(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
22 August 2024 (22.08.2024)

WIPO | PCT

(10) International Publication Number
WO 2024/171116 A1

(51) International Patent Classification:
A61B 34/00 (2016.01) *A61B 90/50* (2016.01)
A61B 34/30 (2016.01)

(21) International Application Number:
PCT/IB2024/051452

(22) International Filing Date:
15 February 2024 (15.02.2024)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
63/485,715 17 February 2023 (17.02.2023) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ,

(54) Title: ROBOTICALLY ASSISTED, FULCRUM-EFFECT CORRECTION DEVICES AND METHODS

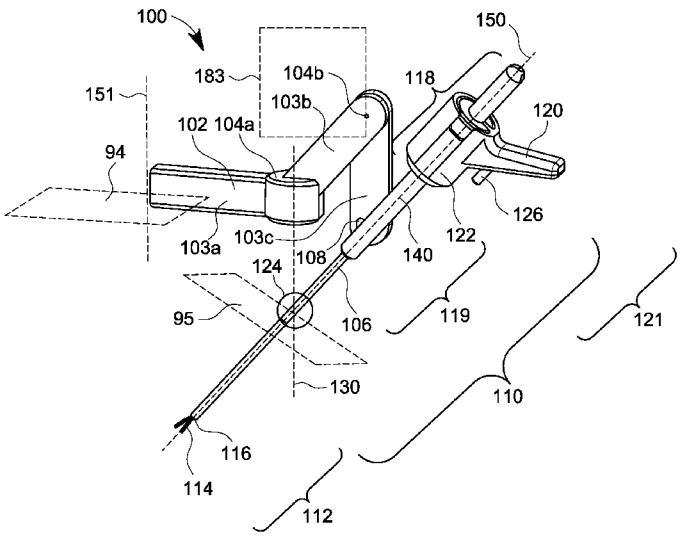

FIG. 1A

(57) Abstract: Described herein are devices and methods for switching between a fulcrum-effect mode and a fulcrum-effect corrected mode. In a fulcrum-effect mode, the method includes receiving a first input at a handle coupled to a medical instrument. The first input causes manual, inverse movement of the medical instrument about a pivot point. In a fulcrum corrected mode, the method includes activating a control at the handle to engage a sensor assembly and a powered actuation unit in communication with the medical instrument, monitoring a position of one or more sensorized joints of the handle, and responsive to detecting, by the sensor assembly, a change in the position, causing the distal portion of the medical instrument to translate using the powered actuation unit.

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DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

ROBOTICALLY ASSISTED, FULCRUM-EFFECT CORRECTION DEVICES AND METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the priority benefit of U.S. Provisional Patent Application Ser. No. 63/485,715, filed February 17, 2023, the contents of which are herein incorporated by reference in their entirety.

INCORPORATION BY REFERENCE

[0002] All publications and patent applications mentioned in this specification are herein incorporated by reference in their entirety, as if each individual publication or patent application was specifically and individually indicated to be incorporated by reference in its entirety.

TECHNICAL FIELD

[0003] This disclosure relates generally to the field of minimally invasive surgery, and more specifically to the field of robot-assisted minimally invasive surgery. Described herein are robotically assisted devices and methods for performing minimally invasive surgery.

BACKGROUND

[0001] Surgical procedures can be performed with either an open method, where a large incision is made to access the surgical site, or a minimally invasive surgery (MIS) method, where multiple smaller incisions are made, and slender instruments are used to manipulate tissue at the surgical site. MIS, also known as keyhole or laparoscopic surgery, offers numerous advantages to the patient, such as decreased blood loss, reduced scarring and reduced length of hospital stay. However, in many cases, the MIS approach is exceedingly difficult to perform, and the open method is implemented instead.

[0002] A number of causes contribute to the challenges of MIS, but the main difficulties stem from the limitations of the control systems (e.g., interface) for surgical instruments. While many control systems have been developed to address some of the difficulties, conventional control systems still suffer from drawbacks. Further, a limitation of conventional MIS procedures, that adds to their difficulty, is the fulcrum point that is created at the incision, about

which the surgical instruments pivot within the patient. Manipulating surgical instruments at the fulcrum point introduces inverse control of the instrument tip relative to movements at the instrument handle or other control interface. Inverse control (i.e., moving up to move the tip down, or moving right to move the tip left) is counterintuitive for the surgeon and reduces the effectiveness of MIS devices.

[0003] Accordingly, there exists a need to develop new control mechanisms that allow for improved control of both orientation and position of surgical instruments while maintaining a comfortable and ergonomic control interface for a surgeon.

SUMMARY

[0004] In some aspects, the techniques described herein relate to a system for performing minimally invasive surgery, including: a stabilizing apparatus transitionable between an unlocked state and a locked state; a control assembly including: a handle pivotally coupled to the stabilizing apparatus and including one or more sensorized joints, and an instrument actuator interface configured to be reversibly coupled to the handle, a medical instrument coupled to the handle and manipulatable by the handle, the medical instrument including: an elongate body having a proximal portion and a distal portion including one or more distal joints, and an end-effector coupled to the distal portion; and wherein, in a first mode, the stabilizing apparatus is configured in the unlocked state such that the medical instrument is manipulatable by the handle about a pivot point or in a first three-dimensional space, wherein, in a second mode, the handle is configured to manipulate the end-effector of the medical instrument, and wherein, in a third mode, the stabilizing apparatus is configured in the locked state, and the handle is enabled to cause movement of the one or more sensorized joints, such that the movement of the one or more sensorized joints causes a corresponding distal movement in the one or more distal joints of the medical instrument about the pivot point.

[0005] In some aspects, the techniques described herein relate to a system for performing minimally invasive surgery, including: an elongate body including a distal end having an end-effector and one or more distal joints, and a proximal end, opposite the distal end; a handle configured to receive the proximal end of the elongate body, wherein the handle includes a sleeve including one or more sensorized joints; a sensor assembly configured to monitor a position of each of the one or more sensorized joints; and an instrument actuator interface coupled to the sleeve of the handle and including: a powered actuation unit, and a controller communicatively linked to the sensor assembly and the powered actuation unit, wherein: the

sensor assembly is configured to monitor at least a first position of the one or more sensorized joints and generate a corresponding sensor signal, wherein the first position is based on a proximal movement of the handle; the controller is configured to receive the corresponding sensor signal and generate a corresponding control signal; and the powered actuation unit is configured to receive the corresponding control signal and to actuate the one or more distal joints to cause translation of the one or more distal joints based on the first position of the one or more sensorized joints.

[0006] In some aspects, the techniques described herein relate to a system for minimally invasive surgery, including: a medical instrument including: an elongate body having a proximal portion and a distal portion including one or more distal joints, and an end-effector; and a control assembly including: a handle configured to couple to the proximal portion of the medical instrument and manipulate the medical instrument, wherein the handle includes one or more sensorized joints, and an instrument actuator interface configured to be reversibly coupled to the handle, wherein the system is configured to be selectively operated in a first control mode or a second control mode, and wherein selecting between the first control mode and the second control mode includes modifying a movement range associated with the one or more sensorized joints.

[0007] In some aspects, the techniques described herein relate to a system for performing minimally invasive surgery, including: a control assembly including: a handle pivotally coupled to a bedside apparatus, wherein the handle includes one or more sensorized joints, and an instrument actuator interface; and a medical instrument couplable to the handle and manipulatable by the handle, the medical instrument including: an elongate body having a proximal portion and a distal portion including one or more distal joints, and wherein, in a fulcrum-effect mode, mechanical movement of the handle coupled to the proximal portion of the medical instrument causes movement of the medical instrument about a pivot point, and wherein, in a fulcrum corrected mode: the pivot point is between the one or more sensorized joints of the handle and the one or more distal joints of the medical instrument, and actuation of the handle causes a movement of the one or more sensorized joints causing the instrument actuator interface to map the movement to a corresponding distal movement in the one or more distal joints at least about the pivot point.

[0008] In some aspects, the techniques described herein relate to a method for performing minimally invasive surgery, including: in a fulcrum-effect mode: receiving a first input at a

handle coupled to a medical instrument, wherein the first input causes manual movement of the medical instrument about a pivot point, wherein the pivot point is between a distal portion of the medical instrument and a proximal portion of the medical instrument; and in a fulcrum corrected mode: activating a control at the handle, the control being configured to engage a sensor assembly and a powered actuation unit in communication with the medical instrument to perform an electronically assisted movement; monitoring a position of one or more sensorized joints of the handle using the sensor assembly communicatively coupled to a controller; and responsive to detecting, by the sensor assembly, a change in the position, causing the distal portion of the medical instrument to translate using the powered actuation unit, wherein the translation of the distal portion of the medical instrument is based on the position of the one or more sensorized joints.

[0009] In some aspects, the techniques described herein relate to a handle configured to be installed at a bedside of a patient support apparatus and to perform a minimally invasive surgery, the handle including: a first input mechanism configured to select a fulcrum-effect mode, wherein the handle is configured to attach to a medical instrument that is mechanically movable about a pivot point; and a second input mechanism configured to select a fulcrum corrected mode, wherein selection of the second input mechanism is configured to activate a sensor assembly, a powered actuation unit, and a controller communicatively coupled to the powered actuation unit and the sensor assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] The foregoing is a summary, and thus, necessarily limited in detail. The above-mentioned aspects, as well as other aspects, features, and advantages of the present technology are described below in connection with various embodiments, with reference made to the accompanying drawings.

[0005] FIG. 1A illustrates a perspective view of an embodiment of a fulcrum-effect correction device.

[0006] FIG. 1B illustrates a schematic of an embodiment of a control system for a fulcrum-effect correction device.

[0007] FIG. 1C illustrates a schematic of an embodiment of a control system for a fulcrum-effect correction device.

[0008] FIG. 2 illustrates a perspective view of the embodiment of FIG. 1A with the medical instrument being installed.

[0009] FIG. 3A illustrates an adjustment about a first joint of a stabilizing apparatus of the embodiment of FIG. 1A.

[0010] FIG. 3B illustrates an inverse adjustment of FIG. 3A about a first joint of a stabilizing apparatus of the embodiment of FIG. 1A.

[0011] FIG. 4A illustrates an adjustment of a stabilizing apparatus of the embodiment of FIG. 1A.

[0012] FIG. 4B illustrates an inverse adjustment of FIG. 4A of a stabilizing apparatus of the embodiment of FIG. 1A.

[0013] FIG. 5A illustrates an axial movement of a medical instrument of the embodiment of FIG. 1A.

[0014] FIG. 5B illustrates an inverse axial movement of FIG. 5A of a medical instrument of the embodiment of FIG. 1A.

[0015] FIG. 6 illustrates roll movement of a medical instrument based on manipulation of an input mechanism of a handle of the embodiment of FIG. 1A.

[0016] FIG. 7 illustrates movement of a wrist assembly of a medical instrument based on manipulation of an input mechanism of a handle of the embodiment of FIG. 1A.

[0017] FIG. 8 illustrates the embodiment of FIG. 1A switching to a fulcrum-effect correction mode.

[0018] FIG. 9 illustrates a configuration of the handle and corresponding configuration of the medical instrument of the embodiment of FIG. 8 in a fulcrum-effect correction mode.

[0019] FIG. 10A illustrates an embodiment of a fulcrum-effect correction device in a fulcrum-effect mode.

[0020] FIG. 10B illustrates a cross-section of a linear guide of a fulcrum-effect correction device.

[0021] FIG. 11 illustrates the embodiment of FIG. 10A switching to a fulcrum-effect correction mode.

[0022] FIG. 12 illustrates a configuration of the handle and corresponding configuration of the medical instrument of the embodiment of FIG. 10A in a fulcrum-effect correction mode.

[0023] FIG. 13 illustrates an embodiment of fulcrum-effect correction device in fulcrum-effect mode.

[0024] FIG. 14 illustrates a configuration of the embodiment of FIG. 13 in a fulcrum-effect correction mode.

[0025] FIG. 15 illustrates another configuration of the embodiment of FIG. 13 in a fulcrum-effect correction mode.

[0026] FIG. 16 illustrates an embodiment of a fulcrum-effect correction device in a fulcrum-effect mode.

[0027] FIG. 17 illustrates the embodiment of FIG. 16 switching to a fulcrum-effect correction mode.

[0028] FIG. 18 illustrates a configuration of the embodiment of FIG. 17 in the fulcrum-effect correction mode.

[0029] FIG. 19 illustrates a plurality of degrees of freedom of a medical instrument based on one or more input mechanisms of the handle of the embodiment of FIG. 17.

[0030] FIG. 20 illustrates a perspective detailed view of a control assembly of the embodiment of FIG. 16.

[0031] FIG. 21A illustrates a counterclockwise roll movement of a handle the control assembly of FIG. 20.

[0032] FIG. 21B illustrates a clockwise roll movement of a handle of the control assembly of FIG. 20.

[0033] FIG. 22A illustrates a control input for manipulation of an end-effector of the embodiment of FIG. 20 in an unactuated state.

[0034] FIG. 22B illustrates a control input for manipulation of an end-effector of the embodiment of FIG. 20 in an actuated state.

[0035] FIG. 23A illustrates a medical instrument in an installed position in an embodiment of a handle.

[0036] FIG. 23B illustrates a medical instrument being installed in the handle of the embodiment of FIG. 23A.

[0037] FIG. 24A illustrates an embodiment of a control handle in a neutral position.

[0038] FIG. 24B illustrates an embodiment of a control handle in a yaw adjustment configuration.

[0039] FIG. 24C illustrates an embodiment of a control handle in a yaw and pitch adjustment configuration.

[0040] FIG. 25 illustrates a linear guide for axial movement of one or more sensorized joints of a handle to disable or enable a fulcrum-effect correction mode, as shown respectively in FIG. 16 and FIG. 17.

[0041] FIG. 26 illustrates an embodiment of a fulcrum-effect correction device in a fulcrum-effect correction mode.

[0042] FIG. 27 illustrates another configuration of an embodiment of the fulcrum-effect correction device of FIG. 26 in a fulcrum-effect correction mode.

[0043] FIG. 28 illustrates the internal components of a linear guide of an embodiment of the fulcrum-effect correction device of FIG. 26 in a fulcrum-effect correction mode.

[0044] FIG. 29 illustrates an embodiment of a fulcrum-effect correction device with two control input handles.

[0045] FIG. 30 illustrates a method of performing a fulcrum-effect procedure with a fulcrum-effect correction device.

