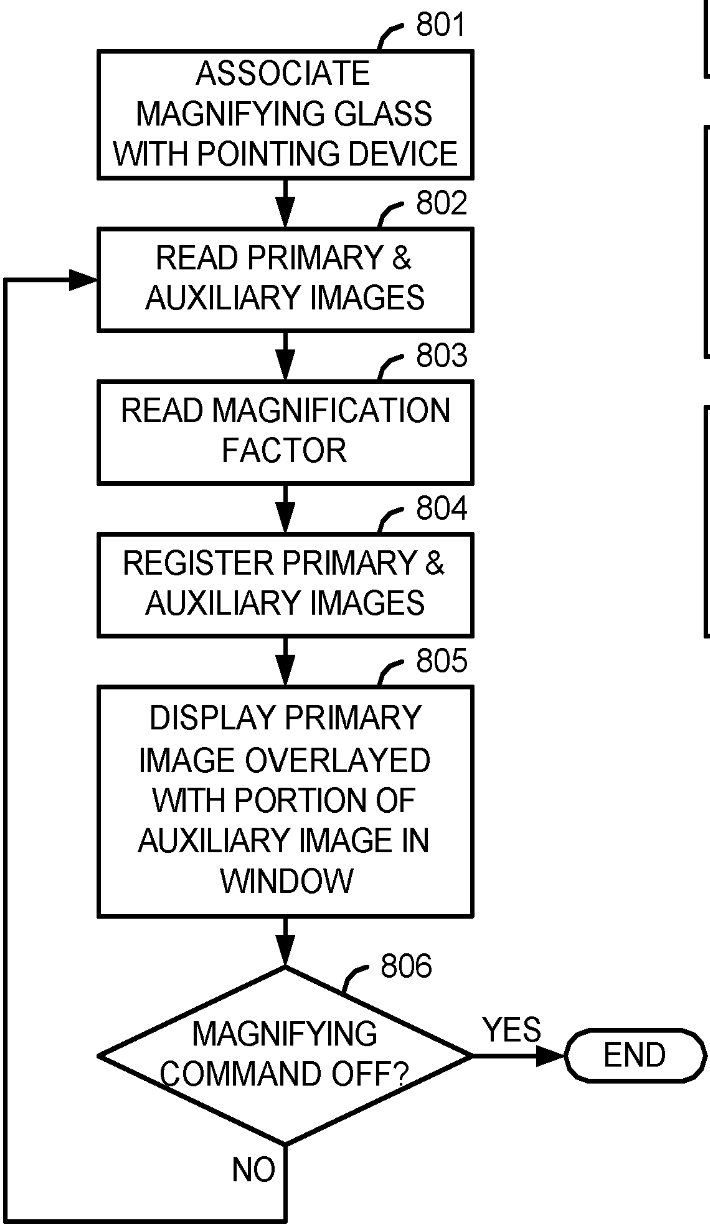

801
ASSOCIATE MAGNIFYING GLASS WITH POINTING DEVICE
802
READ PRIMARY & AUXILIARY IMAGES
803
READ MAGNIFICATION FACTOR
804
REGISTER PRIMARY & AUXILIARY IMAGES
805
DISPLAY PRIMARY IMAGE OVERLAYED WITH PORTION OF AUXILIARY IMAGE IN WINDOW
806
MAGNIFYING COMMAND OFF?
YES
END
NO

fig.8

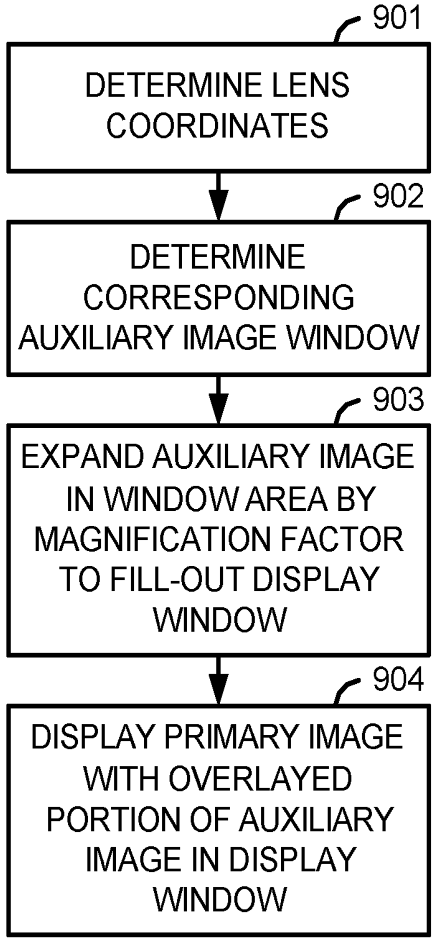

901
DETERMINE LENS COORDINATES
902
DETERMINE CORRESPONDING AUXILIARY IMAGE WINDOW
903
EXPAND AUXILIARY IMAGE IN WINDOW AREA BY MAGNIFICATION FACTOR TO FILL-OUT DISPLAY WINDOW
904
DISPLAY PRIMARY IMAGE WITH OVERLAYED PORTION OF AUXILIARY IMAGE IN DISPLAY WINDOW

