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(54) **Title:** SYSTEMS AND METHODS FOR MINIMALLY INVASIVE SURGICAL TOOLS WITH HAPTIC FEEDBACK

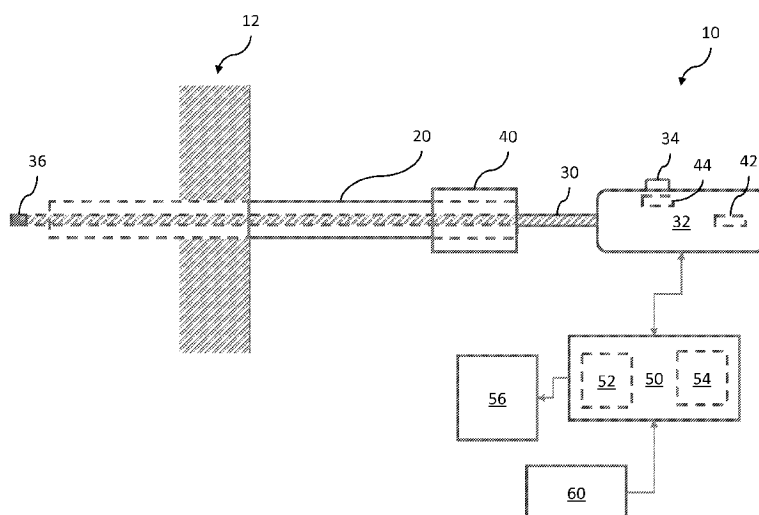


Figure 1

(57) **Abstract:** Systems and methods for minimally invasive surgical tools with haptic feedback are disclosed. One disclosed embodiment of a system includes an insertion sheath configured to be partially inserted within a patient's body, the insertion sheath configured to receive a surgical tool; a roller disposed at least partially within the insertion sheath, the roller configured to contact a surgical tool inserted within the insertion sheath; and an actuator coupled to the roller, the actuator configured to receive an actuator signal and to output a haptic effect based on the actuator signal.



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**SYSTEMS AND METHODS FOR MINIMALLY INVASIVE SURGICAL TOOLS
WITH HAPTIC FEEDBACK**

CROSS-REFERENCES TO RELATED APPLICATION

This application claims priority to U.S. Provisional Patent Application No.
5 61/295,438 filed January 15, 2010, entitled Minimally Invasive Surgical Tools with Haptic
Feedback, the entirety of which is hereby incorporated by reference.

FIELD OF THE INVENTION

The present invention generally relates to surgical tools and more specifically to
systems and methods medical simulation and more particularly to systems and methods for
10 minimally invasive surgical tools with haptic feedback.

BACKGROUND

Minimally invasive surgery is performed without making a major incision or opening,
resulting in reduced trauma for the patient and yielding significant cost savings. These result
from shorter hospitalization times and reduced therapy requirements. Other benefits of
15 minimally invasive surgery include less pain, less need for post-surgical pain medication, less
scarring, and less likelihood of complications related to the incision.

Minimally invasive surgery is defined either as based on the operative procedure (e.g.,
small incisions) or the outcome (e.g., reduced surgical complications or costs). However,
minimally invasive surgery is not the same as minor surgery. Some “minimally invasive”
20 procedures, e.g., coronary artery bypass surgery, still are major operations requiring a
hospital stay.

In minimally invasive surgery, a miniature camera is typically introduced into the
body through a small incision. The camera transmits images to a video monitor, enabling the
physician to diagnose and, if necessary, treat a variety of conditions. To do this, the
25 physician inserts surgical instruments and auxiliary devices (collectively, “minimally
invasive surgical tools”), such as irrigation and drainage devices, through one or more
additional small incisions. Such surgical instruments can be for laparoscopic surgery,
catheterization or endoscopy, as well as for enabling telesurgery and telepresence. Compared
to open surgery, however, minimally invasive surgery presents limitations in visual and
30 haptic perceptions, and creates challenges unique to this type of surgery. One of the major
concerns is the potential for tissue damage, possibly caused by inappropriate use of force.

SUMMARY

Embodiments of the present invention provide systems and methods for minimally invasive surgical tools with haptic feedback. For example, in one embodiment, a system includes an insertion sheath configured to be partially inserted within a patient's body, the insertion sheath configured to receive a surgical tool; a roller disposed at least partially within the insertion sheath, the roller configured to contact a surgical tool inserted within the insertion sheath; and an actuator coupled to the roller, the actuator configured to receive an actuator signal and to output a haptic effect based on the actuator signal.

In one embodiment of a method, the method comprises A computer-implemented method, comprising receiving a sensor signal from a sensor coupled to a surgical tool, the surgical tool configured to be at least partially inserted within a patient's body; generating an actuator signal based at least in part on the sensor signal, the actuator signal configured to cause the actuator to output a haptic effect; and transmitting the actuator signal to an actuator coupled to the surgical tool. In another embodiment, a computer-readable medium comprises program code for causing a processor to execute such a method.

These illustrative embodiments are mentioned not to limit or define the invention, but rather to provide examples to aid understanding thereof. Illustrative embodiments are discussed in the Detailed Description, which provides further description of the invention. Advantages offered by various embodiments of this invention may be further understood by examining this specification.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated into and constitute a part of this specification, illustrate one or more examples of embodiments and, together with the description of example embodiments, serve to explain the principles and implementations of the embodiments.

Figure 1 shows an illustrative system for minimally invasive surgical tools with haptic feedback according to one embodiment of the present invention;

Figures 2-3 show systems for minimally invasive surgical tools with haptic feedback according to embodiments of the present invention;

Figures 4a-b show systems for minimally invasive surgical tools with haptic feedback according to embodiments of the present invention; and

Figure 5 shows a method for minimally invasive surgical tools with haptic feedback according to one embodiment of the present invention.

DETAILED DESCRIPTION

Example embodiments are described herein in the context of systems and methods for minimally invasive surgical tools with haptic feedback. Those of ordinary skill in the art will realize that the following description is illustrative only and is not intended to be in any way limiting. Other embodiments will readily suggest themselves to such skilled persons having the benefit of this disclosure. Reference will now be made in detail to implementations of example embodiments as illustrated in the accompanying drawings. The same reference indicators will be used throughout the drawings and the following description to refer to the same or like items.

In the interest of clarity, not all of the routine features of the implementations described herein are shown and described. It will, of course, be appreciated that in the development of any such actual implementation, numerous implementation-specific decisions must be made in order to achieve the developer's specific goals, such as compliance with application- and business-related constraints, and that these specific goals will vary from one implementation to another and from one developer to another. Further, in the disclosed embodiments below, the term "or" may be used to describe different features of particular embodiments. Use of the term "or" is intended to be interpreted both as inclusive and exclusive, thus combinations may include any or all of the identified features as described herein.

Illustrative System for Minimally Invasive Surgical Tools with Haptic Feedback

In one illustrative system for minimally invasive surgical tools with haptic feedback, the system is configured to assist a surgeon during minimally invasive surgery (MIS) on a live patient. For example, a surgeon may perform a MIS to perform cardio electrophysiology to measure changes in electric potentials (i.e. voltages) on the inside surface of a patient's heart, such as following a heart attack, to detect any abnormalities or to ablate heart tissue to address arrhythmias.

Referring now to Figure 1, Figure 1 shows an illustrative embodiment of a system for minimally invasive surgical tools with haptic feedback according to one embodiment of the present invention. The system in Figure 1 comprises an insertion sheath 20, a surgical tool 30 (a guide wire, in this case) with a handle 32, a computer 50 with a processor 52, memory 54 and a display 56, and a heart rate monitor 60.

To perform the illustrative MIS procedure, the surgeon makes an incision in the patient's leg 12 and inserts an insertion sheath 20, in this case a catheter, into the patient's

femoral artery to provide an insertion path for a surgical tool. The surgeon then inserts the catheter 20 through the patient's vascular system until it reaches the patient's heart. The surgeon may then insert a surgical tool 30, such as a guide wire equipped with a voltage sensor 36 or sensors on the distal end of the guide wire 30 through the catheter 20 to the patient's heart to measure voltages at various points on or within the heart's walls. Such a guide wire 30 typically has a proximal end that is connected to a handle 32 to allow the surgeon to maneuver the guide wire 30 to reach various points of interest on the heart's wall. To maneuver the guide wire 30, the surgeon manipulates one or more manipulanda 34, e.g. knobs or levers, on the guide wire's handle 32 to move the distal tip of the guide wire 30 in any of a number of directions. In such an embodiment, the surgeon may then maneuver the guide wire's distal tip to contact the heart's wall to take voltage measurements with the sensor(s) 36.

In the illustrative embodiment shown in Figure 1, the insertion tube 30 has been equipped with an actuator 40 to assist the surgeon in performing the MIS procedure. An inductive actuator 40 configured in a ring or cylindrical shape has been coupled to the proximal end of the insertion tube 20 such that the guide wire 30 passes through the actuator 40 into the insertion tube 30. The inductive actuator 40 can be actuated by transmitting an electrical current through the coils of the actuator 40 to generate electromagnetic forces on the guide wire 30 to provide kinesthetic haptic effects to assist or resist translational movement of the guide wire 30 within the insertion tube. An advantage of using an inductive actuator may be that, because there is no physical coupling between the actuator and the guide wire as there might be when using a roller, a surgeon manipulating the guide wire may receive more accurate tactile sensations because there is no friction and inertia to overcome as may be the case were rollers or other frictional contact employed. However, other types of actuators may be employed as will be discussed in more detail below.