[0046] FIG. 31 illustrates a method of performing a fulcrum-effect corrected procedure with a fulcrum-effect correction device.

[0047] The illustrated embodiments are merely examples and are not intended to limit the disclosure. The schematics are drawn to illustrate features and concepts and are not necessarily drawn to scale.

DETAILED DESCRIPTION

[0048] The foregoing is a summary, and thus, necessarily limited in detail. The above-mentioned aspects, as well as other aspects, features, and advantages of the present technology will now be described in connection with various embodiments. The inclusion of the following embodiments is not intended to limit the disclosure to these embodiments, but rather to enable any person skilled in the art to make and use the contemplated invention(s). Other embodiments may be utilized, and modifications may be made without departing from the spirit or scope of the subject matter presented herein. Aspects of the disclosure, as described and illustrated herein, can be arranged, combined, modified, and designed in a variety of different formulations, all of which are explicitly contemplated and form part of this disclosure.

[0049] As used herein, “distal or distally” is used to describe a direction of an object the device or system is acting upon, for example, a patient during minimally invasive surgery. For example, a distal portion of a device or system is the portion of the device or system that is near to the object the device or system is acting upon.

[0050] As used herein, "proximal or proximally" is used to describe a direction of a user of the device or system. For example, a proximal portion of a device or system is the portion of the device or system that is near to the user of the device or system.

[0051] The devices and systems described herein include technical improvements for instrument delivery and manipulation during minimally invasive surgeries. Traditional shortcomings of current technologies include the counter-intuitive nature of using traditional devices. For example, many traditional minimally invasive devices are subject to the "fulcrum-effect". Adversely, the fulcrum-effect results in inverse position outputs with respect to position inputs. For example, when a traditional device is used during a minimally invasive surgery, a fulcrum point is created at the point at which the device enters the patient or a trocar entering the patient or at the point of attachment of the device or system to a bedside apparatus. If a handle or other input device on the proximal side of the fulcrum point is pivoted about the fulcrum point, the portion of the device on the distal side of the fulcrum point pivots about the fulcrum point in an opposing direction. For linear movements (e.g., insertion or retraction), movement at the proximal end results in similar movement on the distal end (e.g., insertion at the proximal end results in insertion at the distal end). This type of control operation is referred to as fulcrum-effect mode. The fulcrum-effect mode makes these devices awkward and counter-intuitive in some instances. At least some of the devices and systems described herein solve these technical problems by providing control outputs on the distal side of the fulcrum point that move in the same direction as control inputs on the proximal side of the fulcrum point, which is referred to herein as a fulcrum-effect corrected (FEC) mode. Some embodiments use one or more sensorized joints on the proximal side of the fulcrum point that indicate the position and orientation of the handle and actuate one or more driven joints on the distal side of the fulcrum point to mimic the movements of the handle.

[0052] The devices and systems described herein, when desirable, may also include fulcrum-effect mode operations. The technical solutions provided herein include a handle that allows switching between a fulcrum-effect mode and fulcrum-effect corrected mode (FEC) based on inputs at a handle. The handle may be installed at a bedside, for example, attached to a stabilizing apparatus, mount, or directly to the bedside. Traditional systems and devices with fulcrum-effect correction mode do not provide such simple, compact devices and systems, and, as such, require more space in the operating area, require independent stabilizing apparatuses, and/or require the surgeon to move between a bedside and a remote console. The

devices and systems described herein provide intuitive controls while having a compact configuration to enable bedside positioning. Furthermore, the devices and systems described herein allow for use and switching between multiple modes of operation without, at least in some embodiments, the user moving their hand from a primary control input of the device.

[0053] The control assembly may include one or more inputs for selecting a mode of operation (e.g., a fulcrum-effect mode, a fulcrum-effect corrected mode, an end-effector control mode, etc.). Devices and systems described herein may include one or more controllers contained in the control assembly or in remote computing devices. In some embodiments, various ergonomic features allow for a wide range of control inputs from a single control assembly.

[0054] As used herein and as shown in FIG. 1A, a "fulcrum-effect" operation of a fulcrum-effect correction device 100 defines inverse control of a distal portion 112 of the medical instrument 106 (optionally includes the end-effector 114) with respect to the handle 120. Said another way, a left position change of the handle 120, also described as an input position, generates a right position change of the distal portion 112 of the medical instrument 106, also described as an output position. Further, an upward position change of the handle 120 would generate a downward position change of the distal portion 112 of the medical instrument 106. The position change ratio of the handle 120 versus the distal portion 112 of the medical instrument 106 can be based on a ratio of a length of the distal portion 112 versus a length of the proximal portion 110 of the medical instrument 106. For example, when the length of the distal portion 112 is half the length of the proximal portion 110 of the medical instrument 106, an about 2.00 cm (0.78 in) position change of the handle to the left may generate an about 1.00 cm (0.39 in) position response of the distal portion 112 of the medical instrument 106 to the right.

[0055] As used herein and as shown in FIG. 9, a fulcrum-effect correction operation of a fulcrum-effect correction device 100 defines corresponding control of the distal portion 112 of the medical instrument 106 with respect to the handle 120. Said another way, a left position change of the handle 120, also described as an input position, generates a left position change of the distal portion 112 of the medical instrument 106, also described as an output position. Further, an upward position change of the proximal portion 110 of the medical instrument 106 would generate an upward position change of the distal portion 112 of the medical instrument 106. The mimicked movements of the handle 120 by the distal portion 112 of the medical instrument 106 may be scaled. For example, the mimicked

movements of the handle 120 to the distal portion 112 of the medical instrument 106 may be approximately 10:1, 8:1, 6:1, 4:1: 2:1, 1:1, 1:2, 1:4, 1:6, 1:8, or 1:10. As described herein with respect to the various embodiments, fulcrum-effect correction may be achieved through using electronically assisted movement, for example using a control assembly including an instrument actuator interface and a sensor assembly.

[0056] In general, the devices and systems described herein include handles or mechanisms that enable switching between a fulcrum-effect mode and a fulcrum-effect corrected (FEC) mode. As shown in FIG. 1B, a system 10 for performing a minimally invasive surgery includes a medical instrument 6 having an elongate body and an optional wrist assembly 16 and an optional end-effector 14. The optional end-effector 14 may be coupled to the medical instrument 6 by an optional wrist assembly 16. The optional wrist assembly 16 may be utilized by the system 10 to change a position or an orientation of the optional end-effector 14 with respect to the medical instrument 6. The system 10 can further include a control assembly 18 including a handle 20 and an instrument actuator interface 22 that collectively enable switching between a fulcrum-effect corrected mode and a fulcrum-effect mode. The instrument actuator interface 22, coupled to the medical instrument 6, may include motors, mechanisms, etc. for the manipulation of the medical instrument 6, as will be described elsewhere herein. Additionally, in some embodiments of operation, as will be described elsewhere herein, the handle 20 can be reversibly coupled to the instrument actuator interface 22. In some implementations, control assembly 18 includes input 23 for configuring the system 10 in a fulcrum-effect mode and input 25 for configuring the system 10 in a fulcrum-effect corrected mode. For example, inputs 23, 25 may be mechanical switches (e.g., buttons, toggles, slider, etc.) or separate gripping portions of the handle 20 that release or secure the handle 20 to the instrument actuator interface 22. Additionally, or alternatively, inputs 23, 25 may actuate electromechanical control mechanisms that activate motors, sensors, processors, etc. allowing the device to switch modes. In other implementations, input 23 is for switching between a fulcrum-effect mode and a fulcrum-effect corrected mode while input 25 is for manipulating an end-effector of the system. Inputs 23, 25 may be mechanical switches (e.g., buttons, toggles, slider, joystick, etc.) or separate gripping portions of the handle 20 to switch between modes and manipulate the end-effector, respectively.

[0057] Further, as shown in FIG. 1B, system 10 may optionally include a stabilizing apparatus 2. The optional stabilizing apparatus 2 can at least partially support a weight of the medical instrument 6, handle 20, and/or instrument actuator interface 22. In some

implementations, the optional stabilizing apparatus 2 defines a remote-center-of-motion (e.g., pivot point 124 of FIG. 1A). The optional stabilizing apparatus 2 may have a base member fixedly coupled to or relative to a patient support apparatus (e.g., bed, operating table, wall, floor, frame, etc.). The stabilizing apparatus 2 may be capable of movement of the supported surgical device about one, two, three, or more degrees of freedom. The stabilizing apparatus may allow the user to move the surgical device in general the same way such a device could be moved without the use of the stabilizing apparatus. In some implementations, the stabilizing apparatus can also constrain the movement of the surgical device (when attached) to a predetermined range of motion in one or more of the relevant degrees of freedom such that it can permit movement of the surgical device about a remote-center-of-motion, as described herein. Constraining movement in this may help guide and/or constrain the movement of the distal tip of the attached surgical device within a pre-defined field of motion in addition to supporting at least some of its weight. That is, the configuration of joints in the stabilizing apparatus facilitates surgery by constraining the motion of the attached surgical device to a range of motion about a pivot point for minimally invasive access, also known as a remote-center-of-motion configuration. The surgeon may directly control a position and/or orientation of the end-effector of the attached surgical device via any suitable user input apparatus, such as a multiple-degree-of-freedom (DOF) handle which is part of the devices in the examples described herein. The stabilizing apparatus has capabilities so that the surgeon may control the position of the distal portion or tip of the medical instrument via the handle in substantially the same way as a manual instrument, while the overall motion device is constrained and supported by the remote-center-of-motion mechanism.

[0058] As used herein, a remote-center-of-motion (RCM) is understood to refer to a configuration in which a series of joints or degrees of freedom pivot about a single point to which the mechanism (for example, the stabilizing apparatus in this example) is not physically connected. The RCM can be used for minimally invasive surgical access, as it allows the surgical instrument to enter through a single point (herein referred to as a pivot point or fulcrum point) into the body which remains fixed while allowing the surgical instrument to move within this constraint. This configuration may help prevent the surgical instrument from moving at the point at which it enters the patient's body (often the abdomen wall) and thereby helping to limit soft tissue damage at or around this location. An RCM may be achieved either through mechanical joints or software-imposed constraints. To achieve a software-imposed RCM, the joints are typically actuated or driven. While described with

reference to one type of possible surgery, the systems described herein may be used for surgery where minimally invasive access is feasible and need not be limited to surgeries currently being performed with a minimally invasive approach. Additionally, the systems may be used where the remote-center-of-motion is located outside of the patient, such as for transoral robotic surgery (TORS), for example.

[0059] In optional alternative embodiments, and shown in FIG. 1A, any or all of the three RCM joints 104a, 104b, 108 may include suitable braking apparatuses, such as electronically or mechanically controlled brakes, for additional functionality, such as the ability to actively dampen any or all joints for finer motion control, virtual fixtures to prevent damage to tissue away from the surgical site, or the ability to lock one or more joints during a given surgical task. The ability to selectively lock and unlock one or more joints could, for example, allow the surgeon to hold tissue in a specific position or enable the RCM mechanism to hold its exact position during an instrument exchange. The advanced functionality discussed above, such as joint dampening, joint locking, or virtual fixtures, could be controlled by the surgeon by a plurality of mechanisms, for example, via buttons, switches, knobs or the like. The mechanisms can be included on the surgical handle, on a touchscreen located near the surgeon's reach, via foot pedal, and the like. In an alternative embodiment, the advanced functionality could be activated by the surgical assistant. In an alternative embodiment, any or all of the RCM joints may be motorized through the inclusion of an actuator, such as a motor, either integrated into each joint for direct drive or located away from the joint and driven via a transmission system, for example using a cable or belt or geared system. The motorization of the RCM mechanism, in conjunction with sensorization (i.e., adding sensors to each joint), would allow for more advanced functionality, such as active haptic feedback, full teleoperation (the surgeon controls the robotic unit via a console), or semi-autonomous or fully autonomous surgical tasks.

[0060] As used herein, the stabilizing apparatus may be transitionable between a locked state or configuration and an unlocked state or configuration. In an unlocked state or configuration, the stabilizing apparatus is movable about each of the joints of the stabilizing apparatus. In a locked state or configuration, one or more joints of the stabilizing apparatus are locked, thereby preventing movement of the stabilizing apparatus about the one or more locked joints. The embodiment of FIGs. 1A and 2-9 may include a stabilizing apparatus 102 with RCM capabilities during fulcrum-effect mode (i.e., including the synchronized movement of joints 104a, 104b, 108 described herein). When the stabilizing apparatus 102

locks for fulcrum-effect corrected mode, the stabilizing apparatus 102 may lock joints 104a, 104b, and 108. Embodiments, such as those in FIGs. 10A-12, 16-25, and 26-28 that include linear guides (e.g., linear guides 212, 412, and 614), may include a stabilizing apparatus 102 with RCM functions during fulcrum-effect mode (i.e., including the synchronized movement of joints 104a, 104b, 205 described herein). When the stabilizing apparatus 102 locks for fulcrum-effect corrected mode, it may lock joints 104a, 104b, and 205. In some instances, stabilizing joint 108 may be selectively locked and unlocked, while joints 104a, 104b remain locked, to adjust the fulcrum point.

[0061] FIG. 1C depicts a schematic for performing fulcrum-effect corrected operations including an instrument actuator interface 122, a controller 182, a sensor assembly 184, and a medical instrument 186. The instrument actuator interface 122 includes a powered actuation unit 180. The sensor assembly 184 may include one or more position sensors. The sensor assembly 184 measures or monitors the position of one or more joints that are actuated by a handle, such that a medical instrument 186 is actuated based on the position of the one or more joints. The sensor signals output by sensor assembly 184 are received by a controller 182. The controller 182 may output signals to the instrument actuator interface 122, which includes one or more powered actuation units 180. These output signals from the controller 182 activate the one or more powered actuation units 180 to manipulate the medical instrument 186, for example a distal portion of the medical instrument. In performing fulcrum-effect corrected operations, a position of a distal portion of the medical instrument 186 mimics a position of the handle, an input mechanism of the handle, and/or one or more sensorized joints associated with the handle. Further, movements of a distal portion of the medical instrument 186 are mimicked movements of a position of the handle, an input mechanism of the handle, and/or one or more sensorized joints associated with the handle. As such, from the perspective of the user and in a fulcrum-effect corrected mode, when the input mechanism of the handle, the handle, and/or the one or more sensorized joints associated with the handle are angled or moved to the left, the medical instrument 186 will also angle or move to the left. Further exemplified, when the input mechanism, the handle, and/or the one or more sensorized joints associated with the handle are angled or moved to the right, the medical instrument 186 will also angle or move to the right. Further exemplified, when the input mechanism, the handle, and/or the one or more sensorized joints associated with the handle are angled or moved upward, the medical instrument 186 will also angle or move upward. Further exemplified, when the input mechanism, the handle, and/or the one or more

sensorized joints associated with the handle are angled or moved downward, the medical instrument 186 will also angle or move downward.