fig.9

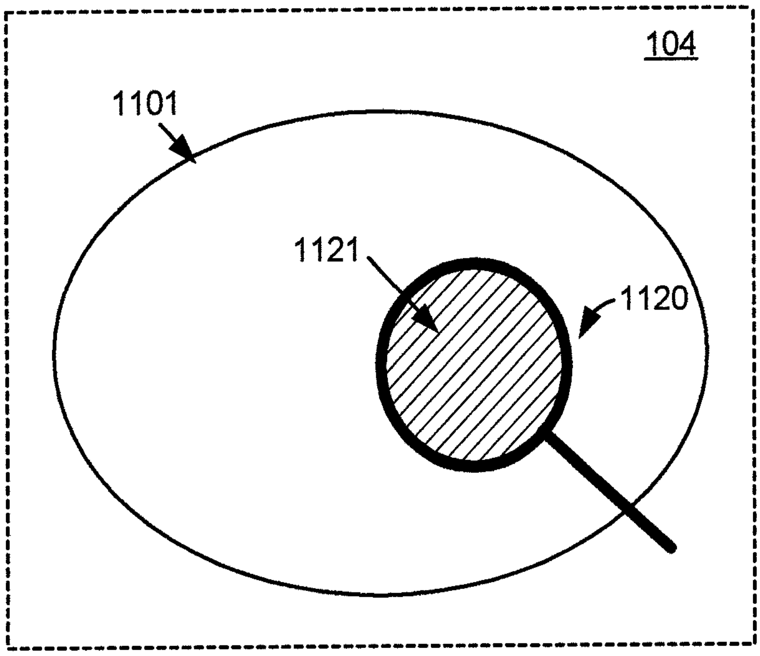


fig.11

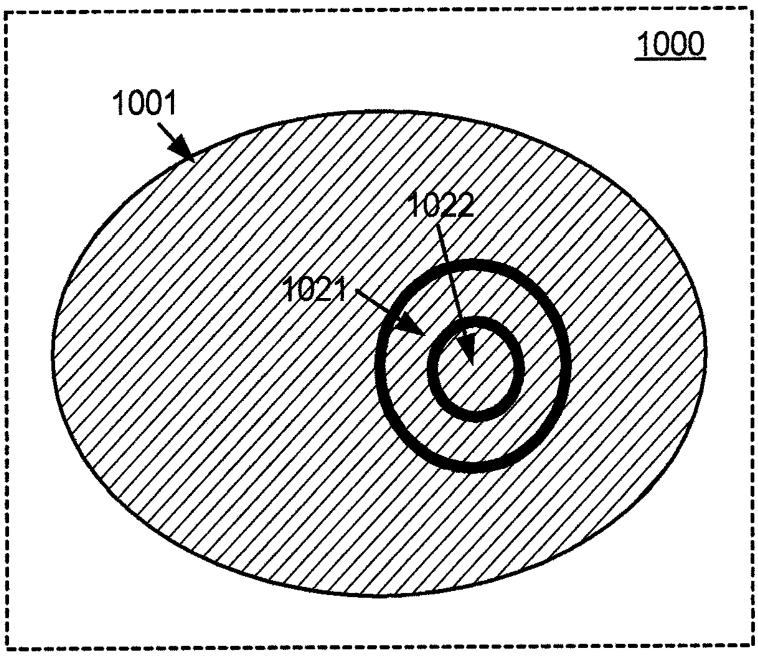


fig.10

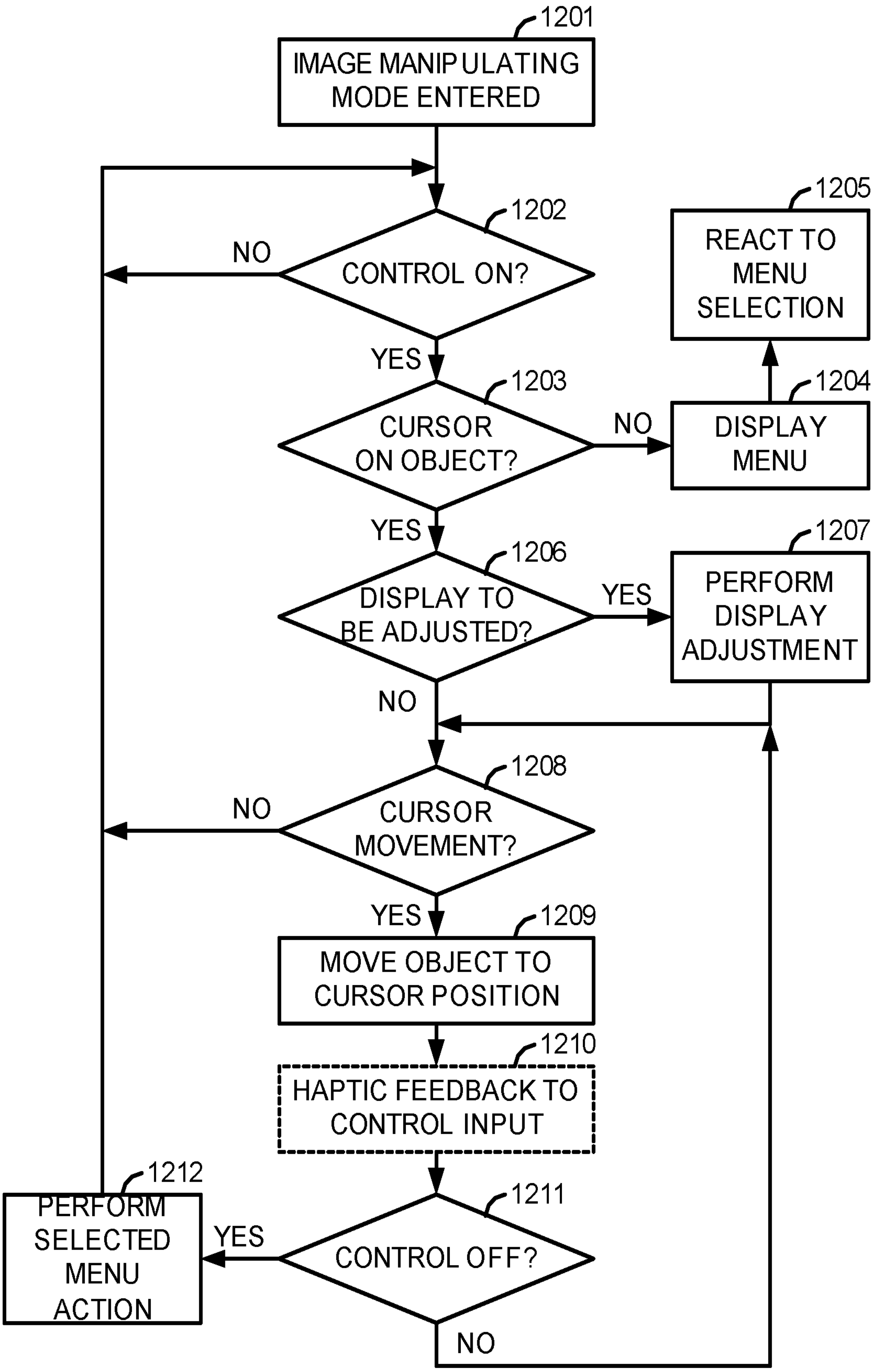

1201
IMAGE MANIPULATING MODE ENTERED
1202
CONTROL ON?
NO
YES
1203
CURSOR ON OBJECT?
NO
1204
DISPLAY MENU
1205
REACT TO MENU SELECTION
YES
1206
DISPLAY TO BE ADJUSTED?
YES
1207
PERFORM DISPLAY ADJUSTMENT
NO
1208
CURSOR MOVEMENT?
NO
YES
1209
MOVE OBJECT TO CURSOR POSITION
1210
HAPTIC FEEDBACK TO CONTROL INPUT
1211
CONTROL OFF?
YES
NO
1212
PERFORM SELECTED MENU ACTION

fig.12

AUXILIARY IMAGE DISPLAY AND MANIPULATION ON A COMPUTER DISPLAY IN A MEDICAL ROBOTIC SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. application Ser. No. 15/139,682 (filed Apr. 27, 2016), which is a division of U.S. application Ser. No. 11/583,963 (filed Oct. 19, 2006), abandoned, which claims priority to U.S. provisional Application No. 60/728,450 (filed Oct. 20, 2005), each of which is incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention generally relates to medical robotic systems and in particular, to the displaying and manipulating of auxiliary images on a computer display in a medical robotic system.

BACKGROUND

[0003] Medical robotic systems such as those used in performing minimally invasive surgical procedures offer many benefits over traditional open surgery techniques, including less pain, shorter hospital stays, quicker return to normal activities, minimal scarring, reduced recovery time, and less injury to tissue. Consequently, demand for minimally invasive surgery using medical robotic systems is strong and growing.

[0004] One example of a medical robotic system is the daVinci® Surgical System from Intuitive Surgical, Inc., of Sunnyvale, Calif. The daVinci® system includes a surgeon's console, a patient-side cart, a high performance 3-D vision system, and Intuitive Surgical's proprietary EndoWrist™ articulating instruments, which are modeled after the human wrist so that when added to the motions of the robotic arm assembly holding the surgical instrument, they allow at least a full six degrees of freedom of motion, which is comparable to the natural motions of open surgery.

[0005] The daVinci® surgeon's console has a high-resolution stereoscopic video display with two progressive scan cathode ray tubes ("CRTs"). The system offers higher fidelity than polarization, shutter eyeglass, or other techniques. Each eye views a separate CRT presenting the left or right eye perspective, through an objective lens and a series of mirrors. The surgeon sits comfortably and looks into this display throughout surgery, making it an ideal place for the surgeon to display and manipulate 3-D intra-operative imagery.

[0006] In addition to primary imagery being displayed on the display screen, it is also desirable at times to be able to concurrently view auxiliary information to gain better insight or to otherwise assist in the medical procedure being performed. The auxiliary information may be provided in various modes such as text information, bar graphs, two-dimensional picture-in-picture images, and two-dimensional or three-dimensional images that are registered and properly overlaid with respect to their primary image counterparts.