In addition, the handle 32 of the guide wire 30 includes a plurality of actuators 42, 44. One of the actuators 42 is a vibrotactile actuator and is used to output vibrational effects to the guide wire handle 32 based on the voltages sensed by the sensor(s) 36 on the distal end of the guide wire. For example, the frequency of a vibration effect may be proportional to the magnitude of the voltage sensed by the sensor(s) 36, thus providing the surgeon with additional information regarding the status of the procedure. The vibrational information in this case is in addition to a display showing graphical information about the various sensor readings.

The second actuator 44 disposed within the handle 32 is configured to provide haptic effects to the manipulandum 34 on the handle. For example, the second actuator 44 may output haptic effects based on a contact force between the distal tip of the guide wire and the wall of the heart, or based on an angle of attack of the distal tip of the guide wire and the wall of the heart. In the embodiment shown, the second actuator 44 outputs a kinesthetic force to resist movement of the manipulandum 34 based on a sensed force on the tip of the distal end of the guide wire (force sensor not shown).

The computer 50, which comprises a processor 52 and a memory 54, receives sensor signals from the surgical tool 30 and, in some instances, the insertion sheath 20, and generates actuator signals to cause haptic effects to be output by the various actuators 40, 42, 44 on the guide wire 30, the guide wire handle 32 or manipulandum 34. In addition, the computer 50 receives information from other external devices, such as the heart monitor 60, which it may use as well to generate haptic effects. Examples of other external sensors include heart rate monitors, blood pressure monitors, oxygen sensors, blood gas sensors, etc.

For example, in this illustrative embodiment, heart rate monitor 60 is connected to the patient and provides heart rate information to the computer 50. The computer 50 can generate haptic effects to indicate if the patient's heart rate falls outside of acceptable limits. Because the surgeon may be focused on the particular voltage readings and manipulating the guide wire, this additional information may not be immediately apparent to the surgeon. For example, if the patient's heart begins beating too rapidly, the computer 50 can generate an actuator signal to cause a haptic effect to indicate a potentially dangerous condition and bring the abnormal heart rate to the surgeon's attention.

In addition, the computer 50 can output display signals to cause the display 56 to display relevant information to the surgeon, such as visual indications of sensed voltages, images from a camera inserted into the catheter, heart rate, etc. Thus, the system 10 can provide an immersive, integrated experience that allows the surgeon to focus on the MIS procedure, while receiving a variety of inputs that provide immediate tactile responses to the surgeon to allow her to better perform the procedure and monitor conditions that might otherwise divert her attention.

Referring now to Figure 2a, Figure 2a shows a system 100 for minimally invasive surgical tools according to one embodiment of the present invention. System 100 comprises an insertion sheath 110, a first surgical tool 120, and a second surgical tool 130. Insertion sheath 110 comprises a plurality of rollers 112a,b and a plurality of actuators 140a,b, each

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coupled to one of the plurality of rollers 112a,b. Insertion sheath 110 is configured to be partially inserted into the patient's body 102 and to receive a surgical tool, such as surgical tool 120. In the embodiment shown, the insertion sheath 110 comprises a trocar.

5 In the embodiment shown, rollers 112a,b are configured to contact surgical tool 120 and are configured to output haptic forces created by the actuation of actuators 140a,b, respectively. In one embodiment, each of actuators 140a,b is an active actuator and is configured to cause its respective roller 112a,b to rotate. By rotating the respective rollers, actuators 140a,b can output kinesthetic forces configured to assist or resist translational movement of surgical tool 120 within the insertion sheath 110. For example, in the
10 embodiment shown, actuators 140a,b comprise DC motors but could also include passive actuators (i.e. magnetic brakes), cams or other friction producing or modulating means. In some embodiments, however, actuators 140a,b comprise passive actuators configured to brake their respective roller 112a,b to resist translational movement of the surgical tool 120 within the insertion sheath 110. In some embodiments, one or both rollers 112a,b are coupled
15 to sensors, such as rotational encoders, that are configured to detect a rotation of the roller 112a,b. In one such embodiment, the sensors are configured to transmit a sensor signal to a processor to indicate a movement or position of the roller based on a corresponding movement of the surgical tool 120.

In some embodiments, the trocar 110 is configured to be sterilized between MIS
20 procedures, though in some embodiments, trocar 110 is configured to be discarded. Because rollers 112a,b are configured to contact surgical tool 120, they are either configured to be discarded or sterilized between MIS procedures. In some embodiments, rollers 112a,b and actuators 140a,b may be disposed within a subassembly that is configured to be releasably coupled to the insertion sheath 110 such that the insertion sheath 110 and the roller/actuator
25 subassembly can be decoupled following a MIS procedure and each can be individually sterilized or discarded.

In addition to actuators 140a,b, insertion sheath 110 also comprises vibrotactile actuator 140c, which is configured to apply vibrotactile haptic effects to the surgical tool 120 or the insertion sheath 110. In the embodiment shown, actuator 140c comprises a
30 piezoelectric actuator, though in other embodiments, other types of actuators may be employed, such as eccentric rotating masses, linear resonant actuators, voice coils, or other suitable actuators. In addition, a plurality of vibrotactile actuators may be incorporated into the sheath, or, in some embodiments, no vibrotactile actuators may be employed.

In the embodiment shown, surgical tool 120 comprises a catheter and thus may be both a surgical tool and an insertion sheath. Surgical tool 120 is configured to be inserted into insertion sheath 110 and to be inserted into a patient's body 102. In the embodiment shown, surgical tool 120 comprises at least one sensor 152 coupled to the distal end of the surgical tool. The sensor 152 comprises a force sensor and is configured to sense a contact force between the distal end of the surgical tool 120 and an obstacle, such as a stenosis or an internal organ. The sensor 152 is configured to generate a sensor signal indicating a magnitude of the sensed force and to transmit the sensor signal to a processor (not shown), which may use the sensor signal to actuate one or more actuators 140a,b coupled to the insertion sheath. For example, the actuators may generate a force to resist further insertion of the surgical tool, such as to amplify a sensed force on a distal tip of the surgical tool 120. In some embodiments, the processor may generate a signal to cause the actuators 140a,b to completely resist or prevent further insertion of the surgical tool 120, or to reverse the motion of the surgical tool to withdraw the surgical tool 120. One such embodiment may be advantageous as it may prevent a surgeon from inadvertently puncturing an internal organ or a blood vessel within a patient.

In some embodiments, other types of sensors 152 may be affixed to the distal tip of the surgical tool 120, such as voltage sensors, temperature sensors, fluid flow sensors, or viscosity sensors. In some embodiments, one or more sensors may be affixed to other portions of the surgical tool 120 or inserted into the surgical tool 120. For example, a sensor (or sensors) may be inserted into surgical tool 120, such as a fiber optic sensor, fluoroscope, or video camera to provide sensor signals to a processor. In some embodiments, one or more sensors may be arrayed within the surgical tool 120, such as to sense a position of a further surgical tool 130 inserted within surgical tool 120 or the amount of bend within a surgical tool. For example, in some MIS procedures, a surgeon may navigate through a tortuous portion of the vascular system, such as in a patient's brain, and may need an indication of much the surgical tool is bending during performance of the procedure. If too much bending is sensed, a processor may generate a haptic effect based on the sensed amount of bend and output a haptic effect to the surgical tool or handle. In some embodiments, a system 100 may comprise non-colocated sensors configured to detect a distance between the sensors, a change in resistance or voltage between the sensors, or other differences in status between the two sensors to generate a sensor signal. In one such an embodiment, the distal end of a surgical tool 120, 130 may comprise a first sensor and the insertion sheath 110, 120 may comprise a

second sensor. A processor may detect a difference in sensor readings between the two sensors and generate an actuator signal based on the difference. In one embodiment, the sensors may be configured to detect a distance between the sensors and generate one or more sensor signals and transmit the sensor signals to a processor.

5 Surgical tool 120 may also comprise an actuator 142 coupled to the surgical tool 120. In the embodiment shown, the actuator 142 is releasably coupled to the surgical tool 120, though in some embodiments the actuator 142 may be permanently coupled to, or integrally disposed within, the surgical tool. In this embodiment, actuator 142 comprises an inductive actuator and is configured to provide haptic effects to surgical tools, such as surgical tool
10 130, that have been inserted within surgical tool 120. As discussed above, surgical tool 120 comprises a catheter and thus is configured to allow one or more surgical tools to be inserted within surgical tool 120. For example, in the embodiment shown in Figure 2a, surgical tool 130 comprises a guide wire and is configured to be inserted within catheter 120. In such an embodiment, actuator 142 is configured to generate electromagnetic forces to resist or assist
15 translational movement of the guide wire 130 within the catheter. In other embodiments, surgical tool 130 may comprise other suitable surgical tools, such as a deflectable catheter or an electrophysiology probe. As discussed above, inductive actuators may provide advantages in such MIS procedures because they do not require a surgeon to overcome friction or inertia of a roller or other physical coupling to move guide wire 130 within surgical tool 120.
20 However, in some embodiments, other types of actuators may be used, such as one or more rollers.

For example, Figure 2b shows a system for minimally invasive surgical tools with haptic feedback in which surgical tool 120 is coupled to an actuator 143 which comprises a plurality of rollers 145a,b at least partially disposed within actuator 143. Each roller 145a,b
25 is in communication with an actuator 146a,b, which are configured to impart forces on surgical tool 130 by rotating rollers 145a,b or resisting rotation of roller 145a,b, thereby assisting or resisting translational movement of surgical tool 130 within surgical tool 120. As discussed above with respect to insertion sheath 110, actuators 145a,b may comprise active or passive actuators, or in some embodiments, may comprise one of each or a plurality of
30 different types of actuators. Actuator 143 may be desirable in embodiments in which surgical tool 130 may be adversely affected by the use of an inductive actuator 142 or surgical tool 130 is not susceptible to forces generated by an inductive actuator 142. Further, as discussed above, actuators 142, 143 may be used to assist with the insertion of a surgical tool 130

within surgical tool 120 or to resist movement or prevent movement if surgical tool 130 may puncture a patient's organ or blood vessel.