[0062] Sensorized joints described herein include position sensors that measure the orientation and/or position of one or more portions of a device or system (see, e.g., FIGs. 3A-4B, FIGs. 9, 17-19, 26-29). For example, a sensorized joint may be included in a stabilizing apparatus, such that movement of the joint about yaw, pitch, and/or roll axes may be determined or actuated (e.g., FIGs. 3A-4B). Further exemplified, a sensorized joint may be actuatable in a fulcrum-effect correction mode, such that a position of the joint may be determined, and a medical instrument may be actuated based on the measured position. Examples of the position sensors may be optical encoders, potentiometers, magnetic encoders, capacitive encoders, linear encoders, rotary encoders, or any other appropriate sensors known in the art.

[0063] Driven joints, actuators, or any other mechanisms driven by the one or more powered actuation units described herein may also include position sensors. Included position sensors may be potentiometers, optical encoders, or any other appropriate sensors known in the art. Measuring the position of the driven joints, actuators, or mechanisms may be needed for control feedback at the controller to ensure correct positioning of distal portions of the medical instrument.

[0064] Gross movements described herein may be defined as any movements of the device other than the movements of a fulcrum-effect corrected mode and an end-effector control mode. For example, gross movements may include linear movement mode, fulcrum-effect movements, movements of the control assembly, and/or movements of the medical instrument for positioning the medical instrument for a pending operation. Gross movements may use a stabilizing apparatus in an unlocked state or configuration, such that the joints of the stabilizing apparatus are movable (see, e.g., FIGs. 3A-5B).

[0065] Medical devices described herein may have an elongate body portion. The elongate body portion may distally terminate at an optional end-effector. An end-effector may include a grasper, a forceps, scissors, a suturing device, a cutting tool, an ablation element, a cryo-element, a camera, a needle driver, electro-cautery tool, and the like. Additionally, medical devices described herein may be operatively coupled to and manipulated by an instrument actuator interface.

SYSTEMS AND DEVICES

[0066] General features and structures of the embodiments described herein are described above with respect to FIGs. 1B-1C. Exemplary embodiments are now described below in accordance with FIGs. 1A and 2-31.

[0067] FIG. 1A depicts an embodiment of a fulcrum-effect correction device 100. Device 100 includes a stabilizing apparatus 102, a control assembly 118, and a medical instrument 106.

[0068] The control assembly 118 may include a handle 120, an instrument actuator interface 122, and, optionally, an insertion tube, shaft, or sleeve 140. The handle 120 may have one or more control inputs, such as, input mechanism 126. The instrument actuator interface 122 is detachably coupled to the handle 120. Further, the instrument actuator interface 122 may be operatively coupled to a base portion 107 (e.g., shown in FIG. 2) of the medical instrument 106 and/or the sleeve 140. The instrument actuator interface 122 may include powered actuation units, for example, for transmission of power at the interface of the instrument actuator interface 122 and the sleeve 140, and/or for the transmission of power at the interface of the instrument actuator interface 122 and the medical instrument 106. The sleeve 140 may include a rail or track for which the handle 120 can slide upon when decoupled from the instrument actuator interface 122. As shown in FIG. 2, the sleeve 140 defines a groove or slot 101 in which the handle 120 interface 129 may slide within, thus locking the roll orientation of the handle 120 and the sleeve 140. The sleeve 140 may include one or more sensorized joints 160a, 160b (shown in FIG. 9). The one or more sensorized joints 160a, 160b may lock, holding each portion of the sleeve 140 concentric with each other (shown in FIGs. 1, 2, 6, and 7). The sensorized joints 160a, 160b may be locked until the handle 120 is decoupled from the instrument actuator interface 122 and slid proximally past the sensorized joints 160a, 160b (shown in FIG. 8). An input at the handle 120 and/or the action of sliding the handle 120 proximally past the sensorized joints 160a, 160b may unlock the sensorized joints 160a, 160b. Some embodiments may include a sleeve 140 with a first portion 119 being part of the stabilizing apparatus. The first portion 119 being distal to the control assembly 118. The sleeve 140 of these embodiments would have a second portion 121 adjacent to the control assembly 118, and the second portion 121 may be considered part of the control assembly 118. The second portion 121 of the sleeve 140 may include the sensorized joints 160a, 160b. Alternatively, the sleeve 140 may be considered as part of the stabilizing apparatus 102 in some embodiments, and as part of the control assembly 118 or handle 120 in other embodiments.

[0069] For example, the locking mechanism for the sensorized joints 160a, 160b may be a directional switch mechanism which unpins the sensorized joints 160a, 160b when flipped one direction, and may re-pin the sensorized joints 160a, 160b when flipped the other direction. Sliding the handle 120 distally past the sensorized joints 160a, 160b may occur, optionally, when the portions of the sleeve 140 coupled to the respective sensorized joint are held concentric with one another. As such, the portions of the sleeve 140 are positioned in an appropriate orientation for locking the sensorized joints. The control assembly 118 may include a controller within or proximal to the handle 120. Additionally, the controller may be located remotely. The controller may include computing capabilities, such as, processors and may be communicatively coupled to the control inputs of the device 100 and/or handle 120.

[0070] As shown in FIG. 1A and FIG. 2, device 100 includes a medical instrument 106. The medical instrument 106 includes a distal portion 112, a proximal portion 110, a base portion 107, an optional end-effector 114, and an optional wrist assembly 116. Further shown in FIG. 1A, the distal portion 112 and the proximal portion 110 are separated by a pivot point 124. The pivot point 124 may be enabled or generated at a predefined point or at a point where the device 100 enters the patient. In some implementations, a pivot point 124 may be a point proximate to or within or aligned with a trocar or introducer. The distal portion 112 of the medical instrument 106 may include one or more driven joints 162a, 162b (as shown in FIG. 9). The one or more driven joints 162a, 162b, with mechanisms described elsewhere herein, may be actuated by cables, pullwires, or other mechanisms housed within the medical instrument 106. Mechanisms for the actuation of the cables or pullwires, described elsewhere herein, may be contained within the base portion 107 of the medical instrument 106. The mechanisms within the end portion of the medical instrument 106 may receive actuation power at the interface with the instrument actuator interface 122. The optional end-effector 114 and optional wrist assembly 116, which couples the end-effector 114 to the medical instrument 106, may both be actuated by cables or pullwires within the medical instrument 106, similarly to the driven joints 162a, 162b. Manipulation of the driven joints 162a, 162b and optional wrist assembly 116 ultimately manipulate the position of the optional end-effector 114. Manipulation of the optional wrist assembly 116 is advantageous in positioning the optional end-effector 114 during use.

[0071] As shown in FIGs. 1A, 3A, 3B, 4A and 4B, device 100 includes a stabilizing apparatus 102. The stabilizing apparatus 102 functions to support a weight of the control assembly 118 and medical instrument 106. Further, the stabilizing apparatus 102 allows for

gross movements for the positioning of the control assembly 118 and therefore medical instrument 106. In some variations, the stabilizing apparatus 102 may include a first arm 103a terminating in a revolute mechanism or joint 104a (see, e.g., revolution of arm 103b about axis 130 as shown in FIGS. 3A and 3B). FIG. 3A illustrates a revolute movement 128 about joint 104a in a clockwise direction to a first position. FIG. 3B illustrates a revolute movement 128 about joint 104b in a counterclockwise direction to a second position. Revolution of arm 103b, relative to arm 103a, about joint 104a and axis 130 is a first degree of freedom of the stabilizing apparatus 102. The stabilizing apparatus 102 can further include a second arm 103b and a third arm 103c. The first arm 103b may include a first set of linkages, and the second arm 103c may include a second set of linkage, the first and second sets collectively forming a parallelogram movement mechanism. The parallelogram movement mechanism of arms 103b, 103c functions to provide coordinated movement, shown by arrow 132, of the first joint 104a, a second joint 104b, and a stabilizing joint 108 about a pitch axis 137, as shown in FIGS. 4A and 4B. Movement about pitch axis 137 is a second degree of freedom of the stabilizing apparatus 102. FIG. 4A illustrates a positioning to a lowered position, about axis 137, of the control assembly 118 and proximal portion 110 of the medical instrument 106 via the stabilizing apparatus 102. FIG. 4B illustrates a positioning to a raised position, about axis 137, of the control assembly 118 and proximal portion 110 of the medical instrument 106 via the stabilizing apparatus 102. In some embodiments, the stabilizing apparatus 102 further includes a sleeve 140 (e.g., including a prismatic joint) which enables linear movement or a third degree of freedom of the stabilizing apparatus 102, as will be described in further detail below.

[0072] As illustrated, the stabilizing apparatus 102 includes a first joint 104a that connects a first arm 103a to the second arm 103b and the third arm 103c (in some embodiments collectively forming a parallelogram movement mechanism). The first joint 104a may function as a revolute joint. For example, the second arm 103b and third arm 103c, collectively, may perform a revolute movement 128 about a yaw axis 130 (shown in FIGS. 3A and 3B), relative to first arm 103a and perpendicular to a horizontal plane 94 (e.g., movement is about the yaw axis 130 that is perpendicular to the horizontal plane 94), as shown in FIGs. 1A, 3A and 3B. Additionally, the first joint 104a may also include a hinge mechanism that allows movement, shown by arrow 132, of the second arm 103b and the third arm 103c, collectively, relative to the first joint 104a, about pitch axis 137 shown in FIGS. 4A and 4B. As described above, the second arm 103b and the third arm 103c form a

parallelogram movement mechanism such that the second arm 103b and the third arm 103c move relative to arm 103a through coordinated movement of joints 104a, 104b, and 108. The stabilizing joint 108 allows for pitch adjustment of the medical instrument 106 with respect to the stabilizing apparatus 102. The adjustment plane 183 of the pitch adjustment performed at the stabilizing joint 108 is perpendicular to the horizontal plane 94, shown in FIG. 1A.

[0073] Some embodiments include RCM capabilities accomplished with the joints 104a, 104b, 108 of the stabilizing apparatus 102. Embodiments with RCM capabilities may include joints 104a, 104b, 108 working synchronously. The synchronized movements of the joints 104a, 104b, 108 may be coupled by mechanical linkages (e.g., parallelogram movement mechanism) or gears. For embodiments with a stabilizing apparatus 102 including motorized RCM joints 104a, 104b, 108, the synchronized movements of the joints 104a, 104b, 108 may be from outputs from the controller moving each joint 104a, 104b, 108 with respect to one another to maintain the remote-center-of-motion point. Embodiments with RCM capabilities, whether mechanical or motorized, include synchronized joints 104a, 104b, 108 that align to maintain the remote-center-of-motion point while the instrument is manipulated or positioned. Further, the stabilizing apparatus 102 may be temporarily locked in any position. Locking of the stabilizing apparatus 102 may be done when the controller receives a corresponding input signal. For example, the input signal may be generated by an input on the handle, and the controller, upon receiving the input signal, generates an output signal to lock the stabilizing apparatus 102. The stabilizing apparatus 102 may be unlocked after the controller receives the same input signal from the handle or, alternatively, another input signal from the handle. The stabilizing apparatus 102, as shown in FIGs. 1A, 2-5B, 8-10A, 11, 12, 16-19, and 25-29, is intended to be rigidly mounted at interface 151. Interface 151 may include a bedside, a wall, a frame, a floor, a ceiling mount, or any other suitable fixture.

[0074] Device 100 functions in one or more modes of operation. The first mode, referred to herein as fulcrum-effect mode, defines a configuration of the device that enables the previously described adjustments of joints 104a, 104b, 108 of the stabilizing apparatus 102, shown in FIGs. 1A, 3A, 3B, 4A, and 4B. In some embodiments, adjustment movements about joints 104a, 104b, 108 of stabilizing apparatus 102 may be manual movements. For example, when the device 100 is used in a minimally invasive procedure, a fulcrum point, a remote-center-of-motion point, or pivot point 124 may be generated at a predefined point or at a point where the device 100 enters the patient. The pivot point 124 (i.e., a remote-center-of-motion) may include a common intersection point for the yaw axis 130 (shown in FIGs.

3A and 3B), pitch axis 137 (shown in FIGs. 4A and 4B), and the longitudinal axis 150 (shown in FIG. 1A) of the medical instrument 106. In some implementations, a pivot point 124 may be a point proximate to or within or aligned with a trocar. Movement of medical instrument 106 about pivot point 124 causes a fulcrum-effect to be experienced, for example, when positioning a distal portion 112 of the medical instrument 106 or an end-effector 114 of the medical instrument 106. The fulcrum-effect mode may further include actuation of an end-effector 114, as described in FIGs. 6-7. Fulcrum-effect mode use of the device 100 may be used during a procedure or may also be used in gross movements of the device, for example, in positioning for a pending procedure.

[0075] In some embodiments, the control assembly 118 includes an input mechanism 142 (shown in FIG. 6) located on or near the handle 120. Although input mechanism 142 is shown as a button; a dial, joystick, switch, etc. may also be used without departing from the scope and intent of the present disclosure. Input mechanism 142 may be used for actuation of an end-effector 114. For example, in embodiments with a grasper-type end-effector 114, as shown in FIG. 1A, depression or actuation of input mechanism 142 causes a grasping action of the end-effector 114. Further, release of the input mechanism 142 may release or open the grasping mechanism of the end-effector 114. In some implementations, end-effector 114 may comprise an ablation element, a cryo-element, a cutting element, a suturing element, a drilling element, milling element, electro-cautery element, etc., such that actuation of input mechanism 142 activates ablation, cryo-activity, cutting, suturing, drilling, milling, electro-cautery, etc.