[0007] For auxiliary images, the images may be captured pre-operatively or intra-operatively using techniques such as ultrasonography, magnetic resonance imaging, computed axial tomography, and fluoroscopy to provide internal details of an anatomic structure being treated. This information may then be used to supplement external views of the anatomic structure such as captured by a locally placed camera.

[0008] Although there are a plethora of auxiliary information sources as well as manners of displaying that information, improvements in the display and manipulation of auxiliary images is still useful to better assist surgeons in performing medical procedures with medical robotic systems.

BRIEF SUMMARY

[0009] Accordingly, one object of various aspects of the present invention is a method for displaying auxiliary information including the effect of a therapeutic procedure as an overlay to or otherwise associated with an image of an anatomic structure being treated at the time by the procedure.

[0010] Another object of various aspects of the present invention is a method for displaying a user selected portion at a user specified magnification factor of a volume rendering of an auxiliary image of an anatomic structure as a registered overlay to a primary image of the anatomic structure on a computer display screen.

[0011] Another object of various aspects of the present invention is a medical robotic system having a master input device that may be used to manually register images in a three-dimensional space of a computer display.

[0012] Another object of various aspects of the present invention is a medical robotic system having a master input device that may be used to define cut-planes of a volume rendering of an anatomic structure in a three-dimensional space of a computer display.

[0013] Another object of various aspects of the present invention is a medical robotic system having a master input device that may be used to selectively modify portions or details of a volume rendering of an anatomic structure in a three-dimensional space of a computer display.

[0014] Another object of various aspects of the present invention is a medical robotic system having a master input device that may be used to vary display parameters for a rendering of an anatomic structure being displayed on a computer display screen.

[0015] Still another object of various aspects of the present invention is a medical robotic system having a master input device that may be switched between an image capturing mode wherein the master input device controls movement of an image capturing device, and an image manipulating mode wherein the master input device controls display and manipulation of images captured by the image capturing device on a computer display screen.

[0016] These and additional objects are accomplished by the various aspects of the present invention, wherein the embodiments of the invention are summarized by the claims that follow below.

[0017] Additional objects, features and advantages of the various aspects of the present invention will become apparent from the following description of its preferred embodiment, which description should be taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] FIG. **1** illustrates a top view of an operating room employing a medical robotic system utilizing aspects of the present invention.

[0019] FIG. **2** illustrates a block diagram of a medical robotic system utilizing aspects of the present invention.

[0020] FIG. **3** illustrates a laparoscopic ultrasound probe useful for a medical robotic system utilizing aspects of the present invention.

[0021] FIG. **4** illustrates a flow diagram of a method for displaying on a computer display screen an effect of a therapeutic procedure being applied by a therapeutic instrument to an anatomic structure, utilizing aspects of the present invention.

[0022] FIG. **5** illustrates an external view of an anatomic structure with a therapeutic instrument inserted in the anatomic structure for performing a therapeutic procedure.

[0023] FIG. **6** illustrates an internal view of an anatomic structure with a discernable therapeutic effect shown as captured by a therapy sensing device.

[0024] FIG. **7** illustrates a computer display screen displaying an effect of a therapeutic procedure registered to an anatomic structure being treated by the procedure, as generated by a method utilizing aspects of the present invention.

[0025] FIG. **8** illustrates a flow diagram of a method for displaying a selected portion of an auxiliary image of an anatomic structure in a user movable magnifying glass on a computer display screen, utilizing aspects of the present invention.

[0026] FIG. **9** illustrates a flow diagram of a method for displaying a manipulatable window of an internal view of an anatomic structure at a specified magnification factor, utilizing aspects of the present invention.

[0027] FIG. **10** illustrates an auxiliary image of an anatomic structure and concentric areas of the auxiliary image representing different magnification factors for display on a computer display screen in a magnifying glass by a method utilizing aspects of the present invention.

[0028] FIG. **11** illustrates a computer display screen with a primary image of an anatomic structure and an overlaid portion of an auxiliary image of the anatomic structure viewed in a magnifying glass lens as displayed by a method utilizing aspects of the present invention.

[0029] FIG. **12** illustrates a flow diagram of a method performed by a processor in a medical robotic system for manipulating objects displayed on a computer display screen utilizing aspects of the present invention.

DETAILED DESCRIPTION

[0030] FIG. **1** illustrates, as an example, a top view of an operating room employing a medical robotic system. The medical robotic system in this case is a Minimally Invasive Robotic Surgical ("MIRS") System **100** including a Console ("C") utilized by a Surgeon ("S") while performing a minimally invasive diagnostic or surgical procedure with assistance from one or more Assistants ("A") on a Patient ("P") who is reclining on an Operating table ("O").

[0031] The Console includes a Master Display **104** (also referred to herein as a "Display Screen" or "computer display screen") for displaying one or more images of a surgical site within the Patient as well as perhaps other information to the Surgeon. Also included are Master Input Devices **107**, **108** (also referred to herein as "Master Manipulators"), one or more Foot Pedals **105**, **106**, a Microphone **103** for receiving voice commands from the Surgeon, and a Processor **102**. The Master Input Devices **107**, **108** may include any one or more of a variety of input devices such as joysticks, gloves, trigger-guns, hand-operated controllers, grippers, or the like. The Processor **102** is preferably a personal computer that may be integrated into the Console or otherwise connected to it in a conventional manner.

[0032] The Surgeon performs a medical procedure using the MIRS System **100** by manipulating the Master Input Devices **107**, **108** so that the Processor **102** causes their respectively associated Slave Arms **121**, **122** to manipulate their respective removably coupled and held Surgical Instruments **138**, **139** (also referred to herein as "Tools") accordingly, while the Surgeon views three-dimensional ("3D") images of the surgical site on the Master Display **104**.

[0033] The Tools **138**, **139** are preferably Intuitive Surgical's proprietary EndoWrist™ articulating instruments, which are modeled after the human wrist so that when added to the motions of the robot arm holding the tool, they allow at least a full six degrees of freedom of motion, which is comparable to the natural motions of open surgery. Additional details on such tools may be found in commonly owned U.S. Pat. No. 5,797,900 entitled "Wrist Mechanism for Surgical Instrument for Performing Minimally Invasive Surgery with Enhanced Dexterity and Sensitivity," which is incorporated herein by this reference. At the operating end of each of the Tools **138**, **139** is a manipulatable end effector such as a clamp, grasper, scissor, stapler, blade, needle, needle holder, or energizable probe.

[0034] The Master Display **104** has a high-resolution stereoscopic video display with two progressive scan cathode ray tubes ("CRTs"). The system offers higher fidelity than polarization, shutter eyeglass, or other techniques. Each eye views a separate CRT presenting the left or right eye perspective, through an objective lens and a series of mirrors. The Surgeon sits comfortably and looks into this display throughout surgery, making it an ideal place for the Surgeon to display and manipulate 3-D intra-operative imagery.

[0035] A Stereoscopic Endoscope **140** provides right and left camera views to the Processor **102** so that it may process the information according to programmed instructions and cause it to be displayed on the Master Display **104**. A Laparoscopic Ultrasound ("LUS") Probe **150** provides two-dimensional ("2D") ultrasound image slices of an anatomic structure to the Processor **102** so that the Processor **102** may generate a 3D ultrasound computer model or volume rendering of the anatomic structure.

[0036] Each of the Tools **138**, **139**, as well as the Endoscope **140** and LUS Probe **150**, is preferably inserted through a cannula or trocar (not shown) or other tool guide into the Patient so as to extend down to the surgical site through a corresponding minimally invasive incision such as Incision **161**. Each of the Slave Arms **121-124** includes a slave manipulator and setup arms. The slave manipulators are robotically moved using motor controlled joints (also referred to as "active joints") in order to manipulate and/or move their respectively held Tools. The setup arms are manually manipulated by releasing normally braked joints (also referred to as "setup joints") to horizontally and vertically position the Slave Arms **121-124** so that their respective Tools may be inserted into the cannulae.