Referring now to Figure 2c, Figure 2c shows a system for minimally invasive surgical tools with haptic feedback according to one embodiment of the present invention. The embodiment shown in Figure 2c is similar to those shown in Figures 2a and 2b, however, the insertion sheath 110 comprises actuators 140a-c but does not include the rollers 112a,b. Instead, actuators 140a-c are configured to output haptic effects to the insertion sheath 110 or to the surgical tool 120. For example, in one embodiment, one or more of actuators 140a-c comprise vibrotactile actuators, such as eccentric rotating masses. In one embodiment, one or more of actuators 140a-c comprise resistive actuators configured to resist movement of the surgical tool 120. For example, in one embodiment, actuators 140a,b each comprise a braking surface configured to be moved into contact with the surgical tool 120 to apply a resistive force on the surgical tool. In one embodiment, one or more of actuators 140a-c may comprise an inductive actuator configured to exert a force on the surgical tool. In a further embodiment, one or more of actuators 140a-c may be configured to alter the surface friction of the surgical tool to create a resistance to movement of the surgical tool within its insertion sheath or delivery catheter. Thus, while some embodiments shown and discussed herein employ one or more rollers to apply forces to surgical tool 120, other embodiments may be configured to only vibrotactile forces on the insertion sheath 110 or to apply forces to the surgical tool 120 using other mechanisms.

Referring again to Figure 2a, in the embodiment shown, surgical tool 130 is configured to be inserted within surgical tool 120 and comprises at least one sensor 150 coupled to the surgical tool's 130 distal tip. The proximal end of surgical tool 130 is coupled to a handle 132, which is configured to allow a surgeon or other user to insert or retract the surgical tool 130 within surgical tool 120. In addition, handle 132 comprises one or more manipulanda 134 to manipulate the distal tip of the surgical tool 130. For example, manipulandum 134 may be used to bend the distal tip of the surgical tool 130 away from the longitudinal axis of the surgical tool 130, thereby "steering" the surgical tool in a particular direction. In addition, handle 132 comprises a plurality of actuators configured to output haptic effects to a user of the handle 132.

In the embodiment shown, handle 132 is releasably coupled to surgical tool 130. As previously discussed, MIS surgical tools typically must be sterilized or discarded after being used in an MIS procedure. Thus, in one embodiment handle 132 is configured to be

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decoupled from surgical tool 132 and discarded after use in an MIS procedure. In another embodiment, handle 132 is configured to be sterilized following an MIS procedure. Further, in some embodiments, handle 132 is permanently coupled to surgical tool 130 and thus may be discarded with surgical tool 130 or sterilized with surgical tool 130.

5 Actuator 146 comprises a vibrotactile actuator configured to output a vibrational or vibrotactile effect to the handle 132. For example, in the embodiment shown, actuator 146 comprises an eccentric rotating mass (ERM) coupled to a rotary motor. In some
embodiments, other types of actuators may be employed, such as piezoelectric actuators,
voice coils, or linear resonant actuators (LRAs). In some embodiments, a plurality of
10 vibrotactile actuators may be disposed within the handle 132, while in other embodiments, no vibrotactile actuators may be used.

The vibrotactile actuator 146 may be employed to provide information associated with the MIS procedure to a surgeon or user of the handle 132. For example, in the illustrative embodiment discussed previously, the distal tip of a surgical tool 130 may be
15 coupled to a voltage sensor 150 which provides sensor signals to a processor indicating sensed voltages on a patient's heart. The processor may then generate actuator signals to cause the vibrotactile actuator 146 to output a vibration to the handle 132 based at least in part on the sensed voltage. In one embodiment, the distal tip of the surgical tool 130 may also, or instead, be fitted with a force sensor 150 which provides a sensor signal comprising
20 force information to the processor, which generates actuator signals to generate vibrational haptic effects proportional in magnitude to the force sensed by the sensor 150. Such an embodiment may provide additional information to a surgeon beyond the information provided by other actuators in the system 100, such as actuator 142 or 143.

While actuators 142, 143 may resist movement of the surgical tool, vibrational effects
25 provided by actuators 146 may provide an indication of the magnitude of the force applied by the tool on an obstacle that may be useful in combination with resistances generated by other actuators 142, 143. Still further information may be output by actuator 146. For example, external sensors may transmit sensor signals to a processor, which may generate actuator signals to actuator 146 to cause it to output a vibrational effect to the handle 132 to apprise a
30 surgeon of another condition that is not related to forces or sensor readings from the surgical tool. For example, external sensors may include heart monitors, blood pressure monitors, blood oxygen monitors, or other sensors monitoring a patient's status.

In addition to, or instead of, vibrotactile actuator 146, handle 132 may comprise actuator 144, which is configured to output kinesthetic forces to manipulandum 134. In the embodiment shown, the actuator is configured to output a force to resist or assist the movement of manipulandum 134. For example, a processor in communication with the surgical tool 130 may detect that further movement of the distal tip of surgical tool 130 is applying too much pressure to a patient's blood vessel or internal organ and generate an actuator signal to cause the actuator 144 to resist movement of the manipulandum 134. In one embodiment, surgical tool 130 may comprise a sensor 150 that detects an angle of attack of the distal tip of the surgical tool as it approaches or contacts an obstruction within a patient. For example, if an angle of attack of the distal tip is too shallow, a second sensor coupled to the tip of the surgical tool 130 may be unable to accurately sense a condition within a patient, or, in a procedure where a puncture must be made (e.g. a trans-septal puncture), if the angle of attack is too shallow, the tool may puncture the organ and exit the organ in the wrong location. In such an embodiment, the actuator 144 may output a force to prevent further movement of the manipulandum 134. In addition, actuator 142, 143 may output a force to prevent further insertion of the surgical tool 130. In some embodiments, actuator 144 may be configured to output a vibrational effect, such as to indicate that the angle of attack is too shallow or that a dangerous amount of pressure is being exerted by the distal tip of the surgical tool 130, rather than a resistive force.

Referring now to Figure 3, Figure 3 shows a system 200 for minimally invasive surgical tools with haptic feedback according to one embodiment of the present invention. The system 200 shown in Figure 3 comprises the embodiment shown in Figure 2a coupled to a power supply 210 and trigger 212 for a therapeutic surgical tool 130a. In the embodiment shown in Figure 3, surgical tool 130a comprises an ablation tool 150a coupled to the distal tip of the surgical tool 130a in addition to sensor(s) 150. The ablation tool 150a is configured to receive power signals from the power supply 210 and to ablate tissue contacted by the ablation tool 150.

Power supply 210 comprises a trigger 212 and an actuator 240 and is configured to supply power signals, such as electric current or electric voltage, to the surgical tool 130a and ablation tool 150a. The trigger 212 is used by an operator, such as a surgeon, to apply power to the ablation tool 150a and may comprise a pressure sensitive switch, a slider control, a knob, an on/off switch, or other trigger mechanism. In one embodiment, as more pressure is applied to the trigger 212, more power may be transmitted to the ablation tool 150a. Actuator

240 is configured to output a force to the trigger 212 to provide feedback to the operator to indicate whether too much power is applied or whether too much tissue may have been ablated. For example, in one embodiment, actuator 240 comprises an electromagnetic actuator configured to output a force to resist depression of the trigger 212. As tissue is ablated, a processor (not shown) may determine the quantity of tissue ablated based on a sensor or calculations made using pre-defined characteristics of a patient. The processor may then generate actuator signals and transmit the actuator signals to cause the electromagnetic actuator to resist depression of the trigger 212 and may cause the trigger to be opened to reduce or halt the flow of power to the ablation tool 150a. Further, a second actuator (not shown) may be in communication with the trigger 212 to output a vibrotactile effect to the trigger 212 to indicate a warning to the operator in addition to the resistance generated by the first actuator 240. Such an indication may be advantageous as it may provide confirmation to the surgeon of an error condition rather than just a sticky power trigger. In a further embodiment, actuator 146 may be actuated to output a vibrational effect as tissue is ablated. In still a further embodiment, actuator 144 may be actuator to resist further movement of the distal tip of the surgical tool 130a towards additional tissue within the patient, thus providing multiple channels of haptic input to the operator: resistance to the trigger 212, vibrational effects on the trigger 212, vibrational effects on the handle 132 and resistance to movement of the distal tip of the surgical tool 130a. Such varied haptic effects may provide more meaningful feedback to a surgeon and help prevent inadvertent injury to a patient.

Referring now to Figure 4a, Figure 4a shows a system 300 for minimally invasive surgical tools with haptic feedback according to embodiments of the present invention. In the embodiment shown in Figure 4a, the system 300 comprises the system 200 shown in Figure 3 in communication with a computer 350 comprising a processor 352 and a memory 354. The system 300 further comprises an external sensor 360 in communication with the computer 350. Computer 350 is configured to receive sensor signals from the various sensors 150, 152 located within system 200 and to generate actuator signals to be transmitted to one or more of the actuators (e.g. 140a-c, 142, 144, 146, 240) in the system 200. In addition, computer 350 is configured to generate and transmit display signals to display 356 to provide information to a surgeon or other operator of the system 300.

Note that while the embodiment shown in Figure 4a comprises the system 200 shown in Figure 3, other systems according to some embodiments of the present invention may be coupled to the computer 350, such as those shown in any of Figures 1-3. Figure 4b shows

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one such alternate embodiment in which a system 400 comprises a system having components arranged as shown in Figure 1, as well as a power supply 210 with a manipulandum 212 and an actuator 240 as shown in Figure 3.