[0076] In some variations, an optional second mode or an optional part of any of the modes described herein, also described herein as end-effector control mode, may be performed by any of the devices described herein. For example, the optional end-effector control mode, when enabled, causes the wrist assembly 116 (shown in FIG. 1A) of the end-effector 114 to be controlled by the control assembly 118. In some embodiments, the control assembly 118 includes input mechanism 126 (shown in FIGs. 6 and 7) for manipulation of the medical instrument 106 and the wrist assembly 116 of the end-effector 114. Although a joystick is shown for input mechanisms 126, a dial, knob, switch, etc. may also be used without departing from the scope and intent of the present application. As shown in FIG. 6, input mechanism 126 is rotatable about a roll axis 144. In some embodiments, rotating the input mechanism 126 in a clockwise direction 148 may cause the medical instrument 106 to rotate about its longitudinal axis 150 (or cause the wrist assembly 116 to rotate about longitudinal

axis 150) in a clockwise direction 146. Further, rotating the input mechanism 126 in a counterclockwise direction (opposite clockwise direction 148) may cause the medical instrument 106 to rotate about its longitudinal axis 150 (or cause the wrist assembly 116 to rotate about longitudinal axis 150) in a counterclockwise direction (opposite clockwise direction 146). Rotation of the medical instrument 106 (or wrist assembly 116) may ultimately change the orientation of end-effector 114. In some embodiments, input mechanism 126 includes electromechanical attachments to the control assembly 118 similar to that of a joystick known in the art.

[0077] As shown in FIG. 7, when pitching the input mechanism 126 about a first or pitch axis 154 and/or a second or yaw axis 156, the wrist assembly 116 may pitch the end-effector 114 about an end-effector first or pitch axis 152 and/or an end-effector second or yaw axis 158, respectively, to mimic a position of the input mechanism 126. For example, if the input mechanism 126 is pitched downward about the pitch axis 154, the wrist assembly 116 may pitch the end-effector 114 downward about the pitch axis 152. Further, if the input mechanism 126 is yawed about the yaw axis 156, the wrist assembly 116 may yaw the end-effector 114 about the yaw axis 158 in the same direction. The end-effector control mode can optionally be used in conjunction with a fulcrum-effect mode, or a fulcrum-effect corrected mode, as described elsewhere herein.

[0078] FIGs. 1A and 3A-7 illustrate the device 100 in the fulcrum-effect mode and, in FIG. 7, combined with the optional end-effector control mode. The device 100 may further function in a third mode, also described herein as a fulcrum-effect corrected (FEC) mode. As shown in FIG. 8, the device 100 may enter a fulcrum-effect corrected mode by decoupling the handle 120 of the control assembly 118 from the instrument actuator interface 122 and translating the handle 120 backwards along sleeve 140. In a fulcrum-effect corrected mode, the stabilizing apparatus 102 may be locked. Translating the handle 120 along sleeve 140 may enable one or more sensorized joints 160a, 160b. These sensorized joints 160a, 160b may include one or more position sensors that measure the position of the respective joints 160a, 160b, which is received by the controller of the instrument actuator interface 122. When the device 100 is in the FEC mode, the instrument actuator interface 122 can adjust one or more driven joints 162a, 162b of the medical instrument 106 to mimic the position of sensorized joints 160a, 160b and/or handle 120, as shown in FIG. 9. The FEC mode produces a mimicked control map in which inputs at the handle 120 cause movements of one or more sensorized joints 160a, 160b. The position of each joint 160a, 160b is measured or monitored

by the sensor assembly and received by the controller. The controller outputs actuation signals to the one or more driven joints 162a, 162b, respectively, to position each joint 162a, 162b, mimicking a position of each joint 160a, 160b, respectively. For example, the mimic plane 95 for the mimicked control map may be at the pivot point 124 of FIG. 1A or anywhere along the length of the medical instrument 106. The mimic plane 95, as shown in FIG. 1A, may be perpendicular to a longitudinal length of the medical instrument 106. The described control is more intuitive than that described for a fulcrum-effect mode. For example, and in reference to FIG. 9, the measured position of sensorized joint 160a is mimicked by the driven joint 162b, and the measured position of sensorized joint 160b is mimicked by the driven joint 162a. Further, the device responds to the measured movement of the handle 120 to the left by moving the end-effector 114 to the left. Further, if it is desired to change the pitch of the distal portion 112 of the medical instrument 106, the handle 120 can be pitched in the desired pitch direction. The mimicked movements of the one or more sensorized joints 160a, 160b by the one or more driven joints 162a, 162b may be scaled. For example, the mimicked movements of the sensorized joints 160a, 160b to the driven joints 162a, 162b may be approximately 10:1, 8:1, 6:1, 4:1: 2:1, 1:1, 1:2, 1:4, 1:6, 1:8, or 1:10. The device 100 may be used in fulcrum-effect corrected mode and, also, in end-effector control mode. In other words, the device 100 may perform fulcrum-effect corrected movements with the distal portion 112 of the medical instrument 106, while making end-effector 114 pitch, yaw, and roll movements at the same time. Additionally, it may be useful to advance (FIG. 5A) and retract (FIG. 5B) the medical instrument 106, shown by arrow 123 of FIGS. 5A and 5B, when the device 100 is in fulcrum-effect corrected mode, but also while in fulcrum-effect mode. The medical instrument 106 may be coupled to the instrument actuator interface 122, and the instrument actuator interface 122 may be operatively coupled to the sleeve 140. The operative coupling of the instrument actuator interface 122 to the sleeve 140 allows the instrument actuator interface 122 to be driven along the length of the sleeve 140. Being coupled to the medical instrument 106, driving the instrument actuator interface 122 along the sleeve 140 produces advancement and retraction, along arrow 123, of the medical instrument 106, as shown in FIGS. 5A and 5B. In some embodiments, the position of the instrument actuator interface 122 along the sleeve 140 length is relative to the handle 120 position along the length of a proximal portion 170 of the sleeve 140. The proximal portion 170 of the sleeve 140 is the portion on the proximal side of the sensorized joint 160b. The proximal portion 170 of the sleeve 140 may comprise one or more position sensors. The

position sensors measure the position of the sleeve 140 (i.e., the joints 160a, 160b that are enabled), which is based on movements at handle 120. The position signals are received by the controller, which in turn outputs a control signal to cause the instrument actuator interface 122 to drive joints 162a, 162b to a mimicked position, as described elsewhere herein.

[0079] FIG. 2 depicts an embodiment of device 100 with the medical instrument 106 is being installed into the device 100. As illustrated, the sleeve 140, which is operatively coupled to the stabilizing apparatus 102, or in some embodiments, an element of the stabilizing apparatus 102, defines a lumen 105 that the elongate body of the medical instrument 106 may slide into. The base portion 107 of the medical instrument 106 defines an aperture 109 which receives the sleeve 140 therein, but with a portion within the lumen 105 defined by the sleeve 140. The medical instrument 106 may slide back and forth within the length of the sleeve 140, but is locked in the sleeve 140 for rotation about the roll or longitudinal axis 150 (seen in FIG. 6) of the sleeve 140. The handle 120, as shown, defines an aperture 125 which allows the passage of the medical instrument 106 base portion 107 therein. Aperture 125 of handle 120 includes interface 129 that mates with a slot 101 defined by the sleeve 140. In this configuration, the handle 120, when disengaged from the instrument actuator interface 122, is capable of sliding back and forth along the length of the sleeve 140 but is locked in the sleeve 140 in terms of rotation about the roll axis 150 (seen in FIG. 6) of the sleeve 140.

[0080] FIGs. 5A and 5B depicts an embodiment of device 100, in which a gross movement of advancing (FIG. 5A) and retracting (FIG. 5B) the medical instrument 106 is depicted. The gross movement of the medical instrument 106 may occur while the handle 120 is coupled to the instrument actuator interface 122, which is further coupled to the medical instrument 106. The advancement or retraction of the medical instrument 106 while the handle 120 is coupled to the instrument actuator interface 122 may be performed during fulcrum-effect mode. The advancing of the medical instrument 106, shown in FIG. 5A, and retracting of the medical instrument 106, shown in FIG. 5B, may be done during fulcrum-effect mode by adjustments of joints 104a, 104b, 108 of the stabilizing apparatus 102. Some embodiments include a linear movement mode for sliding the handle 120 and instrument actuator interface 122 while they are coupled together and while the joints 104a, 104b are locked. Linear movement mode may be entered by activation of an input mechanism on the handle 120. The mechanism for sliding the handle 120 and instrument actuator interface 122 up and down the sleeve 140, may be accomplished by placing the drive mechanism at the interface of the instrument actuator interface 122 and the sleeve 140 in a neutral position (i.e., disengaged from the

powered actuation unit). In instances where the linear movement mode is independent from fulcrum-effect mode or fulcrum-effect corrected mode, the stabilizing apparatus 102 may lock.

[0081] In instances where the linear movement mode is used in conjunction with fulcrum-effect mode, the friction at the instrument actuator interface 122 and the sleeve 140 (e.g., with the drive mechanism in neutral) may be less than the friction (adjusted for leverage) at the joints 104a, 104b (shown in FIG. 1A) of the stabilizing apparatus 102. This friction differential may allow the advancement and retraction of the instrument actuator interface 122, the handle 120, and medical instrument 106 with respect to the stabilizing apparatus 102. To further facilitate fulcrum-effect mode movements of the stabilizing apparatus joints 104a, 104b, the mechanism at the instrument actuator interface 122 and sleeve 140 interface may have a braking mechanism controlled with an input mechanism on the handle 120. The braking mechanism at the instrument actuator interface 122 and sleeve 140 interface may be normally engaged as to facilitate independent fulcrum-effect mode movements as default. When the dedicated input mechanism is engaged, the braking mechanism disengages, allowing for linear movement mode movements. Alternatively, the inverse of this may be used instead. For example, the braking mechanism may be normally disengaged as to facilitate linear movement mode movements as default, and the activation of the dedicated input mechanism engages the braking mechanism, removing the linear movement mode. The braking mechanism may be a literal braking mechanism (e.g., those known in the art) at the instrument actuator interface 122 and the sleeve 140 interface or may be the engagement of the mechanism at the instrument actuator interface 122 and the sleeve 140 interface to the powered activation unit.

[0082] The instrument actuator interface 122 may comprise one or more powered actuation units 180, as shown in FIG. 1C. One such example of a powered actuation unit may be responsible for translating the instrument actuator interface 122 along its actuation length 171 on the sleeve 140. When control signals are received at the instrument actuator interface 122 for the translation of the instrument actuator interface 122 along the sleeve 140, an electrical motor may be activated powering a linear motion mechanism to move the instrument actuator interface 122 with respect to the sleeve 140. For example, the linear motion mechanism may be a rack and pinion, in which the rack is coupled to the sleeve 140 and the pinion is coupled to and driven by the instrument actuator interface 122. Another example of the linear motion mechanism may be one or more wheels coupled to and driven by the instrument actuator

interface 122. The one or more wheels would have sufficient friction at the interface with the sleeve 140 to cause linear motion when power is supplied to the one or more wheels. Additionally, when the medical instrument 106 is coupled to the instrument actuator interface 122, one or more driven actuators may become operatively coupled to one or more respective powered actuation units 180 (shown in FIG. 1C). In some embodiments, these driven actuators, stored in the base portion 107 of the medical instrument 106, are responsible for the actuation of the medical instrument 106, for example, during end-effector control mode or fulcrum-effect corrected mode operations. The one or more driven actuators may interface with the one or more respective powered actuation units at the point where the instrument actuator interface 122 interfaces with the medical instrument 106. The transmission across this interface could be, for example, a gear-to-gear interface, or a friction wheel-to-friction wheel.

[0083] As shown in FIGs. 7 and 9, the medical instrument 106 of the embodiments described herein may be actuated in a multitude of ways. For example, for those embodiments with the medical instrument 106 operatively coupled to the instrument actuator interface 122, the base portion 107 of the medical instrument 106 may comprise one or more driven actuators with drivetrains receiving power transmission from one or more respective powered actuation units across the interface with the instrument actuator interface 122. Each of the one or more driven actuators may comprise a cable spool or pulley, and when powered by a respective powered actuation unit, tensions or relaxes cables or pullwires inside or along the elongate body of the medical instrument 106. These cables or pullwires may be used to actuate one or more of medical instrument 106 capabilities, for example, actuating the end-effector 114 (e.g., clamp or unclamp a grasping end-effector), driving a rotation mechanism of the wrist assembly 116 of the end-effector 114 (shown in FIG. 6), actuating the wrist mechanism of an end-effector 114 (shown in FIG. 7), or manipulating the driven joints 162a, 162b (shown in FIG. 9). Driven joints of the embodiments above and below may be steerable. For example, the driven joints may have a U-joint mechanism with cables or pullwires anchored at points of leverage with respect to the U-joint. The tensioning of one or more of these cables anchored in this way, can produce a variety of articulations. Steerable joints may include planar joints, spatial joints, rolling joints, perpendicular joints, revolved rolling joints, planar sliding joints, perpendicular sliding joints, revolved sliding joints, perpendicular rolling sliding joints, planar rolling sliding joints, revolved rolling sliding joint, planar bending

joints, perpendicular bending joints, and revolved bending joints. These steerable joints may be actuated by pullwires, cables, push rods, or concentric rotatable tubes.

[0084] FIGs. 10A, 10B, 11, and 12 illustrate an embodiment of a fulcrum-correction device. The fulcrum-correction device includes a stabilizing apparatus 102, a linear guide 212, a medical instrument 206, and a control assembly 218. The stabilizing apparatus 102 may perform as the stabilizing apparatus 102 described for FIGs. 1A, 3, and 4. For embodiments with RCM capabilities, the linear guide 212 may be considered as part of the stabilizing apparatus 102, such that, joints 104a, 104b, 205 function synchronously to maintain a remote-center-of-motion, as described for joints 104a, 104b, 108 of FIGs. 1A, and 3A-4B. The control assembly 218 may include an instrument actuator interface 207, a handle cradle 204, and a handle 220. The handle 220 may be used as the primary control input element, which may include the input mechanism 126 of FIG. 1A, and the input mechanism 142 of FIG. 6. The input mechanisms 126, 142 may be received by the controller and carried out by the instrument actuator interface 207 onto the medical instrument 206 as described for FIGs. 6 and 7. The embodiment includes a linear guide 212 to which the instrument actuator interface 207 operatively couples, and the handle cradle 204 operatively couples. The linear guide 212 may couple with the instrument actuator interface 207 as to restrict movement of the instrument actuator interface 207 to along the length of the linear guide 212 (along path 209).