[0037] The number of surgical tools used at one time and consequently, the number of slave arms being used in the System **100** will generally depend on the medical procedure to be performed and the space constraints within the operating room, among other factors. If it is necessary to change one or more of the tools being used during a procedure, the Assistant may remove the tool no longer being used from its slave arm, and replace it with another tool, such as Tool **131**, from a Tray ("T") in the Operating Room.

[0038] Preferably, the Master Display **104** is positioned near the Surgeon's hands so that it will display a projected image that is oriented so that the Surgeon feels that he or she is actually looking directly down onto the surgical site. To that end, an image of the Tools **138**, **139** preferably appear to be located substantially where the Surgeon's hands are located even though the observation points (i.e., that of the Endoscope **140** and LUS Probe **150**) may not be from the point of view of the image.

[0039] In addition, the real-time image is preferably projected into a perspective image such that the Surgeon can manipulate the end effector of a Tool, **138** or **139**, through its associated Master Input Device, **107** or **108**, as if viewing the workspace in substantially true presence. By true presence, it is meant that the presentation of an image is a true perspective image simulating the viewpoint of an operator that is physically manipulating the Tools. Thus, the Processor **102** transforms the coordinates of the Tools to a perceived position so that the perspective image is the image that one would see if the Endoscope **140** was looking directly at the Tools from a Surgeon's eye-level during an open cavity procedure.

[0040] The Processor **102** performs various functions in the System **100**. One important function that it performs is to translate and transfer the mechanical motion of Master Input Devices **107**, **108** to their associated Slave Arms **121**, **122** through control signals over Bus **110** so that the Surgeon can effectively manipulate their respective Tools **138**, **139**. Another important function is to implement the various methods described herein in reference to FIGS. **4-12**.

[0041] Although described as a processor, it is to be appreciated that the Processor **102** may be implemented in practice by any combination of hardware, software and firmware. Also, its functions as described herein may be performed by one unit, or divided up among different components, each of which may be implemented in turn by any combination of hardware, software and firmware. When divided up among different components, the components may be centralized in one location or distributed across the System **100** for distributed processing purposes.

[0042] Prior to performing a medical procedure, ultrasound images captured by the LUS Probe **150**, right and left 2D camera images captured by the stereoscopic Endoscope **140**, and end effector positions and orientations as determined using kinematics of the Slave Arms **121-124** and their sensed joint positions, are calibrated and registered with each other.

[0043] Slave Arms **123**, **124** may manipulate the Endoscope **140** and LUS Probe **150** in similar manners as Slave Arms **121**, **122** manipulate Tools **138**, **139**. When there are only two master input devices in the system, however, such as Master Input Devices **107**, **108** in the System **100**, in order for the Surgeon to manually control movement of either the Endoscope **140** or LUS Probe **150**, it may be required to temporarily associate one of the Master Input Devices **107**, **108** with the Endoscope **140** or the LUS Probe **150** that the Surgeon desires manual control over, while its previously associated Tool and Slave Manipulator are locked in position.

[0044] Although not shown in this example, other sources of primary and auxiliary images of anatomic structures may be included in the System **100**, such as those commonly used for capturing ultrasound, magnetic resonance, computed axial tomography, and fluoroscopic images. Each of these sources of imagery may be used pre-operatively, and where appropriate and practical, intra-operatively.

[0045] FIG. **2** illustrates, as an example, a block diagram of the System **100**. In this system, there are two Master Input Devices **107**, **108**. Master Input Device **107** controls movement of either a Tool **138** or a stereoscopic Endoscope **140**, depending upon which mode its Control Switch Mechanism **211** is in, and Master Input Device **108** controls movement of either a Tool **139** or a LUS Probe **150**, depending upon which mode its Control Switch Mechanism **231** is in.

[0046] The Control Switch Mechanisms **211** and **231** may be placed in either a first or second mode by a Surgeon using voice commands, switches physically placed on or near the Master Input Devices **107**, **108**, Foot Pedals **105**, **106** on the Console, or Surgeon selection of appropriate icons or other graphical user interface selection means displayed on the Master Display **104** or an auxiliary display (not shown).

[0047] When Control Switch Mechanism **211** is placed in the first mode, it causes Master Controller **202** to communicate with Slave Controller **203** so that manipulation of the Master Input **107** by the Surgeon results in corresponding movement of Tool **138** by Slave Arm **121**, while the Endoscope **140** is locked in position. On the other hand, when Control Switch Mechanism **211** is placed in the second mode, it causes Master Controller **202** to communicate with Slave Controller **233** so that manipulation of the Master Input **107** by the Surgeon results in corresponding movement of Endoscope **140** by Slave Arm **123**, while the Tool **138** is locked in position.

[0048] Similarly, when Control Switch Mechanism **231** is placed in the first mode, it causes Master Controller **108** to communicate with Slave Controller **223** so that manipulation of the Master Input **108** by the Surgeon results in corresponding movement of Tool **139** by Slave Arm **122**. In this case, however, the LUS Probe **150** is not necessarily locked in position. Its movement may be guided by an Auxiliary Controller **242** according to stored instructions in Memory **240**. The Auxiliary Controller **242** also provides haptic feedback to the Surgeon through Master Input **108** that reflects readings of a LUS Probe Force Sensor **247**. On the other hand, when Control Switch Mechanism **231** is placed in the second mode, it causes Master Controller **108** to communicate with Slave Controller **243** so that manipulation of the Master Input **108** by the Surgeon results in corresponding movement of LUS Probe **150** by Slave Arm **124**, while the Tool **139** is locked in position.

[0049] Before a Control Switch Mechanism effects a switch back to its first or normal mode, its associated Master Input Device is preferably repositioned to where it was before the switch. Alternatively, the Master Input Device may remain in its current position and kinematic relationships between the Master Input Device and its associated Tool Slave Arm readjusted so that upon the Control Switch Mechanism switching back to its first or normal mode, abrupt movement of the Tool does not occur. For additional details on control switching, see, e.g., commonly owned U.S. Pat. No. 6,659,939 entitled "Cooperative Minimally Invasive Telesurgical System," which is incorporated herein by this reference.

[0050] A third Control Switch Mechanism **241** is provided to allow the user to switch between an image capturing mode and an image manipulating mode while the Control Switch Mechanism **231** is in its second mode (i.e., associating the Master Input Device **108** with the LUS Probe **150**). In its first or normal mode (i.e., image capturing mode), the LUS Probe **150** is normally controlled by the Master Input Device **108** as described above. In its second mode (i.e., image manipulating mode), the LUS Probe **150** is not controlled by the Master Input Device **108**, leaving the Master Input Device **108** free to perform other tasks such as the displaying and manipulating of auxiliary images on the Display Screen **104** and in particular, for performing certain user specified functions as described herein. Note however that although the LUS Probe **150** may not be controlled by the Master Input Device **108** in this second mode of the Control Switch Mechanism **241**, it may still be automatically rocked or otherwise moved under the control of the Auxiliary Controller **242** according to stored instructions in Memory **240** so that a 3D volume rendering of a proximate anatomic structure may be generated from a series of 2D ultrasound image slices captured by the LUS Probe **150**. For additional details on such and other programmed movement of the LUS Probe **150**, see commonly owned U.S. patent application Ser. No. 11/447,668 entitled "Laparoscopic Ultrasound Robotic Surgical System," filed Jun. 6, 2006, which is incorporated herein by this reference.