Processor 352 is configured to execute program code stored in a computer-readable medium to receive sensor information and to generate haptic effects associated with the MIS procedure being performed. Embodiments of various types of processors and computer-readable media are disclosed below. Reference is made now to the method 500 shown in Figure 5, which, in one embodiment, is implemented by programming code stored in memory 354 and executed by the processor 352 shown in Figures 4a-b.

In the embodiment shown in Figure 5, the method 500 begins at block 510 where the processor 352 receives a sensor signal from a sensor, such as sensor 150. In the embodiment shown, sensor 150 comprises a sensor configured to detect an angle of attack of the distal tip of surgical tool 130a when it contacts an obstacle. The sensor signal comprises information associated with the sensed angle of attack. In one embodiment, the processor 352 may receive a plurality of sensor signals from one or more sensors. For example, surgical tool 130a may comprise a plurality of sensors, such as an angle of attack sensor and a force sensor such that the processor 352 receives a sensor signal from each of the sensors, or receives multiple sensor signals from one or more of the sensors.

Other sensors within the system 200 may also transmit sensor signals to the processor. For example, sensor 152 on the distal end of the catheter may transmit a sensor signal that is received by the processor. In addition, as discussed previously, rollers 112a,b may be coupled to, or may comprise, rotational encoders that sense a rotation or position of the rollers 112a,b and transmit a sensor signal to the processor indicating the position or movement of the rollers 112a,b. Processor 352 then receives such sensor signals.

Additionally, as shown in Figure 4a, computer 350 is configured to receive signals from external sensor 360, which comprises a heart rate monitor in the embodiment shown. After receiving a sensor signal, the method 500 proceeds to block 520.

At block 520, the processor 352 determines a status condition associated with the received sensor signal. For example, if the processor 352 receives a sensor signal from a force sensor, the processor 352 may determine a force associated with the sensor signal and compare the force with a threshold. For example, the processor 352 may determine that a force exceeds a first pre-determined threshold and thus a minor danger exists of puncturing tissue within the patient. Or the processor 352 may determine that the force exceeds a higher

threshold and thus a serious or critical danger exists of puncturing tissue within the patient. In one embodiment for performing an ablation procedure, it may be desirable to maintain a relatively constant pressure between the ablation tool 150a and a patient's tissue. In such an embodiment, the processor 352 may apply an assistive force to increase a force between the ablation tool 150a and the tissue if the sensed pressure falls below a lower threshold or apply a resistive force, or withdraw the surgical tool 130a, if the pressure exceeds an upper threshold of sensed force.

In another embodiment, the processor 352 may receive a sensor signal indicating a voltage on the surface of an internal organ. The processor may then compare the voltage to one or more voltage thresholds. Alternatively, the processor 352 may simply store the voltage for later use. Still other types of sensors may result in different types of sensor signals to be received by the processor 352, such as fluid flows, viscosities, pressures, or temperatures associated with conditions present within the patient. Other sensors, such as positional sensors or other sensors located within the insertion sheath or surgical tool (e.g. a catheter) may also transmit sensor signals that are received by the processor 352.

For example, in one embodiment, catheter 120 may comprise a sensor 152 that is configured to detect when a surgical tool 130a has reached the distal end of the catheter 120. In such an embodiment, the processor 352 may receive a sensor signal from the sensor 152 when the surgical tool 130a reaches the sensor 152 and the processor 352 determines that the surgical tool 130a has been fully inserted into the catheter. Alternatively, the processor 352 may receive a sensor signal from the sensor 150 indicating that the surgical tool 130a has not reached the distal end of the catheter. In such an embodiment, the processor 352 may be controlling an actuator, such as actuator 143, to automatically insert the surgical tool 130a into the catheter 120. Thus, the processor 352 determines that the surgical tool has not yet reached the distal end of the catheter. After determining a status condition associated with the sensor signal, the method proceeds to block 530.

At block 530, the processor 352 generates an actuator signal based at least in part on the sensor signal or the status condition. For example, as discussed above, the processor 352 determined a status condition associated with a sensed force between the surgical tool 130a and an obstacle. In such an embodiment, the processor 352 generates an actuator signal configured to increase a resistance to movement of the surgical tool such that the rolling resistance of the rollers 112a,b may be varied to provide an amplification of the actual force being applied by surgical tool 130 to allow increased precision. For example, the processor

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352 may generate an actuator signal to be transmitted to actuator 142 or 143 to generate a force opposing further movement of the surgical tool 130a into surgical tool 120. In a related embodiment, if the processor 352 has determined that a dangerous amount of pressure is being applied, the processor 352 may generate an actuator signal configured to prevent further movement of the surgical tool 130a into surgical tool 120 or to reverse movement of the surgical tool 130a and to withdraw the surgical tool 130a until the sensed force falls below a threshold. Such an embodiment may be advantageous as it may prevent inadvertent injury to a patient.

In a related embodiment, the processor 352 may receive a sensor signal indicating a status associated with manipulandum 134 or power supply 210. For example, in one embodiment, the surgical tool may comprise a manipulandum configured to control the surgical tool. In such an embodiment, the surgical tool 130 or other part of the system 200 may comprise sensors that provide sensor signals associated with the manipulation of the surgical tool, such as force sensors, angle of attack sensors, etc. Processor 352 may receive such sensor signals and generate actuator signals configured to cause an actuator, such as actuator 144, to apply a haptic effect to the manipulandum, such as to assist or resist movement of the manipulandum or to provide a vibrotactile effect to the manipulandum 134.

For example, as discussed above, during an ablation process, once the distal tip of the surgical tool 130a is in place, the actuated rollers 112a,b could be used to generate an actuator signal to ensure a required force on the tissue is maintained. The actuator signal can be configured to force the distal tip of the surgical tool 130 into contact with the tissue within a pre-determined range such as by either applying pressure in addition to pressure applied by the surgeon or by resisting further pressure or retracting to surgical tool 130a. A similar control method could also be utilized in a trans-septal puncture. Once the surgical tool 130 is in place to perform the puncture, the actuated rollers 112a,b could be used to perform a very controlled puncture using a controlled level of pressure to cause the puncture.

In one embodiment, the processor 352 may generate an actuator signal based on a non-tactile sensed condition. For example, a sensor may be configured to sense conditions that are not forces, such as voltages, etc. In such an embodiment, the processor 352 may generate a haptic effect based on such a sensed condition. In one embodiment, a surgeon performs a MIS procedure to measure voltages occurring on a patient's heart. In such an embodiment, the processor 352 may generate an actuator signal based at least in part on a magnitude of a sensed voltage, a fluctuation of a sensed voltage, or whether the voltage is

above or below a threshold. In one such embodiment, the processor may generate an actuator signal to cause an actuator to output a vibrotactile effect. For example, the processor 352 may generate an actuator signal to cause actuator 146 to output a vibrotactile effect based at least in part on a sensed voltage such that the frequency or magnitude of the vibrational effect is proportional to the magnitude of the voltage. Thus, for a relatively high voltage, the processor 352 may generate an actuator signal having a relatively high frequency. Conversely, for a relatively low voltage, the processor 352 may generate an actuator signal having a relatively low frequency.

In a further embodiment, processor 352 may generate an actuator signal based on sensor information or a status condition determined from an external sensor 360. For example, the processor 352 may receive a measured heart rate or blood pressure from the external sensor 360 and determine that the heart rate has fallen below a threshold. In one embodiment, the processor 352 generates an actuator signal configured to cause an actuator 146 to output a vibrotactile effect to the handle 132 of the surgical tool 130, wherein the vibrotactile effect is configured to indicate a warning condition associated with the external sensor. For example, the actuator signal may be configured to cause an actuator, e.g. actuator 146, output a series of pulsed vibrations to simulate a heartbeat to indicate a warning condition associated with the patient's heart rate or blood pressure. In such an embodiment, the magnitude of the vibrations may be proportional to the amount the sensed condition exceeds the threshold. After generating an actuator signal, the method 500 proceeds to block 540

In block 540, the processor 352 transmits the generated actuator signal to an actuator. For example, if the processor 352 has generated an actuator signal to cause a vibrotactile effect to the handle 132 of the surgical tool, the processor 352 transmits the actuator signal to actuator 146. In some embodiments the processor 352 may transmit the actuator signal to a plurality of actuators, or may modify an actuator signal before transmitting the actuator signal. For example, in one embodiment, the processor 352 generates an actuator signal configured to cause actuators 140a,b to rotate rollers 112a,b to resist further insertion of the surgical tool 120 into the insertion sheath 110. However, because the rollers are located on opposite sides of the surgical tool 120, they must rotate in opposite directions to generate the resistive force. Thus, the processor 352 may generate one actuator signal suitable to resist movement of the surgical tool 120 and transmit the actuator signal to actuator 140a but invert the actuator signal before transmit it to actuator 140b.

In a further embodiment, a surgeon may be performing an ablation procedure. During the procedure, the processor 352 may determine that too much tissue is being ablated and may generate an actuator signal to both resist movement of the trigger 212 on the power supply 210 as well as resist movement of the manipulandum 134 that controls movement of the surgical tool 130a performing the ablation. Such effects may provide an indication that further power should not be applied and that the distal tip of the tool should not be further moved towards the tissue being ablated. The processor 352 may generate one actuator signal suitable for both actuators and perform post-processing before transmitting the actuator signal, such as changing a magnitude, to each of the actuators 144, 240. After transmitting the actuator signal to the actuator, the method 500 returns to step 510 to receive another sensor signal or to step 520 to determine another status condition associated with the MIS procedure.

The method 500 shown in Figure 5 is illustrative of one method according to some disclosed embodiments of the present invention and is not intended to limit the scope of the disclosure. Further, while the steps of the method 500 have been set forth in a particular order, there is no requirement that the steps be performed in such an order or that all of the steps shown in Figure 5 be performed. For example, block 530 may be performed independently of whether a sensor signal is received, such as for actuator signals indicating a passage of time or other independent event. Further, a status condition need not be determined prior to generating an actuator signal or even at all.