[0085] For example and shown in a cross-section of the linear guide 212 in FIG. 10B, the linear guide 212 may include an internal Tee track 290 along a portion of its length, which defines the shape of the top portion of the instrument actuator interface 207 (shown in FIG. 10A). The handle cradle 204 may also be coupled to the linear guide 212 in such a way as to restrict movement along path 209 (shown in FIG. 10A). For example, the handle cradle 204 (shown in FIG. 10A) may include a top portion with a Tee shape appropriate for the internal Tee track 290 within the linear guide 212. In a case in which the handle cradle 204 includes a Tee shaped top portion, the handle cradle 204 may be placed in the internal Tee track 290 proximally to the top portion of the instrument actuator interface 207. Another example of coupling of the handle cradle 204 to the linear guide 212 may be an external Tee track 294 (shown in FIG. 10B) defined by linear guide 212. The external Tee track 294 may include a width 298 greater than the width 296 of the entrance aperture 292 defined by the internal Tee track 290. The handle cradle 204 may have a portion which slides into the externally defined Tee track 294 restricting it to movement along path 209 (shown in FIG. 10A). The instrument actuator interface 207 may interface with the internal Tee track 290 with wheels or rollers.

The wheels or rollers of the instrument actuator interface 207 may supply the appropriate interface for translating the instrument actuator interface 207 along path 209 and may be capable of operatively coupling to one or more powered actuation units in the instrument actuator interface 207. Additionally, the handle cradle 204 may interface with the linear guide 212, whether by the internal Tee track 290 or the external Tee track 294, with wheels or rollers. The wheels or rollers of the handle cradle 204 may aid in translating the handle cradle 204 along path 209. The handle cradle 204 may define an aperture between the handle cradle 204 and the linear guide 212 that allows passage of the end portion 208 of the medical instrument 206 and the instrument actuator interface 207. With the handle cradle 204 connected to the external Tee track 294 of FIG. 10B and with the described aperture, the handle cradle 204 is able to pass over the medical instrument 206 and instrument actuator interface 207. Additionally, when installing the medical instrument 206, the medical instrument 206 can slide all the way to the instrument actuator interface 207 without conflict with the handle cradle 204.

[0086] The embodiment of FIGs. 10A, 10B, 11 and 12 includes the capability for the gross movement of advancing and retracting the medical instrument 406. Further, the gross movement of the medical instrument 406 may be done while the handle 220 is coupled to the instrument actuator interface 207, which is further coupled to the medical instrument 206. In some implementations, the advancement or retraction of the medical instrument 206 while the handle 220 is coupled to the instrument actuator interface 207 may be performed during fulcrum-effect mode by adjusting the joints 104a, 104b, 205 of the stabilizing apparatus 102. Alternatively, in some variations in which the linear movement mode is independent of FE mode and/or FEC mode, the linear movement mode may be entered by activation of an input mechanism on the control assembly with the handle 220 being coupled to the instrument actuator interface 207 and while the stabilizing apparatus 102 is locked. The mechanism for sliding the handle 220 and instrument actuator interface 207 up and down the linear guide 212, may be provided by placing the drive mechanism at the interface of the instrument actuator interface 207 and the linear guide 212 in a neutral position (i.e., disengaged from the powered actuation unit).

[0087] In instances where the linear movement mode is independent from fulcrum-effect mode, the stabilizing apparatus 102 may lock. In instances where the linear movement mode is used in conjunction with fulcrum-effect mode, the friction at the instrument actuator interface 207 and the linear guide 212 (e.g., with the drive mechanism in neutral) may be less

than the friction (accounting for leverage) at the joints 104a, 104b of the stabilizing apparatus 102. The friction differential may allow the advancement and retraction of the instrument actuator interface 207, the handle 220, and medical instrument 206 with respect to the stabilizing apparatus 102. To further facilitate fulcrum-effect mode movements of the stabilizing apparatus joints 104a, 104b, the mechanism at the instrument actuator interface 207 and linear guide 212 interface may have a locking mechanism controlled with an input mechanism on the handle 220. The locking mechanism at the instrument actuator interface 207 and the linear guide 212 interface may be normally engaged as to facilitate independent fulcrum-effect mode movements as default. When the dedicated input mechanism is engaged, the braking mechanism disengages, allowing for linear movement mode movements. The inverse of this may be used instead. For example, the braking mechanism may be normally disengaged as to facilitate linear movement mode movements as default, and the activation of the dedicated input mechanism engages the braking mechanism, removing the linear movement mode. The braking mechanism may be a literal braking mechanism (i.e., those known in the art) or may be the engagement of the mechanism at the instrument actuator interface 207 and the linear guide 212 interface to the powered activation unit.

[0088] FIG. 10A illustrates the embodiment of the fulcrum-correction device 200 in a fulcrum-effect mode. As described elsewhere herein, control assembly 218 includes instrument actuator interface 207 and handle 220. The handle cradle 204, which ultimately secures the handle 220, is coupled near or to the instrument actuator interface 207. Being in fulcrum-effect mode, the device is manipulatable with the degrees of freedom supplied by the stabilizing apparatus 102 (e.g., shown in FIGs. 1A, 3A-4B). The handle 220 coupled to or near the instrument actuator interface 207 enables gross movements made at the handle 220 for the fulcrum-effect mode operation.

[0089] FIG. 11 illustrates the embodiment of FIG. 10A switching into the fulcrum-effect corrected mode. The handle cradle 204 is decoupled from the instrument actuator interface 207 and is able to slide over a portion of the instrument actuator interface 207 and a proximal end portion of the medical instrument 206, and toward the proximal end 750 of the linear guide 212. As shown in FIG. 11, instrument actuator interface 207 remains coupled to the medical instrument 206. In this position, a linkage 308 is enabled. The linkage 308 links the handle 220 to the handle cradle 204 and may include one or more sensorized joints. With the handle 220 in the appropriate position and the embodiment in fulcrum-effect corrected mode, the linkage 308 may unlock.

[0090] FIG. 12 shows the device 200 in fulcrum-effect corrected mode and with the linkage 308 between the handle 220 and the handle cradle 204 unlocked. The linkage 308 is connected to the handle cradle 204 by a first sensorized joint 309, for example at linkage 308 or separate from linkage 308, and to the handle 220 by a second sensorized joint 312. The position and/or orientation of the handle 220 may be measured by the one or more position sensors of the one or more sensorized joints 309, 312, and the measurement may be received by the controller. In response to the measured sensorized joints 309, 312 positions, the controller may send control signals to actuate the instrument actuator interface 207 to move the driven joints 162a, 162b to position distal portion 112 of the medical instrument 106 and/or the end-effector 114 to a position mimicking the handle 220 position. Furthermore, in some embodiments, the linkage 308 may include two components which allow the handle 220 to telescope closer or further from the handle cradle 204. The telescopic joint may also include one or more position sensors and the position of the telescopic joint, measured by the one or more sensors, may be received by the controller. The telescopic joint position, as measured by the one or more position sensors and received by the controller, may be mimicked by the instrument actuator interface 207, with respect to its position along the linear guide 212. The controller may receive the measured position of the telescopic joint and send a control signal to the instrument actuator interface 207 to translate distally and proximally along the length of path 209 (shown in FIG. 10A). For example, pushing the handle 220 forward and shortening the measured linkage 308 length may cause the instrument actuator interface 207 to drive the medical instrument 206 away from the handle 220, and distally along path 209. Pulling the handle 220 away and lengthening the linkage 308 may cause the instrument actuator interface 207 to drive the medical instrument 206 toward the handle 220, and proximally along path 209. Alternatively, the position of the instrument actuator interface 207, with respect to the linear guide 212, may be controlled by measuring the position of the handle cradle 204, with respect to the linear guide 212. The interface of the handle cradle 204 and the linear guide 212 may include position sensors (e.g., a roller with an encoder). The controller may receive the measured position of the handle cradle 204 and send a control signal to the instrument actuator interface 207 to translate distally and proximally along the length of path 209 (shown in FIG. 10A). Further, pushing the handle 220 forward may cause the instrument actuator interface 207 to drive the medical instrument 206 away from the handle 220, and distally along path 209. Pulling the handle 220

away may cause the instrument actuator interface 207 to drive the medical instrument 206 toward the handle 220, and proximally along path 209.

[0091] Alternatively, in FEC mode, the handle cradle 204 may lock to the instrument actuator interface 207, thereby locking the proximal and distal movements of the handle 220 to the instrument actuator interface 207. In FEC mode, embodiments with the handle cradle 204 locked to the instrument actuator interface 207 would allow the handle 220 to manipulate the medical instrument 206 for advancement and retraction. In some implementations, locking the handle cradle 204 to the instrument actuator interface 207 results in or necessitates prerequisites including one or more of: a scaling factor of 1:1 for handle movements to movements at the distal tip of the medical instrument; similar type and/or geometry of proximal joints of the handle and distal joints of the medical instrument; and/or the distal joints 162a,b may compensate for undesirable movements at the handle that are transferred to the medical instrument.

[0092] The capability of controlling the position of the instrument actuator interface 207, with respect to the linear guide 212, allows for advancement and retraction of the medical instrument 206 during use in fulcrum-effect corrected mode. Additionally, some embodiments may include a handle 220 of the type described in FIG. 19 (i.e., handle 401). The position and orientation of the handle 220 may be measured as will be described for FIG. 19.

[0093] FIGs. 13, 14 and 15 depict an embodiment of a fulcrum-effect correction device 300 which includes a control assembly 369, a first arcuate track 360, a second arcuate track 358, a control hub 366, an end-effector actuator interface 351, and a medical instrument 368. The control hub 366 may be supported by a support apparatus, mechanical or robotic, supporting at least a portion of the weight of the device 300. The support apparatus of the device 300 may also include the capability of temporarily locking the control hub 366 of the device 300 in a position. Additionally, the support apparatus may be similar to the stabilizing apparatus 102 of FIGs. 1A, and 3A-4B, but not requiring the RCM capabilities described. In other embodiments, the control hub 366 may otherwise be anchored to the bedside. The control hub 366 includes an instrument actuator interface 352, a sensorized mechanism 354 and a driven actuator 356. In some embodiments, the control hub 366, sensorized mechanism 354, and/or instrument actuator interface 352 may function as part of a stabilizing apparatus. For example, the control hub 366 and/or sensorized mechanism 354 may include functionality similar to revolute joint 104a (shown in FIG. 1A). For example, the control hub 366 and/or

sensorized mechanism 354 may allow for a revolute movement 128 about a yaw axis 130 (shown in FIGs. 3A and 3B), relative to the instrument actuator interface 352 and perpendicular to a horizontal plane 94 (e.g., movement is about the yaw axis 130 that is perpendicular to the horizontal plane 94), as shown in FIGs. 1A and 3.

[0094] The driven actuator 356 and the sensorized mechanism 354 may be constrained to rotate, independently, with respect to the instrument actuator interface 352, about the concentric axis 355. The first arcuate track 360 may be tracked within the sensorized mechanism 354. The interface of the first arcuate track 360 and the sensorized mechanism 354 may measure the position of the first arcuate track 360 with respect to the sensorized mechanism 354 with one or more position sensors (e.g., a roller coupled to an optical encoder, a potentiometer, etc.). The interface of the sensorized mechanism 354 and the instrument actuator interface 352 may include one or more sensors (e.g., a roller and optical encoder, a potentiometer, etc.) to measure the position of the sensorized mechanism 354 with respect to the instrument actuator interface 352. The second arcuate track 358 may be operatively coupled within the driven actuator 356. For example, the second arcuate track 358 may include a rack matching the arcuate shape of the second arcuate track 358 and the driven actuator 356 may include a pinion operatively coupled to the rack. Alternatively, the driven actuator 356 may include one or more friction wheels in contact with the second arcuate track 358. Furthermore, the driven actuator 356 may be operatively coupled to the instrument actuator interface 352. For example, the driven actuator 356 may include a ring mated to a pinion from the instrument actuator interface 352, or the instrument actuator interface 352 may include one or more friction wheels in contact with the driven actuator 356. One or more powered actuation units in the instrument actuator interface 352 may be operatively coupled to the pinion or one or more friction wheels at the driven actuator 356 interface. Additionally, the driven actuator 356 may include one or more powered actuation units coupled to the pinion or one or more wheels at the interface with the second arcuate track 358. Alternatively, control hub 366 may include one or more mechanisms to manipulate each arcuate track and thus the medical instrument, as described in WO2021046658, filed September 14, 2020, which is herein incorporated by reference in its entirety.

[0095] The control assembly 369 may include a handle 362 attached to a handle cradle 364 by an assortment of sensorized joints 363, 365, 367. The position of the handle 362 may be measured at one or more of joints 363, 365, 367. For example, sensorized joint 367 may measure the roll of the handle 362 about the roll axis 359; sensorized joint 363 may measure

the pitch of the handle 362 about the pitch axis 361; and sensorized joint 365 may measure the yaw of the handle 362 about the yaw axis 357. The measured position of the handle 362 may be received by the controller and corresponding control signals for control mode operations for a distal portion of the medical instrument may be sent by the controller.

[0096] For the embodiments of FIGs. 13, 14, and 15, the fulcrum-effect correction device 300 may perform end-effector control mode operations as described for FIGs. 6 and 7, for example in embodiments in which distal tip 370 includes an end-effector thereon. The end-effector control mode may be controlled based off the measured position of the handle 362 or one or more input mechanisms on the handle 362 or device 300. The end-effector, which is located at the distal tip 370, may be controlled with the end-effector actuator interface 351. The end-effector actuator interface 351 may be located on the medical instrument 368. The end-effector actuator interface 351 may include one or more powered actuation units. The one or more powered actuation units may actuate the end-effector as described in connection with FIG. 7. Additionally, the end-effector actuator interface 351 may be coupled to the proximal portion 371 of the medical instrument 368 and the distal portion 373 of the medical instrument 368 may be operatively coupled to the end-effector actuator interface 351. The operative coupling of the medical instrument 368 to the end-effector actuator interface 351 may allow the end-effector actuator interface 351 to extend and retract the distal portion 373 of the medical instrument 368. The end-effector actuator interface 351 may also include the capability of rotating the distal portion 373 of the medical instrument 368 about the longitudinal axis 375. The extension and retraction of the distal portion 373 of the medical instrument 368 may be performed by one or more friction wheels in contact with the distal portion 373 of the medical instrument 368. The one or more wheels for the extension and retraction of the distal portion 373 of the medical instrument 368 may be operatively coupled to the end-effector actuator interface 351, and operatively coupled to one or more powered actuation units within the end-effector actuator interface 351. Additionally, the rotation, about its longitudinal axis 375, of the distal portion 373 of the medical instrument 368 may be performed by one or more friction wheels in contact with the distal portion 373 of the medical instrument 368. The one or more wheels for the rotation of the distal portion 373 of the medical instrument 368 may be operatively coupled to the end-effector actuator interface 351, and operatively coupled to one or more powered actuation units within the end-effector actuator interface 351. The end-effector actuator interface 351 may receive output signals from the controller that cause the end-effector control mode processes.