[0051] The Auxiliary Controller **242** also performs other functions related to the LUS Probe **150** and the Endoscope **140**. It receives output from a LUS Probe Force Sensor **247**, which senses forces being exerted against the LUS Probe **150**, and feeds the force information back to the Master Input Device **108** through the Master Controller **222** so that the Surgeon may feel those forces even if he or she is not directly controlling movement of the LUS Probe **150** at the time. Thus, potential injury to the Patient is minimized since the Surgeon has the capability to immediately stop any movement of the LUS Probe **150** as well as the capability to take over manual control of its movement.

[0052] Another key function of the Auxiliary Control **242** is to cause processed information from the Endoscope **140** and the LUS Probe **150** to be displayed on the Master Display **104** according to user selected display options. Examples of such processing include generating a 3D ultrasound image from 2D ultrasound image slices received from the LUS Probe **150** through an Ultrasound Processor **246**, causing either 3D or 2D ultrasound images corresponding to a selected position and orientation to be displayed in a picture-in-picture window of the Master Display **104**, causing either 3D or 2D ultrasound images of an anatomic structure to overlay a camera captured image of the anatomic structure being displayed on the Master Display **104**, and performing the methods described below in reference to FIGS. **4-12**.

[0053] Although shown as separate entities, the Master Controllers **202**, **222**, Slave Controllers **203**, **233**, **223**, **243**, and Auxiliary Controller **242** are preferably implemented as software modules executed by the Processor **102**, as well as certain mode switching aspects of the Control Switch Mechanisms **211**, **231**, **241**. The Ultrasound Processor **246** and Video Processor **236**, on the other hand, may be software modules or separate boards or cards that are inserted into appropriate slots coupled to or otherwise integrated with the Processor **102** to convert signals received from these image capturing devices into signals suitable for display on the Master Display **104** and/or for additional processing by the Auxiliary Controller **242** before being displayed on the Master Display **104**.

[0054] Although the present example assumes that each Master Input Device is being shared by only one pre-assigned Tool Slave Robotic Arm and one pre-assigned Image Capturing Device Robotic Arm, alternative arrangements are also feasible and envisioned to be within the full scope of the present invention. For example, a different arrangement wherein each of the Master Input Devices may be selectively associated with any one of the Tool and Image Capturing Device Robotic Arms is also possible and even preferably for maximum flexibility. Also, although the Endoscope Robotic Arm is shown in this example as being controlled by a single Master Input Device, it may also be controlled using both Master Input Devices to give the sensation of being able to "grab the image" and move it to a different location or view. Still further, although only an Endoscope and LUS Probe are show in this example, other Image Capturing Devices such as those used for capturing camera, ultrasound, magnetic resonance, computed axial tomography, and fluoroscopic images are also fully contemplated within the System **100**, although each of these Image Capturing Devices may not necessarily be manipulated by one of the Master Input Devices.

[0055] FIG. **3** illustrates a side view of one embodiment of the LUS Probe **150**. The LUS Probe **150** is a dexterous tool with preferably two distal degrees of freedom. Opposing pairs of Drive Rods or Cables (not shown) physically connected to a proximal end of the LUS Sensor **301** and extending through an internal passage of Elongated Shaft **312** mechanically control pitch and yaw movement of the LUS Sensor **301** using conventional push-pull type action.

[0056] The LUS Sensor **301** captures 2D ultrasound slices of a proximate anatomic structure, and transmits the information back to the Processor **102** through LUS Cable **304**. Although shown as running outside of the Elongated Shaft **312**, the LUS Cable **304** may also extend within it. A Clamshell Sheath **321** encloses the Elongate Shaft **312** and LUS Cable **304** to provide a good seal passing through a Cannula **331** (or trocar). Fiducial Marks **302** and **322** are placed on the LUS Sensor **301** and the Sheath **321** for video tracking purposes.

[0057] FIG. **4** illustrates, as an example, a flow diagram of a method for displaying the effect of a therapeutic procedure or treatment on the Display Screen **104**. In **401**, a primary image of an anatomic structure is captured by an image capturing device. As an example, FIG. **5** illustrates a primary image which has been captured by the Endoscope **140** and includes an anatomic structure **501** and therapeutic instrument **511** that has been partially inserted into the anatomic structure **501** in order to perform a therapeutic procedure at a therapy site within the anatomic structure **501**. In another application, the therapeutic instrument **511** may only need to touch or come close to the anatomic structure **501** in order to perform a therapeutic procedure.

[0058] The primary image may be captured before or during the therapeutic procedure. A primary image captured before the procedure is referred to as being a "pre-operative" image, and a primary image captured during the procedure is referred to as being an "intra-operative" image. When the primary image is a pre-operative image, the image is generally not updated during the procedure, so that the method generally only employs one primary image. On the other hand, when the primary image is an intra-operative image, the image is preferably updated periodically during the procedure, so that the method employs multiple primary images in that case.

[0059] Pre-operative images are typically captured using techniques such as Ultrasonography, Magnetic Resonance Imaging (MM), or Computed Axial Tomography (CAT). Intra-operative images may be captured at the surgical or therapeutic site by image capturing devices such as the stereoscopic Endoscope **140** or LUS Probe **150**, or they may be captured externally by techniques such as those used to capture the pre-operative images.

[0060] In **402** of FIG. **4**, the therapeutic instrument is turned on, or otherwise activated or energized, so as to be capable of applying therapy to the anatomic structure within the patient. The instrument generally has a tip for applying the therapeutic energy to abnormal tissue such as diseased or damaged tissue. As one example of such a therapeutic procedure, Radio Frequency Ablation (RFA) may be used to destroy diseased tissue such as a tumor located in an anatomic structure such as the liver by applying heat to the diseased tissue site using an RFA probe. Examples of other procedures include High Intensity Focused Ultrasound (HIFU) and Cauterization. The therapeutic instrument may be one of the Tools **138**, **139** attached to Slave Arms **121**, **122** so that it may be moved to and manipulated at the therapy site through the master/slave control system by the Surgeon.

[0061] In **403**, an auxiliary image is generated, wherein the auxiliary image indicates the effect of the therapeutic procedure on the anatomic structure. The auxiliary image may be an actual image of the anatomic structure that has been provided by or generated from information captured by a sensing device which is capable of sensing the effect of the therapeutic procedure. Alternatively, the auxiliary image may be a computer model indicating the effect of the therapy, which may be generated using an empirically derived or otherwise conventionally determined formula of such effect. In this latter case, the computer model is generally a volumetric shape determined by such factors as the geometry of the tip of the therapeutic instrument, the heat or energy level being applied to the anatomic structure by the tip of the therapeutic instrument, and the features of the surrounding tissue of a therapy site being subjected to the therapeutic procedure in the anatomic structure.

[0062] As an example of an auxiliary image provided or otherwise derived from information captured by a sensing device, FIG. **6** illustrates a three-dimensional ultrasound image of an anatomic structure **601** which has been conventionally derived from two-dimensional ultrasound slices captured by the LUS probe **150**. In this example, an ablation volume **621** is shown which represents the effect of a therapeutic procedure in which a tip **613** of an RFA probe **612** is being applied to a tumor site of the anatomic structure **601**. The growth of the ablation volume in this case is viewable due to changes in tissue properties from the heating and necrosis of the surrounding tissue at the tumor site.

[0063] In **404**, the primary and auxiliary images are registered so as to be of the same scale and refer to a same position and orientation in a common reference frame. Registration of this sort is well known. As an example, see commonly owned U.S. Pat. No. 6,522,906 entitled "Devices and Methods for Presenting and Regulating Auxiliary Information on an Image Display of a Telesurgical System to Assist an Operator in Performing a Surgical Procedure," which is incorporated herein by this reference.