While the methods and systems herein are described in terms of software executing on various machines, the methods and systems may also be implemented as specifically-configured hardware, such a field-programmable gate array (FPGA) specifically to execute the various methods. For example, referring again to Figures 1 and 2, embodiments can be implemented in digital electronic circuitry, or in computer hardware, firmware, software, or in combination of them. In one embodiment, a computer may comprise a processor or processors. The processor comprises a computer-readable medium, such as a random access memory (RAM) coupled to the processor. The processor executes computer-executable program instructions stored in memory, such as executing one or more computer programs for editing an image. Such processors may comprise a microprocessor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), field programmable gate arrays (FPGAs), and state machines. Such processors may further comprise programmable electronic devices such as PLCs, programmable interrupt controllers (PICs), programmable

logic devices (PLDs), programmable read-only memories (PROMs), electronically programmable read-only memories (EPROMs or EEPROMs), or other similar devices.

Such processors may comprise, or may be in communication with, media, for example computer-readable media, that may store instructions that, when executed by the processor, can cause the processor to perform the steps described herein as carried out, or assisted, by a processor. Embodiments of computer-readable media may comprise, but are not limited to, an electronic, optical, magnetic, or other storage device capable of providing a processor, such as the processor in a web server, with computer-readable instructions. Other examples of media comprise, but are not limited to, a floppy disk, CD-ROM, magnetic disk, memory chip, ROM, RAM, ASIC, configured processor, all optical media, all magnetic tape or other magnetic media, or any other medium from which a computer processor can read. The processor, and the processing, described may be in one or more structures, and may be dispersed through one or more structures. The processor may comprise code for carrying out one or more of the methods (or parts of methods) described herein.

The foregoing description of some embodiments of the invention has been presented only for the purpose of illustration and description and is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Numerous modifications and adaptations thereof will be apparent to those skilled in the art without departing from the spirit and scope of the invention.

Reference herein to "one embodiment" or "an embodiment" means that a particular feature, structure, operation, or other characteristic described in connection with the embodiment may be included in at least one implementation of the invention. The invention is not restricted to the particular embodiments described as such. The appearance of the phrase "in one embodiment" or "in an embodiment" in various places in the specification does not necessarily refer to the same embodiment. Any particular feature, structure, operation, or other characteristic described in this specification in relation to "one embodiment" may be combined with other features, structures, operations, or other characteristics described in respect of any other embodiment.

CLAIMS

That which is claimed is:

1. A system, comprising:
5 an insertion sheath configured to be partially inserted within a patient's body, the insertion sheath configured to receive a surgical tool; and
an actuator coupled to the insertion sheath, the actuator configured to output a haptic effect to the insertion sheath.
2. The system of claim 1, further comprising:
10 a roller disposed at least partially within the insertion sheath, the roller configured to contact a surgical tool inserted within the insertion sheath; and
wherein the actuator is coupled to the roller, the actuator configured to receive an actuator signal and to output a haptic effect based on the actuator signal.
3. The system of claim 2, further comprising a second actuator coupled to the insertion
15 sheath, the second actuator configured to receive a vibrotactile actuator signal and to output a vibrotactile effect based on the vibrotactile actuator signal.
4. The system of claim 1, further comprising:
a sensor configured to generate a sensor signal indicating a movement of the surgical tool.
- 20 5. The system of claim 4, further comprising a host processor in communication with the actuator and the sensor, the host processor configured to:
receive the sensor signal;
generate the actuator signal based on the sensor signal; and
transmit the actuator signal to the actuator.
- 25 6. The system of claim 1, further comprising:
wherein the surgical tool has a distal end and comprising:
a sensor disposed at the distal end of the surgical tool, the sensor configured to generate a sensor signal;
a host processor in communication with the actuator and the sensor, the host processor
30 configured to:
receive the sensor signal;
generate the actuator signal based on the sensor signal; and
transmit the actuator signal to the actuator.

7. The system of claim 6, wherein the sensor is configured to detect a force.
8. The system of claim 7, wherein the sensor signal comprises a sensed force associated with a contact force between the surgical tool and an obstacle, and wherein the actuator is configured to output a force configured to maintain a contact force between a first threshold and a second threshold..
9. The system of claim 6, wherein the sensor is configured to detect one of a voltage, a temperature, a fluid flow, or a viscosity.
10. The system of claim 9, further comprising a second actuator coupled to the insertion sheath, the second actuator configured to receive a vibrotactile actuator signal and to output a vibrotactile effect based on the vibrotactile actuator signal,
- wherein the processor is further configured to:
- generate the vibrotactile actuator signal based on the sensor signal, and
 - transmit the vibrotactile actuator signal to the vibrotactile actuator.
11. The system of claim 1, wherein the surgical tool comprises:
- a guide wire having a handle configured to be manipulated by a surgeon;
 - a second actuator coupled to the handle, the second actuator configured to output a haptic effect to the handle.
12. The system of claim 11, wherein the handle comprises a trigger and a third actuator, the third actuator configured to output a haptic effect to the trigger.
13. The system of claim 11, wherein the handle and the second actuator are configured to be removed from the guide wire and discarded following a surgical procedure.
14. The system of claim 1, wherein the surgical tool comprises:
- a therapeutic surgical tool; and
 - a power supply coupled to the therapeutic surgical tool, the power supply configured to control an intensity of a therapeutic effect provided by the therapeutic surgical tool, the power supply comprising:
 - a trigger, and
 - a second actuator coupled to the trigger, the second actuator configured to receive a second actuator signal and to output a trigger haptic effect to the trigger based on the second actuator signal.
15. The system of claim 14, wherein the trigger haptic effect comprises a vibration.
16. The system of claim 14, wherein the trigger haptic effect comprises a kinesthetic force configured to resist movement of the trigger.

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17. The system of claim 1, further comprising:

a sensor, the sensor configured to be coupled to a patient to sense a status of the patient;

a vibrotactile actuator configured to output a vibrotactile effect to the surgical tool;

5 and

a host processor in communication with the vibrotactile actuator and the sensor, the host processor configured to:

receive the sensor signal;

generate a vibrotactile actuator signal based on the sensor signal; and

10

transmit the vibrotactile actuator signal to the vibrotactile actuator.

18. The system of claim 17, wherein the sensor comprises a blood pressure monitor or a heart rate monitor.

19. A system, comprising:

an insertion sheath configured to be partially inserted within a patient's body, the insertion sheath configured to receive a surgical tool; and

15

an non-contact inductive actuator coupled to the insertion sheath, the inductive actuator configured to receive an actuator signal and to output a haptic effect to the surgical tool based on the actuator signal.

20. The system of claim 19, wherein the haptic effect comprises a kinesthetic force configured to assist or resist movement of the surgical tool within the insertion sheath.

20

21. A computer-implemented method, comprising:

receiving a sensor signal from a sensor coupled to a surgical tool, the surgical tool configured to be at least partially inserted within a patient's body;

generating an actuator signal based at least in part on the sensor signal, the actuator signal configured to cause the actuator to output a haptic effect; and

25

transmitting the actuator signal to an actuator coupled to the surgical tool.

22. The method of claim 21, wherein the sensor comprises a voltage sensor and wherein the actuator comprises a vibrotactile actuator and is configured to output a vibrotactile haptic effect based at least in part on the actuator signal.

30

23. The method of claim 22, wherein the frequency of the vibrotactile effect is proportional to the magnitude of the sensed voltage.

24. The method of claim 21, wherein the sensor signal comprises a sensed force associated with a contact force between the surgical tool and an obstacle, and wherein

the actuator is configured to output a force configured to maintain a contact force between a first threshold and a second threshold.