[0097] FIG. 13 illustrates the embodiment of the fulcrum-effect correction device in fulcrum-effect mode. The second arcuate track 358 may be coupled to the medical instrument 368. In fulcrum-effect mode, the arcuate tracks 358, 360 are physically, or virtually locked with respect to one another. When the first arcuate track 360 is slid in and out of the sensorized mechanism 354, the second arcuate track 358 slides in and out of the driven actuator 356. The mimicked movements of the first arcuate track 360 by the second arcuate track 358 may Be performed by locking the first arcuate track 360 to the second arcuate track 358 and placing the drive mechanism at the interface of the driven actuator 356 and the second arcuate track 358 in neutral, or equivalent state. Alternatively, the first arcuate track 360 and second arcuate track 358 may be virtually locked together. For example, the position of the first arcuate track 360 may be measured with respect to the sensorized mechanism 354 by the described one or more sensors, and these measurements may be received by the controller. After receiving the position measurement of the first arcuate track 360, the controller may send a control signal to the powered actuator within the driven actuator, which moves the second arcuate track 358 to a corresponding position that matches the position of the first arcuate track 360. Additionally, the first arcuate track 360 and the second arcuate track 358 may be locked together physically, or virtually with respect to their angular position about the axis 355. As above, locking the arcuate tracks 358, 360 may be done by physically locking the first arcuate track 360 to the second arcuate track 358 and placing the drive mechanism at the interface of the driven actuator 356 and the instrument actuator interface 352 in neutral, or an equivalent state. Alternatively, the first arcuate track 360 and second arcuate track 358 may be virtually locked together. For example, the angular position of the first arcuate track 360 may be measured with respect to instrument actuator interface 352 by the described one or more position sensors, and these measurements may be received by the controller. After receiving the angular position measurement of the first arcuate track 360, the controller may send a control signal to the powered actuator within the instrument actuator interface 352, which moves the second arcuate track 358 to a corresponding position that matches the position of the first arcuate track 360. The described movements of the second arcuate track 358 with respect to the first arcuate track 360 may be directly proportional (i.e., 1:1) or scaled, for example, 2:1, 1.5:1, 1.1:1, 1:1.1, 1:1.5, 1:2, etc. In fulcrum-effect mode, the distal tip 370 may include an end-effector and may be moved as the end-effector of previous embodiments (FIGs. 6 and 7) in fulcrum-effect mode. In other words, if the handle 362 is pressed up the two arcuate tracks 360, 358 move into the sensorized mechanism 354 and

driven actuator 356, respectively, causing the distal tip 370 to move down. If the handle 362 is pressed to the left, the arcuate tracks 360, 358 rotate about the axis 355, causing the distal tip 370 to move right.

[0098] FIG. 14 shows the device 300 in fulcrum-effect corrected mode. When entering fulcrum-effect corrected mode by activating an input mechanism on the handle 362, the arcuate tracks 360, 358 are no longer locked together. As shown, as the handle 362 is moved left, position sensors at the interface of the instrument actuator interface 352 and the sensorized mechanism 354 measures this position change, and these measurements are received by the controller. Based on the position measurements, the controller will output control signals that will actuate a respective powered actuation unit in the instrument actuator interface 352, that will cause the driven actuator 356 to rotate to a position angularly inverse of the measured handle 362 position, about the axis 355. Additionally, when the handle 362 is pressed up, the first arcuate track 360 is pressed into the sensorized mechanism 354, and the sensorized mechanism 354, via position sensors, measures the position change. The position change measurement is received by the controller and a corresponding output signal is sent to the instrument actuator interface 352 to drive the driven actuator 356 to move the second arcuate track 358 to an inverse position. Being that the distal tip 370 is located across the axis 355 from the handle, right movements by the handle cause right movements by the distal tip 370, and left movements by the handle cause left movements from the distal tip 370. Inverse position changes of the second arcuate track 358 based the measured position of the first arcuate track 360 may be directly proportional (i.e., 1:1) or scaled, for example, 2:1, 1.5:1, 1.1:1, 1:1.1, 1:1.5, 1:2, etc. As such, fulcrum-effect corrected mode operations may be performed by this embodiment. Furthermore, end-effector control mode operations, for example when the distal tip 370 includes an end-effector thereon, can be performed by this embodiment in either fulcrum-effect mode or fulcrum-effect corrected mode. In embodiments where the end-effector is included on the distal tip 370 and coupled by the wrist mechanism of FIGs. 1A, 6 and 7, the end-effector actuator interface 351 (shown in FIG. 12) may manipulate the end-effector as described for FIG. 7. Additionally, the end-effector actuator interface 351 may be used for actuation of an end-effector. For example, in embodiments with a grasper-type end-effector 114, as shown in FIG. 1A, the end-effector actuation interface 351 may cause a grasping action of the end-effector 114. Actuation of the end-effector may be performed after the end-effector actuation interface 351 has received a corresponding output signal from the controller.

[0099] FIG. 15 illustrates a right input movement of the handle 362 of the embodiment. As explained in FIG. 14, the handle 362 and corresponding first arcuate track 360 position change generates an inverse movement of the second arcuate track 358 causing the distal tip 370 to move to the right as well.

[00100] FIGs. 16-25 illustrate an embodiment of a fulcrum-effect correction device that includes a stabilizing apparatus 102, a linear guide 412, a control assembly 415, and a medical instrument 406. The stabilizing apparatus 102 may be the stabilizing apparatus 102 of FIGs. 1A, and 3A-4B. For embodiments with RCM capabilities, the linear guide 412 may be considered as part of the stabilizing apparatus 102, such that, joints 104a, 104b, 205 function synchronously to maintain a remote-center-of-motion, as described for joints 104a, 104b, 108 of FIG. 1A, and 3A-4B. The control assembly 415 includes a handle 401 coupled to a handle cradle 414 and an instrument actuator interface 402. The handle cradle 414 is coupled to a plurality of sensorized linkages stored within the linear guide 412 during fulcrum-effect mode. The handle 220 may be used as the primary control input element, which may include the input mechanism 126 of FIG. 1A, and the input mechanism 142 of FIG. 6. The input mechanisms 126, 142 may be received by the controller and carried out by the instrument actuator interface 207 onto the medical instrument 206 as described for FIGs. 6 and 7. The handle 401 and handle cradle 414 define an aperture through which the medical instrument 406 end portion 404 may slide through.

[00101] FIG. 16 illustrates the embodiment of the fulcrum-effect corrected device in fulcrum-effect mode. The handle 401 is locked in the position shown by the release mechanism 410. The device 400 in fulcrum-effect mode, shown, is capable of the fulcrum-effect mode movements described for FIGs. 1A, and 3A-4B.

[00102] FIG. 17 illustrates the embodiment of the fulcrum-effect correction device switching into fulcrum-effect corrected mode. Release mechanism 410 is released either manually as a latch or electromechanically after a mode switch input mechanism is selected on the handle 401. Once the handle is released, the plurality of sensorized linkages 416 (e.g., a delta mechanism) are allowed to slide from within the linear guide 412 until the locking plate 420 is engaged. Once locked in this position, the device 100 is ready for fulcrum-effect corrected mode operations.

[00103] FIG. 18 illustrates the embodiment of the fulcrum-effect correction device in fulcrum-effect corrected mode. The plurality of sensorized linkages 416 (three shown but other numbers are contemplated herein, for example, two, four, etc.) each include a first

linkage 430 and a second linkage 432. The first linkage 430 is coupled to the locking plate 420 by a first sensorized joint 436. The first linkage 430 is coupled to the second linkage 432 by a second sensorized joint 438. The second linkage 432 is coupled to the handle cradle plate 434 by a third sensorized joint 440. Each sensorized linkage of the plurality of sensorized linkages 416 includes the capabilities of sensorized joints described elsewhere herein, and in doing so, may measure the position of the handle 401. These sensor measurements are received by the controller and the controller may output a corresponding control signal to the instrument actuator interface 402 to actuate the driven joints 162a, 162b to mimic the position of the handle 401 with the end-effector 114. The sensors of the plurality of sensorized linkages 416 (e.g., a delta mechanism) are capable of measuring the handle 401 as a point in a three-dimensional space. As such, the driven joints 162a, 162b of medical instrument 406, and advancement and retraction of the instrument actuator interface 402, in combination, are able to mimic the position of the handle 401 with the end-effector 114. The described movements of the end-effector 114 with respect to the handle 401 may be directly proportional (i.e., 1:1) or scaled, for example, 2:1, 1.5:1, 1.1:1, 1:1.1, 1:1.5, 1:2, etc.

[00104] FIG. 19 illustrates additional, measured degrees of freedom that may be performed by the handle 401. The handle 401, which may be a Gimbal type handle 401, may be used to control the orientation mechanisms of the end-effector 114 during end-effector control mode operations. As described above, the end-effector 114 can be rotated about the roll axis 150 (shown in FIG. 6), and the wrist mechanism of the end-effector allow the end-effector 114 to be pitched about the pitch axis and yawed about yaw axis (shown in FIG. 7). The handle 401 is rotatably coupled to a sub-cradle 450 at first joint 454, the sub-cradle is rotatably coupled to the handle cradle 414 at a second joint 456, and the handle cradle 414 is rotatably coupled to the handle cradle plate 434 at a third joint 452. The first joint 454, second joint 456, and third joint 452 enable the device 400 to produce the movements to be mimicked by the end-effector 114. In addition, the first joint 454, second joint 456, and third joint 452 may include position sensors that can measure the position of each joint 454, 456, 452. For example, first joint 454 may measure the roll of the handle 401 about the roll axis 490; second joint 456 may measure the pitch of the handle 401 about the pitch axis 494; and third joint 452 may measure the yaw of the handle 401 about the yaw axis 492. The controller, receiving these position measurements, may then produce control signals (as described for FIGs. 6 and 7) to adjust the end-effector 114 in such a way as to mimic the orientation of the handle 401.

[00105] The embodiment of FIGs. 16-25 includes the capability for the gross movement of advancing and retracting the medical instrument 406. The gross adjustment of the medical instrument 406 when the handle 401 is connected to the instrument actuator interface 402 may be accomplished as described for FIGs. 10A, 10B, 11 and 12.

[00106] FIG. 20 illustrates a zoomed-in view of the release mechanism 410 of the embodiment of the fulcrum-effect correction device 300. When the sub-cradle 450 is removably coupled to the instrument actuator interface 402 by the release mechanism 410. While coupled to the instrument actuator interface, the second joint 456, and third joint 452 (shown in FIG. 19) are secured and locked from rotating. Locking the handle 401 in this way may be advantageous during the manipulation of the device 300 in fulcrum-effect mode. FIGs. 21A and 21B illustrate the remaining roll input capability of the handle 401 when locked in fulcrum-effect mode. Since the first joint 454 (shown in FIGs. 19 and 20) remains unlocked when the sub-cradle 450 (shown in FIGs. 19 and 20) is locked into the release mechanism 410 (shown in FIG. 16), the handle 401 can still be used to cause roll, measured by the first joint 454, and to be received by the controller. Based on the roll measurements received by the controller, the controller can send control outputs to the instrument actuator interface 402 to actuate a roll at the end-effector 114 mimicking the roll position of the handle 401.

[00107] FIGs. 22A and 22B illustrate another possible control input mechanism for the actuation of an end-effector. For example, a clasp-type end-effector 114 (shown in FIG. 6) may mimic the position of paddles 470, 472. The paddles 470, 472, located near the handle, may be biased toward the open position (shown in FIG. 22A). Biasing the paddles 470, 472 may be accomplished by spring loading the paddle hinges 474, 476. In addition, the paddle hinges 474, 476 may include position sensors (e.g., potentiometers, etc.). By receiving the position measurements of the position sensors in the paddle hinges 474, 476, the controller can output a corresponding control signal to the instrument actuator interface to manipulate the end-effector in such a way as to mimic the position of the paddles 470, 472. Said another way, when the paddles are squeezed together, the device response would be, for example, to cause a clasp-type end-effector to clamp. Inversely, when the paddles are released, the device response would be, for example, to cause a clasp-type end-effector to open.

[00108] FIGs. 23A and 23B illustrate the installment of a medical instrument 406 into the embodiment of the fulcrum-effect correction device. As shown, the sub-cradle 450 defines an aperture 451 that allows the passage of the end portion 407 of the medical

instrument 406 between the sub-cradle 450 and the linear guide 412. The medical instrument 406 has an elongate portion 409 that, when inserted into an aperture defined in the instrument actuator interface 402, allows the medical instrument 406 to slide in until a point of contact between the end portion 407 and the instrument actuator interface 402. At the point of contact, the medical instrument 406 operatively couples to the instrument actuator interface 402. Changing the medical instrument 406, may require disengagement of the medical instrument 406 from the instrument actuator interface 402. Disengagement may be manual or electromechanical with a control input mechanism being on or near the handle 401. Once disengaged, the medical instrument 406 can be slid out of the instrument actuator interface 402, and a new medical instrument can then be installed and operatively coupled to the instrument actuator interface 402.

[00109] FIGs. 24A, 24B and 24C illustrate the degrees of freedom of the handle of the embodiments of FIGs. 16-20. For example, FIG. 24A shows a neutral position of the handle 401, FIG. 24B illustrates rotation of the handle 401 about the yaw axis 492, and FIG. 24C illustrates rotation of the handle 401 about the pitch axis 496. The illustrated movements and corresponding position measurements are described in FIG. 19.

[00110] FIG. 25 illustrates the embodiment of the fulcrum-effect correction device with a transparent linear guide 412. The illustration depicts the plurality of sensorized linkages 416, in a collapsed state, and at least partially stored in the hollow aperture defined by the linear guide 412. In addition, the locking plate 420 and handle cradle plate 434 may be at least partially stored in the hollow aperture defined by the linear guide 412.