[0064] In **405**, the primary image is displayed on the Display Screen **104** while the therapeutic procedure is being performed, with the registered auxiliary image preferably overlaid upon the primary image so that corresponding structures or objects in each of the images appear as the same size and at the same location and orientation on the Display Screen **104**. In this way, the effect of the therapeutic procedure is shown as an overlay over the anatomic structure that is being subjected to the procedure.

[0065] As an example, FIG. **7** shows an exemplary Display Screen **104** in which an auxiliary image, distinguished as a dotted line for illustrative purposes, is overlaid over the primary image of FIG. **5**. When the auxiliary image is provided by or derives from information captured by a sensing device, the therapy effect **521**, therapeutic instrument **512**, and instrument tip **513** is provided by or derived from the captured information. On the other hand, when the therapy effect **521** is generated as a volumetric shaped computer model using an empirically determined formula, the therapeutic instrument **512** and instrument tip **513** may be determined using conventional tool tracking computations based at least in part upon joint positions of its manipulating slave arm.

[0066] In **406** of FIG. **4**, the method then checks whether the therapeutic instrument has been turned off. If it has, then this means that the therapeutic procedure is over, and the method ends. On the other hand, if the therapeutic instrument is still on, then the method assumes that the therapeutic procedure is still being performed, and proceeds in **407** to determine whether a new primary image has been captured. If no new primary image has been captured, for example, because the primary image is a pre-operative image, then the method jumps back to **403** to update the auxiliary image and continue to loop through **403**-**407** until the therapeutic procedure is determined to be completed by detecting that the therapeutic instrument has been turned off. On the other hand, if a new primary image has been captured, for example, because the primary image is an intra-operative image, then the method updates the primary image in **408** before jumping back to **403** to update the auxiliary image and continue to loop through **403**-**408** until the therapeutic procedure is determined to be completed by detecting that the therapeutic instrument has been turned off.

[0067] FIG. **8** illustrates, as an example, a flow diagram of a method for displaying an auxiliary image of an anatomic structure as a registered overlay to a primary image of the anatomic structure at a user specified magnification in a window defined as the lens area of a magnifying glass whose position and orientation as displayed on the Display Screen **104** is manipulatable by the user using an associated pointing device.

[0068] In **801**, the method starts out by associating the magnifying glass with the pointing device so that as the pointing device moves, the magnifying glass being displayed on the Display Screen **104** (and in particular, its lens which may be thought of as a window) moves in a corresponding fashion. The association in this case may be performed by "grabbing" the magnifying glass in a conventional manner using the pointing device, or by making the magnifying glass effectively the cursor for the pointing device. Since the Display Screen **104** is preferably a three-dimensional display, the pointing device is correspondingly preferably a three-dimensional pointing device with orientation indicating capability.

[0069] In **802**, current primary and auxiliary images are made available for processing. The primary image in this example is captured by the Endoscope **140** and the auxiliary captured by the LUS Probe **150**. However, other sources for the primary and auxiliary images are also usable and contemplated in practicing the invention, including primary and auxiliary images captured from the same source. As an example of this last case, a high resolution camera may capture images at a resolution greater than that being used to display images on a display screen. In this case, the high resolution image captured by the camera may be treated as the auxiliary image, and the downsized image to be displayed on the display screen may be treated as the primary image.

[0070] In **803**, a user selectable magnification factor is read. The magnification factor is user selectable by, for example, a dial or wheel type control on the pointing device. Alternatively, it may be user selectable by user selection of item in a menu displayed on the Display Screen **104**, or any other conventional user selectable parameter value scheme or mechanism. If the user fails to make a selection, then a default value is used, such as a magnification factor of 1.0.

[0071] In **804**, the primary and auxiliary images are registered so as to be of the same scale and refer to a same position and orientation in a common reference frame so that corresponding structures and objects in the two images have the same coordinates.

[0072] In **805**, the primary image is displayed on the Display Screen **104** such as a three-dimensional view of the anatomic structure, in which case, a portion of a two-dimensional slice of the auxiliary image of the anatomic structure may be displayed as an overlay in the lens of the magnifying glass. The portion of the two-dimensional slice in this case is defined by a window area having a central point that has the same position and orientation of as the central point of the lens of the magnifying glass, and an area determined by the magnification factor so that the portion of the two-dimensional slice may be enlarged or reduced so as to fit in the lens of the magnifying glass. Since the position and orientation of the magnifying glass is manipulatable by the positioning device to any position in the three-dimensional space of the Display Screen **104**, including those within the volume of the anatomic structure, the two-dimensional slice can correspond to any user selected depth within the anatomic structure. Unlike a physical magnifying glass, its view is not limited to inspecting only the exterior of the anatomic structure. For additional details on **805**, see the description below in reference to FIG. **9**.

[0073] In **806**, the method then determines whether the magnifying glass command has been turned off by, for example, the user releasing a "grabbed" image of the magnifying glass, or otherwise switching off the association between the magnifying glass and the pointing device by the use of a conventional switch mechanism of some sort. If it has, then the method ends. On the other hand, if it has not, then the method jumps back to **802** and continues to loop through **802-806** until the magnifying glass command is detected to have been turned off. Note that each time the method loops through **802-806**, updated versions, if any, of the primary and auxiliary images are processed along with updated values, if any, for the user selectable magnification factor. Thus, if the method proceeds through the looping in a sufficiently fast manner, the user will not notice any significant delay if the user is turning a dial or knob to adjust the magnification factor while viewing the anatomic structure at a selected position and orientation of the magnifying glass.

[0074] FIG. **9** illustrates, as an example, a flow diagram of a method for displaying an auxiliary image view of an anatomic structure at a specified magnification factor as an overlay to a primary image view of the anatomic structure in the lens of a user movable magnifying glass. As previously explained, this method may be used to perform **805** of FIG. **8**.

[0075] In **901**, the current position and orientation of a central point of the lens of the magnifying glass are determined in the three-dimensional space of the Display Screen **104**. In **902**, a two-dimensional slice of the registered volumetric model of the auxiliary image is taken from the perspective of that position and orientation, and a portion of the two-dimensional slice is taken as defined in an auxiliary view window having a central point preferably at that same position and orientation. The area of the auxiliary view window in this case is inversely proportional to that of the lens according to the current magnification factor for the magnifying glass. In **903**, the portion of the two-dimensional slice defined by the auxiliary view window is then enlarged by the magnification factor so that it fits in the lens area of the magnifying glass, and in **904**, the primary image of the anatomic structure is displayed on the Display Screen **104** with the enlarged portion of the two-dimensional slice of the auxiliary image overlaid in the lens area of the magnifying glass being displayed on the Display Screen **104**.

[0076] As a pictorially example of **901-904**, in FIGS. **10-11**, a two-dimensional slice **1001** of an auxiliary image of an anatomic structure is shown along with two circular windows **1021**, **1022** on the two-dimensional slice as illustrated in FIG. **10**. Each of the windows **1021**, **1022** in this case corresponds in shape to and having a central point equal to that of a lens **1121** of a magnifying glass **1120** which is being displayed along with a primary image of an external view **1101** of the anatomic structure on the Display Screen **104** as illustrated in FIG. **11**. In this example, the area of the window **1021** is equal to the area of the lens **1121**, so that if the magnification factor was 1.0, then window **1021** would be selected for use in **902**. On the other hand, the area of the window **1022** is less than the area of the lens **1121**, so that if the magnification factor is greater than 1.0, then the window **1022** may be selected for use in **902**. Note that although the lens **1121** of the magnifying glass **1120** is depicted as being circularly shaped, it may also have other common shapes for a magnifying glass, such as a rectangular shape.

[0077] FIG. **12** illustrates, as an example, a flow diagram of a method performed by a processor in a medical robotic system for manipulating image objects displayed on a computer display screen of the medical robotic system in response to corresponding manipulation of an associated master input device when the master input device is in an image manipulating mode.