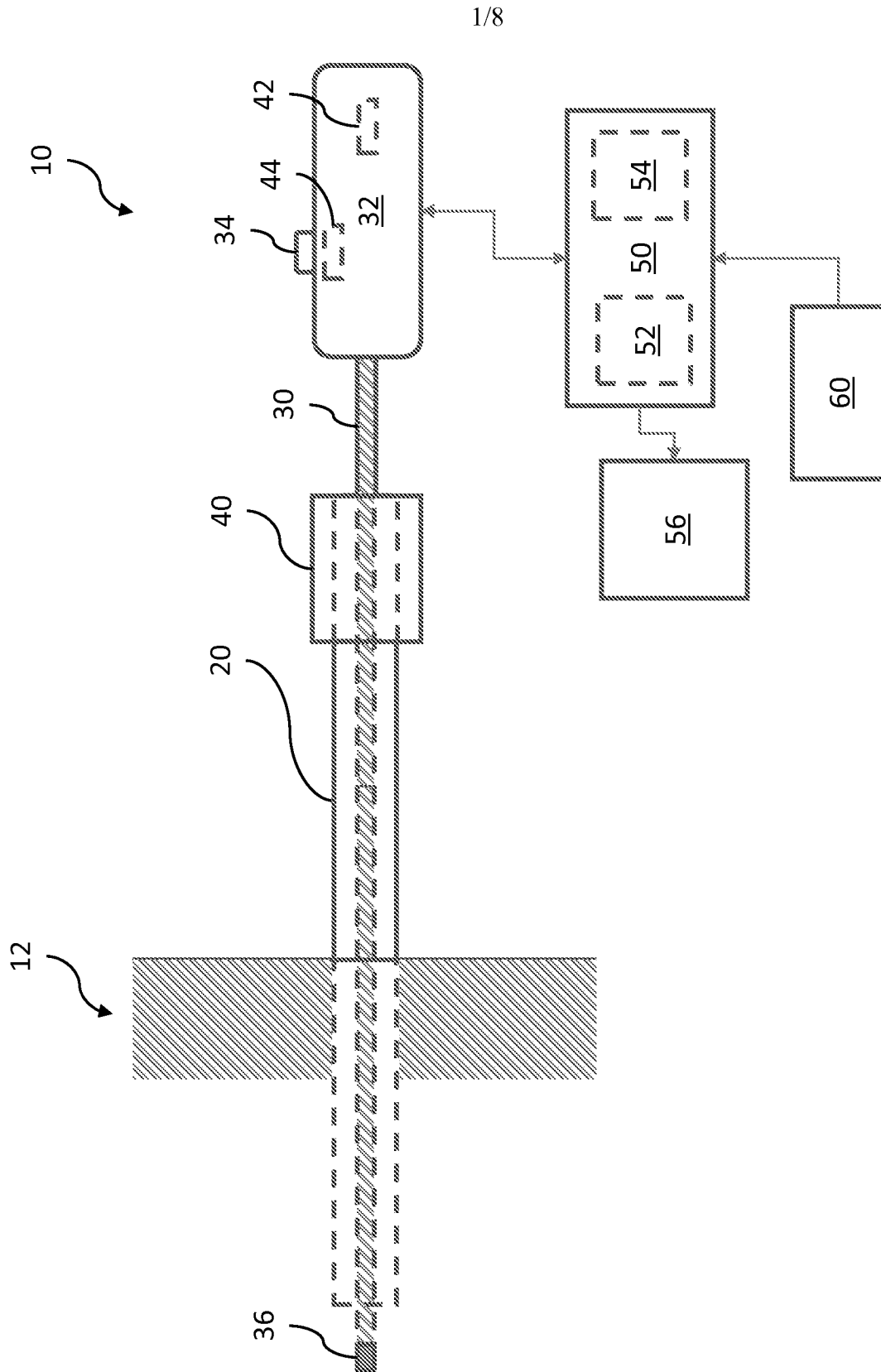


Figure 1

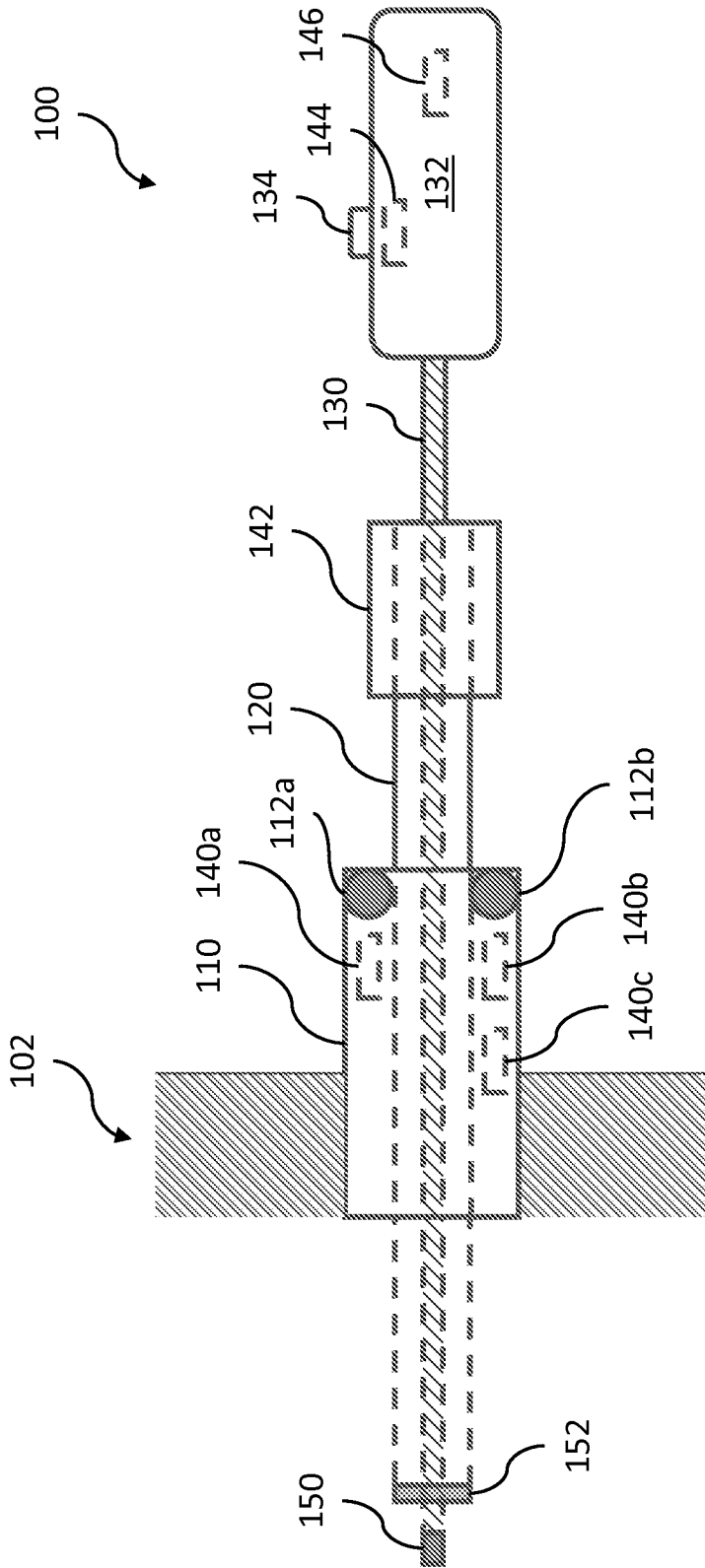


Figure 2a

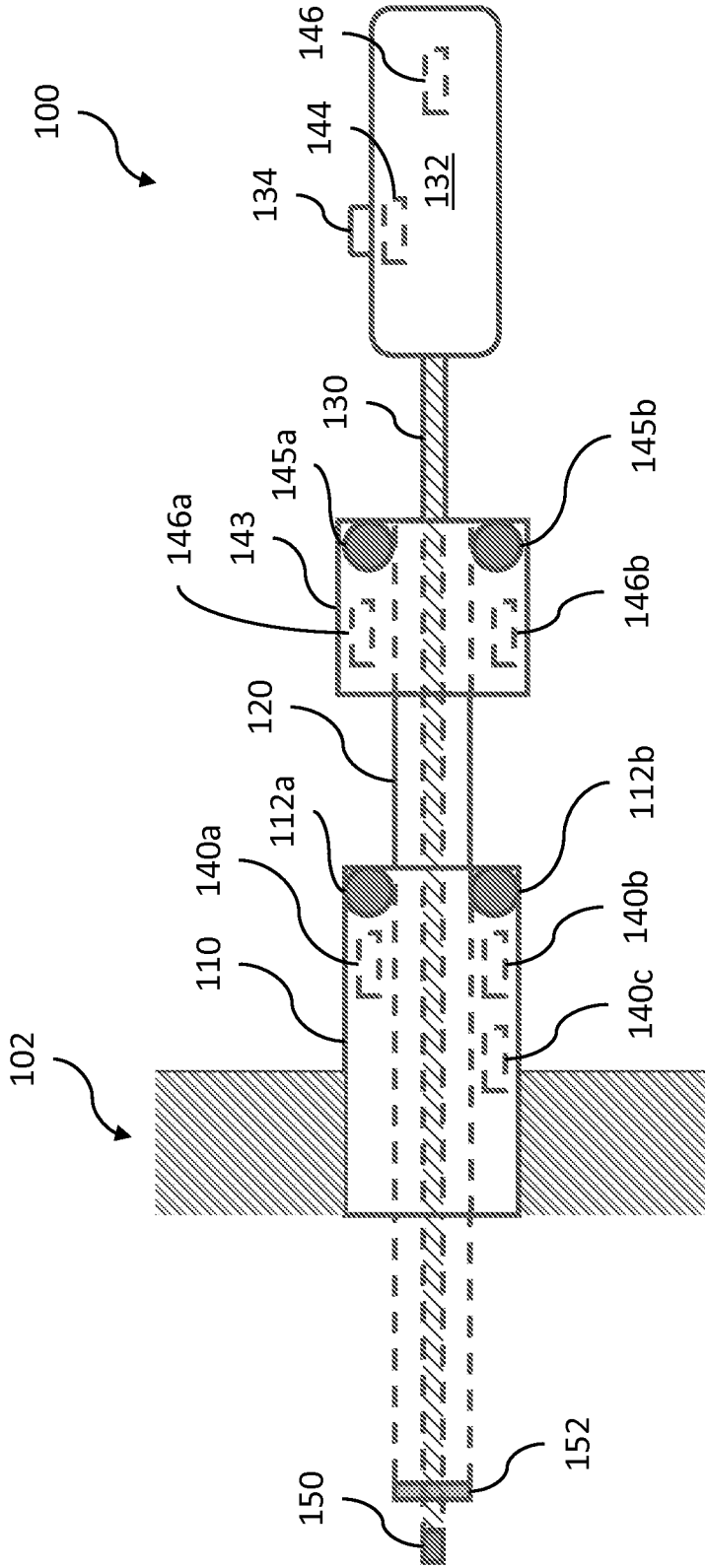


Figure 2b

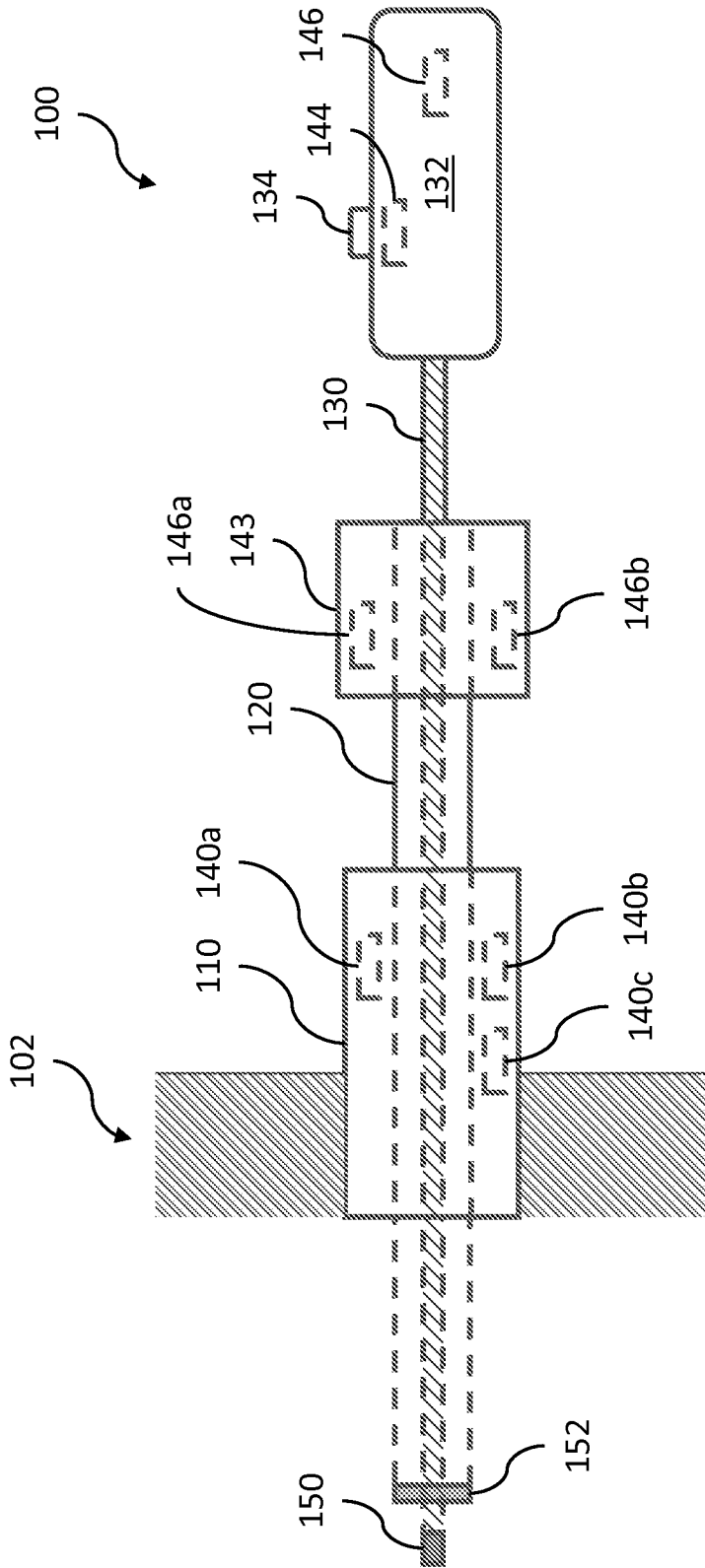


Figure 2c

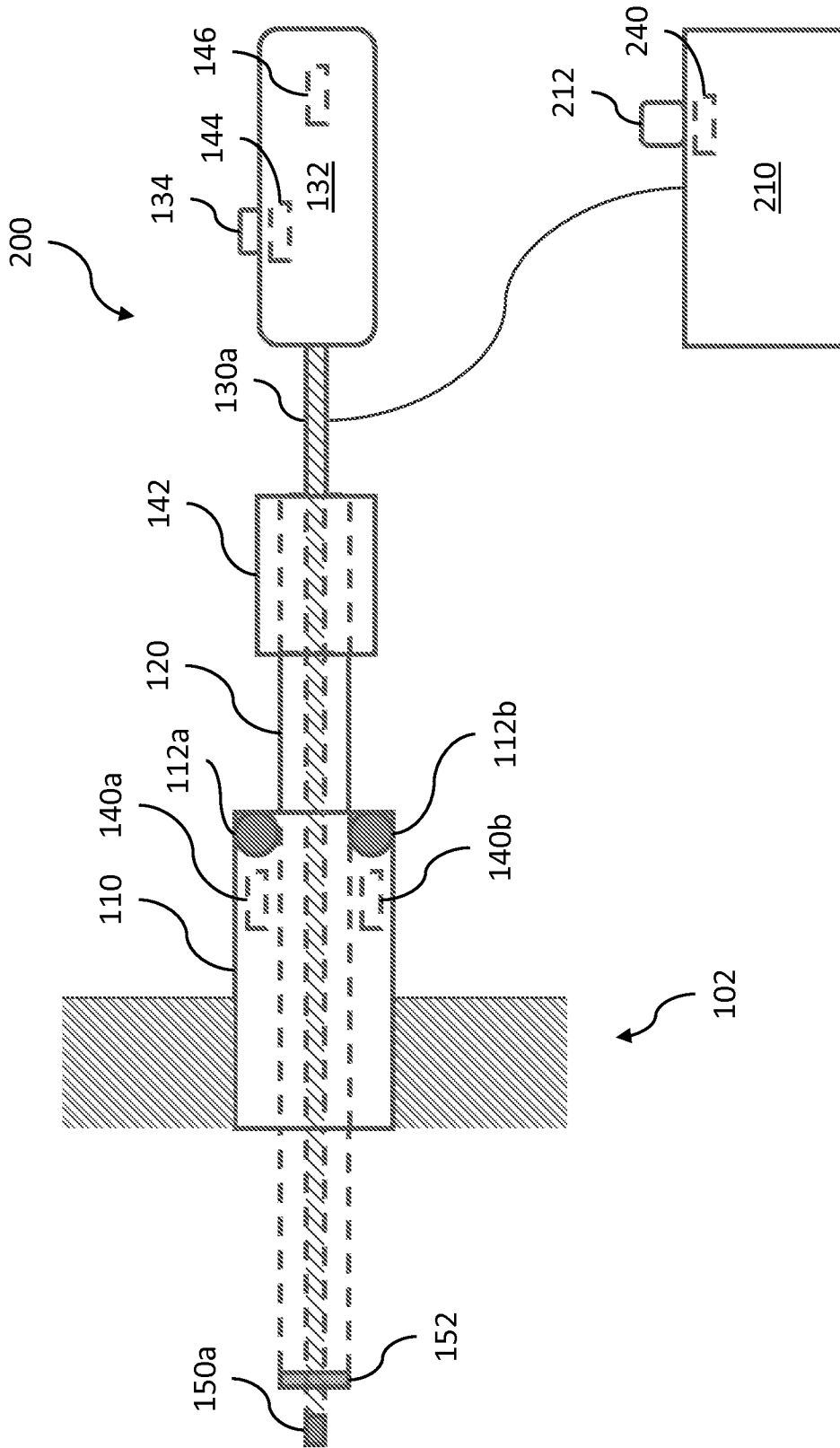


Figure 3

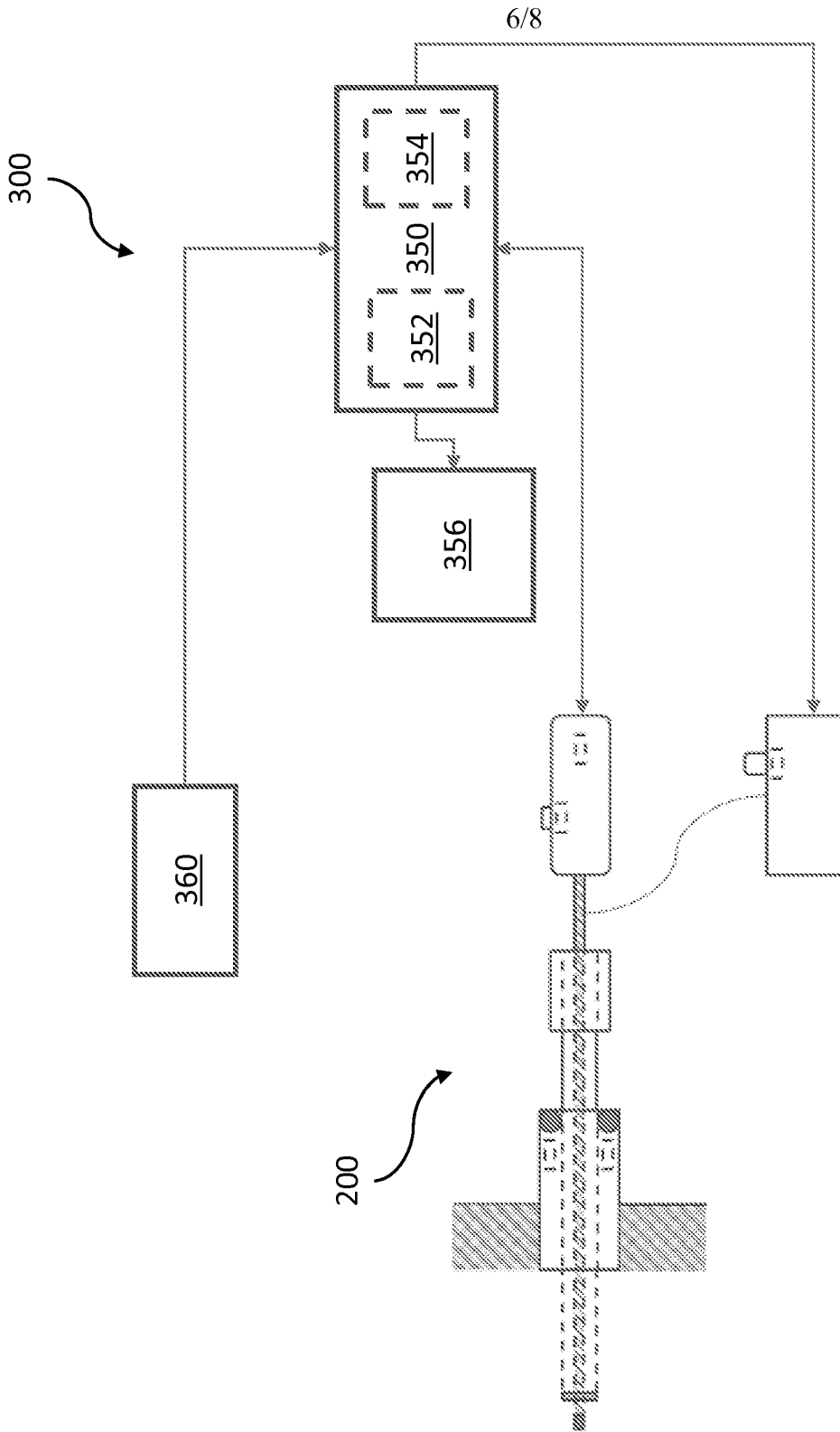


Figure 4a

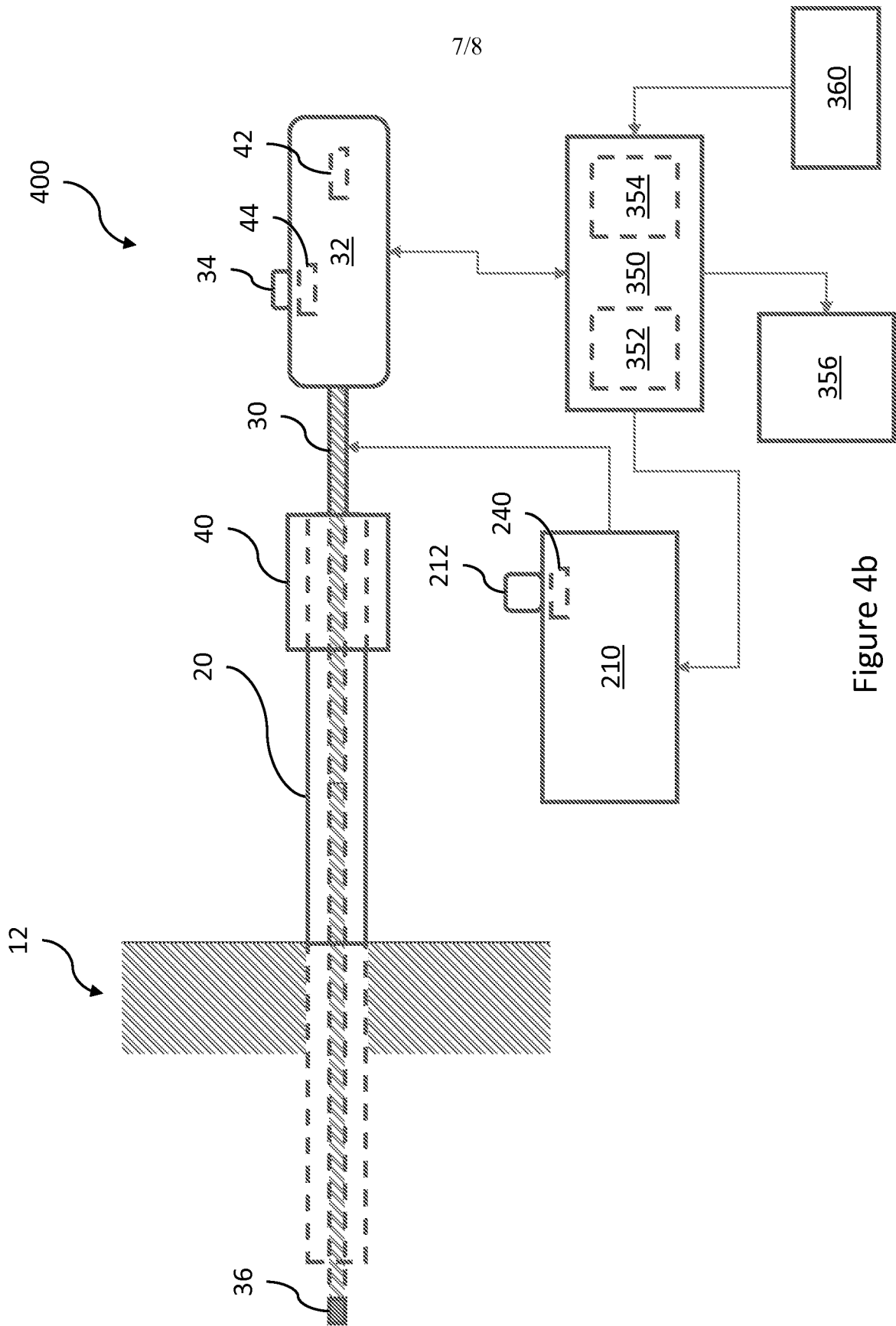


Figure 4b

500

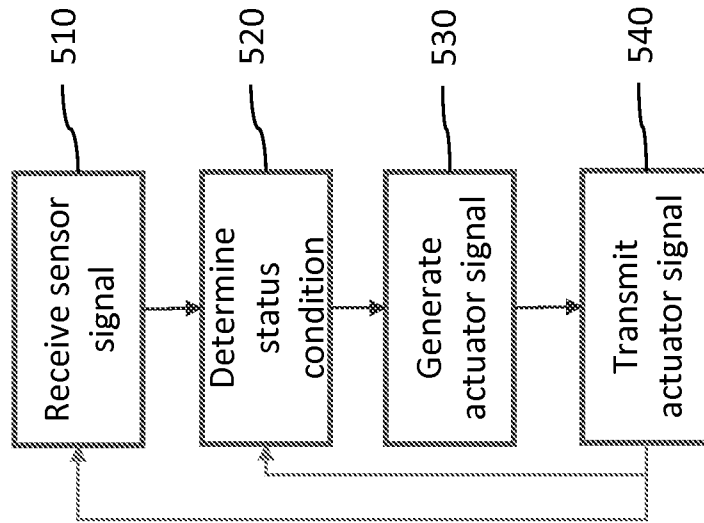


Figure 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/021349

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B17/34 A61B19/00
ADD.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
A61B A61M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	US 2006/161045 A1 (MERRIL GREGORY L [US] ET AL) 20 July 2006 (2006-07-20) paragraphs [0020] - [0024], [0025], [0026], [0028], [0031]; figures 2,3 -----	1-13, 21-24 14,15 19,20
X	US 6 171 234 B1 (WHITE DAVID A [US] ET AL) 9 January 2001 (2001-01-09) figure 6A -----	1,2
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X	US 2006/041245 A1 (FERRY STEVEN J [US] ET AL) 23 February 2006 (2006-02-23) paragraphs [0086] - [0088]; figure 17 ----- -/--	1,2

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