[00111] FIGs. 26, 27 and 28 illustrate an embodiment of a fulcrum-effect correction device 600 that includes a stabilizing apparatus 102, a linear guide 614, an instrument actuator interface 602, medical instrument 606, a sensorized member 601, and a handle 401. The embodiment may include a stabilizing apparatus 102 which performs as the stabilizing apparatus 102 of FIGs. 1A, and 3A-4B or any other bedside configuration or apparatus known in the art. For embodiments with RCM capabilities, the linear guide 614 may be considered as part of the stabilizing apparatus 102, such that, joints 104a, 104b, 205 function synchronously to maintain a remote-center-of-motion, as described for joints 104a, 104b, 108 of FIG. 1A, and 3A-4B. The instrument actuator interface 602 may manipulate the driven joints 162a, 162b, and end-effector 114 as described for FIGs. 16-25. Additionally, the handle 401 and the handle 401 orientation may be used for end-effector control mode as

described for FIGs. 19, 21A, 21B, 22A, and 22 B. Further, the medical instrument 606 may be installed or changed similarly as described for FIGs. 23A, and 23B.

[00112] FIG. 26 illustrates the embodiment of a fulcrum-effect correction device 600 in fulcrum-effect correction mode. The embodiment utilizes a sensorized member 601 that, similarly to the plurality of sensorized linkages as described herein (FIGs. 16-25), stores and deploys from the linear guide 614. The sensorized member 601 may comprise a first linkage 608 and a second linkage 610. The first linkage 608 may be coupled to a second linkage 610 by a first sensorized joint 603. The second linkage 610 may be coupled to the handle cradle plate 616 by a second sensorized joint 604. When in fulcrum-effect corrected mode, as depicted, the position of the handle 401 may be measured by the first sensorized joint 603 and the second sensorized joint 604. These position measurements may be received by the controller, and, in response, the controller may output control signals to the instrument actuator interface 602 to manipulate the driven joints 162a, 162b to mimic the position of the handle 401. Further, the device may comprise a sliding plate 612 that is capable of sliding to different positions within, and with respect to, the linear guide 614. The sliding plate 612 may comprise a position sensor that measures the position of the sliding plate 612 with respect to the linear guide 614. The instrument actuator interface 602, operatively coupled to the linear guide 614, may be capable of translating back and forth along the length of the linear guide 614, thus advancing or retracting the medical instrument 606. The controller may receive the position measured by the sensors of the sliding plate 612 and output control signals to change the position of the instrument actuator interface 602 in such a way as to mimic the sliding plate 612 position adjustments. With this capability, when the handle 401 is manipulated toward the instrument actuator interface 602, the controller may output a control signal to the instrument actuator interface 602 to push the medical instrument 606 away from the handle 401. If the handle 401 is pulled away from the instrument actuator interface 602, the controller may output a control signal to the instrument actuator interface 602 to pull or manipulate the medical instrument 606 toward the handle 401. FIG. 27 illustrates the embodiment with the sliding plate 612 pressed to a position closer to the instrument actuator interface 602. In turn, the instrument actuator interface 602 has moved away from the handle 401 and distally along the linear guide 614, in direction 755. FIG. 28 further illustrates the configuration of FIG. 27 with the linear guide 614 transparent showing the position of the sliding plate 612 and with a portion of the first linkages 608 within the linear guide 614. Some embodiments may include manual sliding of the instrument actuator interface 602 for

advancing and retracting the medical instrument 606. In these embodiments, the sliding plate 612 may couple to the instrument actuator interface 602 when the handle is slid back during FEC mode. For example, the sliding plate 612 may slide within a tube 757 coupled to the instrument actuator interface 602 and may lock to the tube 757 at the proximal end of the tube 757. With the sliding plate 612 locked to the tube 757 coupled to the instrument actuator interface 602, pressing the handle 401 proximally moves the medical instrument 606 proximally, and pulling the handle 401 distally moves the medical instrument 606 distally.

[00113] FIG. 29 illustrates an embodiment of the fulcrum-effect correction device 600 that includes a first handle 702 and a second handle 704. The first handle 702 may be able to manipulate the device in fulcrum-effect mode. The second handle 704 may be used for fulcrum-effect corrected mode. As such, when the device is set for fulcrum-effect mode operations, either by manual inputs or inputs generating electromechanical mode switching, the first handle 702 may be used. In addition, the first handle 702 may have the end-effector control mode control capabilities described herein as to perform end-effector control mode operations during the fulcrum-effect mode operations. When the device is set for fulcrum-effect corrected mode operations, either by manual inputs or inputs generating electromechanical mode switching, the second handle 704 may be used. In addition, the second handle 704 may have the end-effector control mode capabilities described herein as to perform end-effector control mode operations during the fulcrum-effect corrected mode operations. The fulcrum-effect corrected mode operations may be as described for FIGs. 17, 18, and 19.

METHODS

[00114] As shown in FIG. 30, a method for performing minimally invasive surgery includes positioning the elongate body of a medical instrument with an attached handle for manual movement about a pivot point (i.e., a remote-center-of-motion) in block S802; and controlling a position of a distal end of a medical instrument by inverse movements (e.g., pivoting about a pivot point) of the proximal end of the medical instrument in block S804. The method functions to control the position of a distal end of a medical instrument (optionally including an end-effector) during minimally invasive procedures in a fulcrum-effect mode. In some embodiments, the method functions to position the medical instrument in an appropriate position before control modes are switched (e.g., switching into fulcrum-effect corrected mode, which is described with respect to FIG. 31). The method is used for

the surgical field, but can additionally or alternatively be used for any suitable applications, clinical or otherwise. The method can be configured and/or adapted to function for any suitable operation or procedure.

[00115] As shown in FIG. 30, one embodiment of a method for performing minimally invasive surgery includes block S802, which recites positioning the elongate body of a medical instrument with an attached handle for manual movement about a pivot point. Block S802 functions to introduce a distal end of a medical instrument into a surgical site or control a distal end of a medical instrument near a surgical site. As described above for FIGs. 1A, and 3A-4B, a stabilizing apparatus may function to support at least a portion of the weight of the control assembly and medical instrument. The stabilizing apparatus may supply the necessary degrees of freedom to manipulate the medical instrument to a position appropriate for operational use. The stabilizing apparatus may lock in any position suitable for processes. The position appropriate for operational use may include gross movements in three-dimensional space and/or inserting the elongate portion of the medical instrument through a trocar or otherwise into an access site or incision.

[00116] As shown in FIG. 30, one embodiment of a method for performing minimally invasive surgery includes block S804, which recites controlling a position of a distal end of the medical instrument by inverse input movements of the handle moving the proximal end of the medical instrument. Block S804 functions to control the distal portion of the medical instrument in a fulcrum-effect mode. Fulcrum-effect mode defines inverse pivotal-control of the distal portion of the medical instrument with respect to the handle. Said another way, a left position change of the handle, also described as an input position, generates a right position change of the distal end, also described as an output position. Further, an upward position change of the handle would generate a downward position change of the distal end.

[00117] Any of the devices shown in FIGs. 1A-10A and 11-29 may be operable or configured to operate in the fulcrum-effect mode described with respect to FIG. 30 and as described elsewhere herein.

[00118] As shown in FIG. 31, a method for performing minimally invasive surgery includes positioning the elongate body of a medical instrument with an attached handle, such that a distal portion of the medical instrument is separated from a proximal portion of the medical instrument by a pivot point in block S902; activating a sensor assembly and a powered actuation unit in communication with the medical instrument in block S904; measuring the position of the handle and/or one or more joints with the sensor assembly in

block S906; and actuating the distal portion of the medical instrument to mimic, about the pivot point, the position of the handle in block S908. The method functions to control the position of a distal portion of a medical instrument during minimally invasive procedures in a fulcrum-effect corrected mode. Fulcrum-effect corrected mode defines corresponding control of the distal end of the medical instrument with respect to the handle. Said another way, a left position change of the handle, also described as an input position, generates a left position change of the distal end of the medical instrument, also described as an output position. Further, an upward position change of the distal end of the medical instrument generates an upward position change of the distal end of the medical instrument. The mimicked movements of the handle by the distal end of the medical instrument may be scaled. The method is used for the surgical field, but can additionally or alternatively be used for any suitable applications, clinical or otherwise. The method can be configured and/or adapted to function for any suitable operation or procedure.

[00119] As shown in FIG. 31, one embodiment of a method for performing minimally invasive surgery includes block S902, positioning the elongate body of a medical instrument with an attached handle, such that a distal portion of the medical instrument is separated from a proximal portion of the medical instrument by a pivot point. Block S902 functions to introduce a distal end of a medical instrument (with optional end-effector) to a surgical site or near a surgical site to a position appropriate for operational use. The position appropriate for operational use may be inserting the elongate portion of the medical instrument through a trocar or otherwise into an access site or incision, such that a position of a first portion of the medical instrument within (e.g., distal to) the incision and a position of a second portion of the medical instrument exterior (e.g., proximal to) the incision. As such, a pivot point (e.g., remote-center-of-motion) is created. With the medical instrument in this position, embodiments that employ the stabilizing apparatus may then have the at least a portion of the stabilizing apparatus lock, as described for FIGs. 8 and 9. Locking the stabilizing apparatus prepares the device for fulcrum-effect corrected mode operations. In some implementations, the user may perform all the adjustments and locking of the stabilizing apparatus without removing their control hand from the handle.

[00120] As shown in FIG. 31, one embodiment of a method for performing minimally invasive surgery includes block S904, which recites activating a sensor assembly and a powered actuation unit in communication with the medical instrument. Block S904 functions to switch into the fulcrum-effect correction mode. Switching modes may be done without the

user removing their hand from the handle. In some embodiments, switching into fulcrum-effect correction mode is done by activating a control input on the handle that, when received by the controller, causes the controller to send control signals to activate a sensor assembly and a powered actuation unit in communication with the medical instrument. In some embodiments, switching into fulcrum-effect correction mode is done by unlocking the handle and sliding the handle proximally to a position appropriate for fulcrum-effect correction mode. Further, sliding the handle distally may unlock, thus activating, the sensor assembly.

[00121] As shown in FIG. 31, one embodiment of a method for performing minimally invasive surgery includes block S906, which recites measuring or monitoring the position of the handle and/or one or more joints with the sensor assembly. Block S906 functions to map the position of the handle and/or one or more joints. Mapping the position of the handle and/or one or more joints is performed by one or more sensors of the sensor assembly (e.g., the sensorized joint 160a, 160b of FIG. 9) and receiving the measurements by the controller.

[00122] As shown in FIG. 31, one embodiment of a method for performing minimally invasive surgery includes block S908, which recites actuating the distal portion of the medical instrument to mimic, about the pivot point, the position of the handle and/or one or more joints. Block S908 functions to mimic the position of the handle and/or one or more joints by moving the distal portion of the medical instrument to a position and/or orientation matching, equally or to scale, the position and/or orientation of the handle and/or one or more joints (e.g., shown FIG. 9). Further, an example of a mimic plane 95 created at the pivot point 124, for which the mimicked movements are made about, may be seen in FIG. 1A. In some implementations, the described fulcrum-effect correction mode operations may not require the user to remove their hand from the handle.

[00123] Any of the devices shown in FIGs. 1A-10A and 11-29 may be operable or configured to operate in the fulcrum-effect correction mode described with respect to FIG. 31 and as described elsewhere herein.

[00124] The systems and methods of the preferred embodiment and variations thereof can be embodied and/or implemented at least in part as a machine configured to receive a computer-readable medium storing computer-readable instructions. The instructions are preferably executed by computer-executable components preferably integrated with the system and one or more portions of the processor of the controller and/or computing device. The computer-readable medium can be stored on any suitable computer-readable media such as RAMs, ROMs, flash memory, EEPROMs, optical devices (e.g., CD or DVD), hard drives, floppy

drives, or any suitable device. The computer-executable component is preferably a general or application-specific processor, but any suitable dedicated hardware or hardware/firmware combination can alternatively or additionally execute the instructions.

[00125] References in the specification to "one embodiment," "an embodiment," "an illustrative embodiment," "some embodiments," etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may or may not necessarily include that particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[00126] As used in the description and claims, the singular form "a", "an" and "the" include both singular and plural references unless the context clearly dictates otherwise. For example, the term "a powered actuation unit" may include, and is contemplated to include a plurality of powered actuation units. At times, the claims and disclosure may include terms such as "a plurality," "one or more," or "at least one;" however, the absence of such terms is not intended to mean, and should not be interpreted to mean, that a plurality is not conceived.

[00127] The term "about" or "approximately," when used before a numerical designation or range (e.g., to define a length or pressure), indicates approximations which may vary by (+) or (-) 5%, 1% or 0.1%. All numerical ranges provided herein are inclusive of the stated start and end numbers. The term "substantially" indicates mostly (i.e., greater than 50%) or essentially all of a device, substance, or composition.

[00128] As used herein, the term "comprising" or "comprises" is intended to mean that the devices, systems, and methods include the recited elements, and may additionally include any other elements. "Consisting essentially of" shall mean that the devices, systems, and methods include the recited elements and exclude other elements of essential significance to the combination for the stated purpose. Thus, a system or method consisting essentially of the elements as defined herein would not exclude other materials, features, or steps that do not materially affect the basic and novel characteristic(s) of the claimed disclosure. "Consisting of" shall mean that the devices, systems, and methods include the recited elements and exclude anything more than a trivial or inconsequential element or step.

Embodiments defined by each of these transitional terms are within the scope of this disclosure.

[00129] The examples and illustrations included herein show, by way of illustration and not of limitation, specific embodiments in which the subject matter may be practiced. Other embodiments may be utilized and derived therefrom, such that structural and logical substitutions and changes may be made without departing from the scope of this disclosure. Such embodiments of the inventive subject matter may be referred to herein individually or collectively by the term "invention" merely for convenience and without intending to voluntarily limit the scope of this application to any single invention or inventive concept, if more than one is in fact disclosed. Thus, although specific embodiments have been illustrated and described herein, any arrangement calculated to achieve the same purpose may be substituted for the specific embodiments shown. This disclosure is intended to cover any and all adaptations or variations of various embodiments. Combinations of the above embodiments, and other embodiments not specifically described herein, will be apparent to those of skill in the art upon reviewing the above description.