[0078] As a preface to the method, the medical robotic system includes an image capturing device to capture images (such as either the Endoscope **140** or the LUS Probe **150**); a robotic arm holding the image capturing device (such as the Slave Arm **123** or the Slave Arm **124** respectively holding the Endoscope **140** and the LUS Probe **150**); a computer display screen (such as the Display Screen **104**); a master input device adapted to be manipulatable by a user in multiple degrees-of-freedom movement (such as the Master Input Device **107** or the Master Input Device **108**); and a processor (such as the Auxiliary Controller **242**) that is configured to control movement of the image capturing device according to user manipulation of the master input device when the master input device is in an image capturing mode, and control the displaying of images derived from the captured images on the computer display screen according to user manipulation of the master input device when the master input device is in the image manipulating mode.

[0079] In **1201**, the processor detects that the user has placed the master input device into its image manipulating mode. One way that this may be implemented is using a master clutch mechanism provided in the medical robotic system, which supports disengaging the master input device from its associated robotic arm so that the master input device may be repositioned. When this mode is activated by some mechanism such as the user depressing a button on the master input device, pressing down on a foot pedal, or using voice activation, the associated robotic arm is locked in position, and a cursor (nominally an iconic representation of a hand, e.g. ✋) is presented to the user on the computer display screen. When the user exits this mode, the cursor is hidden and control of the robotic arm may be resumed after readjusting its position if required.

[0080] In **1202**, the processor determines whether a control input such as that generated by depressing a button on a conventional mouse has been activated by the user. The control input in this case may be activated by depressing a button provided on the master input device, or it may be activated by some other fashion such as squeezing a gripper or pincher formation provided on the master input device. For additional details on clutching, and gripper or pincher formations on a master input device, see, e.g., commonly owned U.S. Pat. No. 6,659,939 entitled "Cooperative Minimally Invasive Telesurgical System," which has been previously incorporated herein by reference. If the control input is not determined to be "on" (i.e., activated) in **1202**, then the processor waits until it either receives an "on" indication or the image manipulating mode is exited.

[0081] In **1203**, after receiving an indication that the control input is "on", the processor checks to see if the cursor is positioned on (or within a predefined distance to) an object being displayed on the computer display screen. If it is not, then in **1204**, the processor causes a menu of user selectable items or actions to be displayed on the computer display screen, and in **1205**, the processor receives and reacts to a menu selection made by the user.

[0082] Examples of user selectable menu items include: magnifying glass, cut-plane, eraser, and image registration. If the user selects the magnifying glass item, then an image of a magnifying glass is displayed on the computer display screen and the method described in reference to FIG. **8** may be performed by the processor. When the user is finished with the magnifying glass function, then the user may indicate exiting of the function in any conventional manner and the processor returns to **1202**.

[0083] If the user selects the cut-plane item, then a plane (or rectangular window of fixed or user adjustable size) is displayed on the computer display screen. The master input device may then be associated with the plane so that the user may position and orientate the plane in the three-dimensional space of the computer display screen by manipulating the master input device in the manner of a pointing device. If the plane is maneuvered so as to intersect a volume rendering of an anatomic structure, then it functions as a cut-plane defining a two-dimensional slice of the volume rendering at the intersection. Alternatively, the master input device may be associated with the volume rendering of the anatomic structure, which may then be maneuvered so as to intersect the displayed plane to define the cut-plane. Association of the plane or volume rendering with the pointing device may be performed in substantially the same manner as described in reference to the magnifying glass with respect to **801** of FIG. **8**.

[0084] The two-dimensional slice may then be viewed either in the plane itself, or in a separate window on the computer display screen such as in a picture-in-picture. The user may further select the cut-plane item additional times to define additional two-dimensional slices of the volume rendering for concurrent viewing in respective planes or picture-in-picture windows on the computer display screen. So as not to clutter the computer display screen with unwanted cut-plane slices, a conventional delete function is provided so that the user may selectively delete any cut-planes and their corresponding slices. When the user is finished with the cut-plane function, then the user may indicate exiting of the function in any conventional manner and the processor returns to **1202**.

[0085] If the user selects the eraser item, then an eraser is displayed on the computer display screen. The master input device is then associated with the eraser so that the user may position and orientate the eraser in the three-dimensional space of the computer display screen by manipulating the master input device in the manner of a pointing device. Association of the eraser with the pointing device in this case may be performed in substantially the same manner as described in reference to the magnifying glass with respect to **801** of FIG. **8**. If the eraser is maneuvered so as to intersect a volume rendering of an anatomic structure, then it functions to either completely or partially erase such rendering wherever it traverses the volume rendering. If partial erasing is selected by the user (or otherwise pre-programmed into the processor), then each time the eraser traverses the volume rendering, less detail of the anatomic structure may be shown. Less detail in this case may refer to the coarseness/fineness of the rendering, or it may refer to the stripping away of layers in the three-dimensional volume rendering. All such characteristics or options of the erasing may be user selected using conventional means. If the user inadvertently erases a portion of the volume rendering, a conventional undo feature is provided to allow the user to undo the erasure. When the user is finished with the erasing function, then the user may indicate exiting of the function in any conventional manner and the processor returns to **1202**.

[0086] In addition to an eraser function as described above, other spatially localized modifying functions are also contemplated and considered to be within the full scope of the present invention, including selectively sharpening, brightening, or coloring portions of a displayed image to enhance its visibility in, or otherwise highlight, a selected area. Each such spatially localized modifying function may be performed using substantially the same method described above in reference to the eraser function.

[0087] If the user selects the image registration item, then the processor records such selection for future action as described below in reference to **1212** before jumping back to process **1202** again. Image registration in this case typically involves manually registering an auxiliary image of an object such as an anatomic structure with a corresponding primary image of the object.

[0088] As an alternative to the above described menu approach, icons respectively indicating each of the selectable items as described above may be displayed on the computer display screen upon entering image manipulating mode and selected by the user clicking on them, after which, the processor proceeds to perform as described above in reference to selection of their corresponding menu items.

[0089] Now continuing with the method described in reference to FIG. **12**, after receiving an indication that the control input is on in **1201** and determining that the cursor is positioned on or near an object (not an icon) being displayed on the computer display screen in **1202**, the processor preferably changes the cursor from an iconic representation of a hand, for example, to that of a grasping hand to indicate that the object has been "grabbed" and is ready to be moved or "dragged" to another position and/or orientation in the three-dimensional space of the computer display screen through user manipulation of the master input device.

[0090] In **1206**, the processor then determines whether the user has indicated that a display parameter of the selected object is to be adjusted, and if the user has so indicated, in **1207**, the processor performs the display adjustment. As an example, a dial on the master input device may be turned by the user to indicate both that a display adjustment for a display parameter associated with dial is to be adjusted according to the amount of rotation of the dial on the selected object. Alternatively, if the master input device is equipped with a gripper, the gripper may be rotated so as to function as a dial. Examples of display parameters that may be adjusted in this manner include: brightness, contrast, color, and level of detail (e.g., mesh coarseness/fineness, or voxel size and/or opaqueness) of the selected object being displayed on the computer display screen.

[0091] The processor then proceeds to **1208** to determine whether the cursor has moved since "grabbing" the selected object after an affirmative determination in **1203**. If it has not moved, then the processor jumps back to **1202** since the user may only have wanted to adjust a display parameter of a selected object at this time. On the other hand, if the cursor has moved since "grabbing" the selected object, then in **1209**, the processor moves the selected object to the new cursor position. Since the cursor operates in the three-dimensional space of the computer display screen, when it moves "into" the display screen, it may indicate such movement by, for example, getting progressively smaller in size. Where the three-dimensional nature of the computer display screen is achieved through the use of right and left two-dimensional views of the object with disparities of common points between the two views indicating depth values, decreasing of the depth values for images of the cursor in the right and left views indicates that the cursor is moving "into" the display screen.