<p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p>	<p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&" document member of the same patent family</p>
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Date of the actual completion of the international search 8 June 2011	Date of mailing of the international search report 16/06/2011
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Mayer-Martenson, E
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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/021349

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2007/299304 A1 (MURAKAMI KAZUSHI [JP] ET AL) 27 December 2007 (2007-12-27) paragraphs [0053], [0054]; figures 1,2 -----	1,2
X	US 2002/120188 A1 (BROCK DAVID L [US] ET AL) 29 August 2002 (2002-08-29) paragraphs [0080], [0081], [0090] -----	21-23
X	WO 2008/085919 A2 (TYCO HEALTHCARE [US]; BETTUCHI MICHAEL [US]) 17 July 2008 (2008-07-17) page 8, paragraph 2 - page 9, paragraph 1; figure 3 -----	19,20
Y	US 2008/275442 A1 (PAUL SAURAV [US] ET AL) 6 November 2008 (2008-11-06) paragraph [0054] -----	14,15
A	US 2008/009791 A1 (COHEN TODD J [US] ET AL) 10 January 2008 (2008-01-10) paragraph [0229] -----	1
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2011/021349

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-18, 21-24

System outputting a trigger haptic effect

2. claims: 19, 20

System with non contact inductive actuator

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No PCT/US2011/021349

Patent document cited in search report	Publication date	Patent family member(s)	Publication date	
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US 2009158852	A1	25-06-2009	WO 2009082646 A1	02-07-2009

专利名称(译)	用于具有触觉反馈的微创手术工具的系统和方法		
公开(公告)号	EP2523613A1	公开(公告)日	2012-11-21
申请号	EP2011703519	申请日	2011-01-14
[标]申请(专利权)人(译)	伊梅森公司		
申请(专利权)人(译)	Immersion公司		
当前申请(专利权)人(译)	Immersion公司		
[标]发明人	ULLRICH CHRISTOPHER J		
发明人	ULLRICH, CHRISTOPHER, J.		
IPC分类号	A61B17/34 A61B19/00 A61B5/00 A61B5/0205 A61B5/042		
CPC分类号	A61B34/70 A61B5/0084 A61B5/0205 A61B5/042 A61B5/7455 A61B17/00234 A61B34/30 A61B34/76 A61B34/77 A61B2034/301 A61B2090/065 A61M25/01 A61M25/0113 A61M25/0116		
优先权	61/295438 2010-01-15 US		
其他公开文献	EP2523613B1		
外部链接	Espacenet		

摘要(译)

公开了用于具有触觉反馈的微创手术工具的系统和方法。一种公开的系统实施例包括插入护套，该插入护套构造成部分地插入患者体内，该插入护套构造成接收手术工具；至少部分地设置在所述插入护套内的辊子，所述辊子构造成接触插入所述插入护套内的手术工具；和致动器连接到辊子，致动器配置成接收致动器信号并基于致动器信号输出触觉效果。