[0092] Optionally, in **1210**, haptic feedback may be provided back to the master input device so that the user may sense reflected forces while the "grabbed" object is being moved in **1209**. As an example, user interactions with the object may be reflected haptically back to the user by associating a virtual mass and inertial properties with the object so that the user feels a reflected force when coming into contact with the object or when translating or rotating the object as it is accelerated/decelerated. The haptic feedback performed in this **1210** may only be performed for some types of objects and not for others, or it may take effect only in certain circumstances. Use of such haptic feedback may also be applied to the movement of the magnifying glass and/or the plane used for defining cut-planes as described above. In such cases, however, the haptic feedback may be restricted to only occurring after the magnifying glass or the plane enters into an anatomic structure of interest.

[0093] In **1211**, the processor determines whether the control input is still in an "on" state. If the control is still "on", then the processor jumps back to **1208** to track and respond to cursor movement. On the other hand, if the control has been turned off by, for example, the user releasing a button that was initially depressed to indicate that control was turned "on", then in **1212**, the processor performs a selected menu action.

[0094] For example, if the image registration item had been selected by the user in response to the processor displaying the menu in **1204** (or alternatively, the user clicking an icon indicating that item), then the object that has been moved is registered with another image of the object that is now aligned with and is being displayed on the computer display screen at the time so that they have the same coordinate and orientation values in a common reference frame such as that of the computer display screen. This feature facilitates, for example, manual registration of an auxiliary image of an anatomic structure (such as obtained using the LUS Probe **150**) with a primary image of the anatomic structure (such as obtained using the Endoscope **140**). After the initial registration, changes to the position and/or orientation of the corresponding object in the primary image may be mirrored so as to cause corresponding changes to the selected object in the auxiliary image so as to maintain its relative position/orientation with respect to the primary image. When the user is finished with the image registration function, then the processor returns to **1202**.

[0095] Although the various aspects of the present invention have been described with respect to a preferred embodiment, it will be understood that the invention is entitled to full protection within the full scope of the appended claims.

What is claimed is:

1. A medical system comprising:

a stereo display;

an input device; and

a processor configured to:

generate a three-dimensional image of an anatomical object from scanned images of the object;

cause the three-dimensional image of the anatomical object and a two-dimensional window to be displayed on the stereo display;

cause a position and an orientation of the two-dimensional window relative to the three-dimensional image of the anatomical object to be changed on the stereo display, according to manipulation of the input device after associating the two-dimensional window with the input device;

define a cut-plane by an intersection of the two-dimensional window with the three-dimensional image of the anatomical object so as to indicate a two-dimensional slice of the three-dimensional image of the anatomical object; and

cause the two-dimensional slice of the three-dimensional image of the anatomical object to be displayed on the stereo display.

2. The medical system according to claim **1**,

wherein the input device is configured so as to be manipulatable in multiple degrees of freedom so that the input device operates as a three-dimensional mouse.

3. The medical system according to claim **1**,

wherein the processor is further configured to:

associate the input device with the two-dimensional window after a user activates a control input while a cursor associated with the input device is being displayed on the two-dimensional window on the stereo display.

4. The medical system according to claim **1**,

wherein the processor is further configured to:

provide haptic feedback to the input device while causing the position and the orientation of the two-dimensional window to be changed on the stereo display.

5. The medical system according to claim **4**,

wherein the haptic feedback is provided by associating a virtual mass and inertial properties to the two-dimensional window so that a user manipulating the input device would feel a reflected force on the input device while the position and the orientation of the two-dimensional window is being changed in response to the user manipulating the input device.

6. The medical system according to claim **1**,

wherein the two-dimensional slice is displayed in the two-dimensional window on the stereo display.

7. The medical system according to claim **1**,

wherein the two-dimensional slice is displayed in a picture-in-picture window on the stereo display.

8. The medical system according to claim **1**,

wherein the processor is further configured to:

display a second two-dimensional window on the stereo display,

cause a position and an orientation of the second two-dimensional window relative to the three-dimensional image of the anatomical object to be changed on the stereo display, according to manipulation of the input device after associating the second two-dimensional window with the input device,

define a cut-plane by an intersection of the second two-dimensional window with the three-dimensional image of the anatomical object so as to indicate a second two-dimensional slice of the three-dimensional image of the anatomical object; and

cause the second two-dimensional slice of the three-dimensional image of the anatomical object to be displayed on the stereo display.

9. The medical system according to claim **8**,

wherein the two-dimensional slice and the second two-dimensional image slice are displayed in corresponding picture-in-picture windows on the stereo display.

10. The medical system according to claim **1**,

wherein the processor is further configured to:

display the two-dimensional window on the stereo display in response to user selection of an item included in a menu being displayed on the stereo display.

11. The medical system according to claim **1**,

wherein the processor is further configured to:

display the two-dimensional window on the stereo display in response to user selection of an icon being displayed on the stereo display.

12. The medical system according to claim **11**,

wherein the icon is displayed in a periphery area of the stereo display, and

wherein the processor is further configured to:

interpret user mouse-type actions of clicking on the icon and dragging the icon away from the periphery area as a user selection of the icon.

13. The medical system according to claim **12**,

wherein the scanned images of the anatomical object comprise two-dimensional ultrasound slices captured by an ultrasound probe.

14. A method comprising:

a processor generating a three-dimensional image of an anatomical object from scanned images of the object;

the processor causing the three-dimensional image of the anatomical object and a two-dimensional window to be displayed on a stereo display;

the processor changing a position and an orientation of the two-dimensional window relative to the three-dimensional image of the anatomical object on the stereo display, according to manipulation of an input device after associating the two-dimensional window with the input device;

the processor defining a cut-plane by an intersection of the two-dimensional window with the three-dimensional image of the anatomical object so as to indicate a two-dimensional slice of the three-dimensional image of the anatomical object; and

the processor causing the two-dimensional slice of the three-dimensional image of the anatomical object to be displayed on the stereo display.

15. The method according to claim **14**, further comprising:

the processor associating the input device with the two-dimensional window after a user activates a control input while a cursor associated with the input device is being displayed on the two-dimensional window on the stereo display.

16. The method according to claim **14**, further comprising:

the processor providing haptic feedback to the input device while changing the position and the orientation of the two-dimensional window on the stereo display.

17. The method according to claim **14**,

wherein the processor causes the two-dimensional slice of the three-dimensional image of the anatomical object to be displayed on the stereo display by causing the two-dimensional slice to be displayed in the two-dimensional window on the stereo display.

18. The method according to claim **14**,

wherein the processor causes the two-dimensional slice of the three-dimensional image of the anatomical object to be displayed on the stereo display by causing the two-dimensional slice to be displayed in a picture-in-picture window on the stereo display.

19. The method according to claim **14**,

wherein the processor causes the two-dimensional window to be displayed on the stereo display in response to user selection of an item included in a menu being displayed on the stereo display.

20. The method according to claim **14**,

wherein the processor causes the two-dimensional window to be displayed on the stereo display in response to user selection of an icon being displayed on the stereo display.

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摘要(译)

为了帮助外科医生执行医疗程序，外科医生通常在计算机显示屏上显示和操纵通常指示被治疗的解剖结构的内部细节的辅助图像，以补充通常解剖结构的外部视图的主图像。 外科医生可以将在第一模式下控制机械臂的主输入设备切换到第二模式，以便代替地用作鼠标状指示设备，以方便外科医生执行这种辅助信息的显示和操纵。