[00130] EXAMPLES

[00131] Example 1. A system for performing minimally invasive surgery, comprising: a stabilizing apparatus transitionable between an unlocked state and a locked state; a control assembly comprising: a handle pivotally coupled to the stabilizing apparatus and comprising one or more sensorized joints, and an instrument actuator interface configured to be reversibly coupled to the handle, a medical instrument coupled to the handle and manipulatable by the handle, the medical instrument comprising: an elongate body having a proximal portion and a distal portion comprising one or more distal joints, and an end-effector coupled to the distal portion; and wherein, in a first mode, the stabilizing apparatus is configured in the unlocked state such that the medical instrument is manipulatable by the handle about a pivot point or in a first three-dimensional space, wherein, in a second mode, the handle is configured to manipulate the end-effector of the medical instrument, and wherein, in a third mode, the stabilizing apparatus is configured in the locked state, and the handle is enabled to cause movement of the one or more sensorized joints, such that the movement of the one or more sensorized joints causes a corresponding distal movement in the one or more distal joints of the medical instrument about the pivot point.

[00132] Example 2. The system of any one of the preceding examples, particularly Example 1, wherein, in the first mode, the handle is connected to the instrument actuator interface.

[00133] Example 3. The system of any one of the preceding examples, particularly Example 2, wherein a first input of the handle is configured to manipulate the end-effector of the medical instrument.

[00134] Example 4. The system of any one of the preceding examples, particularly Example 3, wherein the first input or a second input of the handle is configured to roll the elongate body about a longitudinal axis of the medical instrument.

[00135] Example 5. The system of any one of the preceding examples, particularly Example 1, wherein the stabilizing apparatus comprises one or more joints, and wherein manipulation of the elongate body of the medical instrument in the first three-dimensional space comprises movement of the medical instrument about a yaw axis of the one or more joints of the stabilizing apparatus.

[00136] Example 6. The system of any one of the preceding examples, particularly Example 1, wherein manipulation of the elongate body of the medical instrument in the first three-dimensional space comprises insertion or retraction of the medical instrument relative to the stabilizing apparatus.

[00137] Example 7. The system of any one of the preceding examples, particularly Example 1, wherein the handle comprises an input element configured to switch between the first mode, the second mode, and the third mode.

[00138] Example 8. The system of any one of the preceding examples, particularly Example 1, wherein the handle comprises a first input element configured to manipulate the end-effector of the medical instrument in the second mode.

[00139] Example 9. The system of any one of the preceding examples, particularly Example 8, wherein the first input element is manipulatable about a pitch axis, a roll axis, or a yaw axis associated with the first input element to manipulate the end-effector of the medical instrument in the second mode.

[00140] Example 10. The system of any one of the preceding examples, particularly Example 9, wherein manipulation of the first input element about the pitch axis of the first input element causes a corresponding movement of the end-effector about an end-effector pitch axis.

[00141] Example 11. The system of any one of the preceding examples, particularly Example 9, wherein manipulation of the first input element about the yaw axis of the first input element causes a corresponding movement of the end-effector about an end-effector yaw axis.

[00142] Example 12. The system of any one of the preceding examples, particularly Example 9, wherein manipulation of the first input element about the roll axis of the first input element causes a corresponding movement of the end-effector about an end-effector roll axis.

[00143] Example 13. The system of any one of the preceding examples, particularly Example 1, wherein the pivot point comprises a remote pivot point that is configured to reside proximate to or within a trocar through which the medical instrument is inserted during a procedure.

[00144] Example 14. The system of any one of the preceding examples, particularly Example 1, wherein the one or more sensorized joints comprise a sensor assembly, and the instrument actuator interface comprises a powered actuation unit and a controller, the controller being communicatively linked to the sensor assembly and the powered actuation unit.

[00145] Example 15. The system of any one of the preceding examples, particularly Example 14, wherein the sensor assembly is configured to monitor at least a first position of the one or more sensorized joints and generate a corresponding sensor signal; the controller is configured to receive the corresponding sensor signal and generate a corresponding control signal; and the powered actuation unit is configured to receive the corresponding control signal and to actuate the one or more distal joints to cause translation of the one or more distal joints based on the first position.

[00146] Example 16. The system of any one of the preceding examples, particularly Example 1, wherein the handle comprises a sleeve comprising the one or more sensorized joints, and wherein the handle is configured to manipulate the sleeve to cause the movement in the one or more sensorized joints.

[00147] Example 17. The system of any one of the preceding examples, particularly Example 1, wherein the handle is coupled to the proximal portion of the medical instrument.

[00148] Example 18. The system of any one of the preceding examples, particularly Example 1, wherein, in the third mode, the handle is configured to be disengaged from the instrument actuator interface.

[00149] Example 19. A system for performing minimally invasive surgery, comprising: an elongate body comprising a distal end having an end-effector and one or more distal joints, and a proximal end, opposite the distal end; a handle configured to receive the proximal end of the elongate body, wherein the handle comprises a sleeve comprising one or more sensorized joints; a sensor assembly configured to monitor a position of each of the one or more sensorized joints; and an instrument actuator interface coupled to the sleeve of the handle and comprising: a powered actuation unit, and a controller communicatively linked to the sensor assembly and the powered actuation unit, wherein: the sensor assembly is configured to monitor at least a first position of the one or more sensorized joints and generate a corresponding sensor signal, wherein the first position is based on a proximal movement of the handle; the controller is configured to receive the corresponding sensor signal and generate a corresponding control signal; and the powered actuation unit is configured to receive the corresponding control signal and to actuate the one or more distal joints to cause translation of the one or more distal joints based on the first position of the one or more sensorized joints.

[00150] Example 20. The system of any one of the preceding examples, particularly Example 19, further comprising a stabilizing apparatus that is transitionable between an unlocked state and a locked state.

[00151] Example 21. The system of any one of the preceding examples, particularly Example 20, wherein the stabilizing apparatus is configured to be in the locked state when the powered actuation unit actuates the one or more distal joints to cause the translation.

[00152] Example 22. The system of any one of the preceding examples, particularly Example 21, wherein the one or more distal joints are configured to be manipulated about a remote pivot point.

[00153] Example 23. The system of any one of the preceding examples, particularly Example 22, wherein the remote pivot point is configured to align with a trocar through which the elongate body is inserted during a procedure.

[00154] Example 24. A system for minimally invasive surgery, comprising: a medical instrument comprising: an elongate body having a proximal portion and a distal portion comprising one or more distal joints, and an end-effector; and a control assembly comprising: a handle configured to couple to the proximal portion of the medical instrument and manipulate the medical instrument, wherein the handle comprises one or more sensorized joints, and an instrument actuator interface configured to be reversibly coupled to the handle,

wherein the system is configured to be selectively operated in a first control mode or a second control mode, and wherein selecting between the first control mode and the second control mode comprises modifying a movement range associated with the one or more sensorized joints.

[00155] Example 25. The system of any one of the preceding examples, particularly Example 24, wherein: the first control mode is a fulcrum-effect mode, wherein a first input of the handle is configured to manipulate the end-effector of the medical instrument, and the second control mode is a fulcrum corrected mode, wherein a movement of the one or more sensorized joints of the handle is enabled, such that manipulation of the handle causes the movement of the one or more sensorized joints which results in a corresponding distal movement of the one or more distal joints at least: about a predefined pivot point or in a predefined three-dimensional space.

[00156] Example 26. The system of any one of the preceding examples, particularly Example 25, wherein, in the first control mode, the first input or a second input is configured to roll the elongate body about a longitudinal axis of the medical instrument.

[00157] Example 27. A system for performing minimally invasive surgery, comprising: a control assembly comprising: a handle pivotally coupled to a bedside apparatus, wherein the handle comprises one or more sensorized joints, and an instrument actuator interface; and a medical instrument couplable to the handle and manipulatable by the handle, the medical instrument comprising: an elongate body having a proximal portion and a distal portion comprising one or more distal joints, and wherein, in a fulcrum-effect mode, mechanical movement of the handle coupled to the proximal portion of the medical instrument causes movement of the medical instrument about a pivot point, and wherein, in a fulcrum corrected mode: the pivot point is between the one or more sensorized joints of the handle and the one or more distal joints of the medical instrument, and actuation of the handle causes a movement of the one or more sensorized joints causing the instrument actuator interface to map the movement to a corresponding distal movement in the one or more distal joints at least about the pivot point.

[00158] Example 28. A method for performing minimally invasive surgery, comprising: in a fulcrum-effect mode: receiving a first input at a handle coupled to a medical instrument, wherein the first input causes manual movement of the medical instrument about a pivot point, wherein the pivot point is between a distal portion of the medical instrument and a proximal portion of the medical instrument; and in a fulcrum corrected mode:

activating a control at the handle, the control being configured to engage a sensor assembly and a powered actuation unit in communication with the medical instrument to perform an electronically assisted movement; monitoring a position of one or more sensorized joints of the handle using the sensor assembly communicatively coupled to a controller; and responsive to detecting, by the sensor assembly, a change in the position, causing the distal portion of the medical instrument to translate using the powered actuation unit, wherein the translation of the distal portion of the medical instrument is based on the position of the one or more sensorized joints.

[00159] Example 29. The method of any one of the preceding examples, particularly Example 28, wherein the one or more sensorized joints are proximal relative to the pivot point.

[00160] Example 30. A handle configured to be installed at a bedside of a patient support apparatus and to perform a minimally invasive surgery, the handle comprising: a first input mechanism configured to select a fulcrum-effect mode, wherein the handle is configured to attach to a medical instrument that is mechanically movable about a pivot point; and a second input mechanism configured to select a fulcrum corrected mode, wherein selection of the second input mechanism is configured to activate a sensor assembly, a powered actuation unit, and a controller communicatively coupled to the powered actuation unit and the sensor assembly.

[00161] Example 31. The handle of any one of the preceding examples, particularly Example 30, wherein the first input mechanism comprises a first gripping portion of the handle; and the second input mechanism comprises a second gripping portion of the handle.

[00162] Example 32. The handle of any one of the preceding examples, particularly Example 30, wherein the first input mechanism comprises a button, a joystick, or a grip portion of the handle; and the second input mechanism comprises a second button.

CLAIMS

WHAT IS CLAIMED IS:

1. A system for performing minimally invasive surgery, comprising:

a stabilizing apparatus transitionable between an unlocked state and a locked state;

a control assembly comprising:

a handle pivotally coupled to the stabilizing apparatus and comprising one or more sensorized joints, and

an instrument actuator interface configured to be reversibly coupled to the handle,

a medical instrument coupled to the handle and manipulatable by the handle, the medical instrument comprising:

an elongate body having a proximal portion and a distal portion comprising one or more distal joints, and

an end-effector coupled to the distal portion; and

wherein, in a first mode, the stabilizing apparatus is configured in the unlocked state such that the medical instrument is manipulatable by the handle about a pivot point or in a first three-dimensional space,

wherein, in a second mode, the handle is configured to manipulate the end-effector of the medical instrument, and

wherein, in a third mode, the stabilizing apparatus is configured in the locked state, and the handle is enabled to cause movement of the one or more sensorized joints, such that the movement of the one or more sensorized joints causes a corresponding distal movement in the one or more distal joints of the medical instrument about the pivot point.

2. The system of claim 1, wherein, in the first mode, the handle is connected to the instrument actuator interface.
3. The system of claim 2, wherein a first input of the handle is configured to manipulate the end-effector of the medical instrument.
4. The system of claim 3, wherein the first input or a second input of the handle is configured to roll the elongate body about a longitudinal axis of the medical instrument.

5. The system of claim 1, wherein the stabilizing apparatus comprises one or more joints, and wherein manipulation of the elongate body of the medical instrument in the first three-dimensional space comprises movement of the medical instrument about a yaw axis of the one or more joints of the stabilizing apparatus.
6. The system of claim 1, wherein manipulation of the elongate body of the medical instrument in the first three-dimensional space comprises insertion or retraction of the medical instrument relative to the stabilizing apparatus.
7. The system of claim 1, wherein the handle comprises an input element configured to switch between the first mode, the second mode, and the third mode.
8. The system of claim 1, wherein the handle comprises a first input element configured to manipulate the end-effector of the medical instrument in the second mode.
9. The system of claim 8, wherein the first input element is manipulatable about a pitch axis, a roll axis, or a yaw axis associated with the first input element to manipulate the end-effector of the medical instrument in the second mode.
10. The system of claim 9, wherein manipulation of the first input element about the pitch axis of the first input element causes a corresponding movement of the end-effector about an end-effector pitch axis.
11. The system of claim 9, wherein manipulation of the first input element about the yaw axis of the first input element causes a corresponding movement of the end-effector about an end-effector yaw axis.
12. The system of claim 9, wherein manipulation of the first input element about the roll axis of the first input element causes a corresponding movement of the end-effector about an end-effector roll axis.
13. The system of claim 1, wherein the pivot point comprises a remote pivot point that is configured to reside proximate to or within a trocar through which the medical instrument is inserted during a procedure.
14. The system of claim 1, wherein the one or more sensorized joints comprise a sensor assembly, and the instrument actuator interface comprises a powered actuation unit and a controller, the controller being communicatively linked to the sensor assembly and the powered actuation unit.
15. The system of claim 14, wherein the sensor assembly is configured to monitor at least a first position of the one or more sensorized joints and generate a corresponding sensor signal; the controller is configured to receive the corresponding sensor signal

and generate a corresponding control signal; and the powered actuation unit is configured to receive the corresponding control signal and to actuate the one or more distal joints to cause translation of the one or more distal joints based on the first position.

16. The system of claim 1, wherein the handle comprises a sleeve comprising the one or more sensorized joints, and wherein the handle is configured to manipulate the sleeve to cause the movement in the one or more sensorized joints.
17. The system of claim 1, wherein the handle is coupled to the proximal portion of the medical instrument.
18. The system of claim 1, wherein, in the third mode, the handle is configured to be disengaged from the instrument actuator interface.
19. A system for performing minimally invasive surgery, comprising:

an elongate body comprising a distal end having an end-effector and one or more distal joints, and a proximal end, opposite the distal end;

a handle configured to receive the proximal end of the elongate body, wherein the handle comprises a sleeve comprising one or more sensorized joints;

a sensor assembly configured to monitor a position of each of the one or more sensorized joints; and

an instrument actuator interface coupled to the sleeve of the handle and comprising:

a powered actuation unit, and

a controller communicatively linked to the sensor assembly and the powered actuation unit,

wherein:

the sensor assembly is configured to monitor at least a first position of the one or more sensorized joints and generate a corresponding sensor signal, wherein the first position is based on a proximal movement of the handle;

the controller is configured to receive the corresponding sensor signal and generate a corresponding control signal; and

the powered actuation unit is configured to receive the corresponding control signal and to actuate the one or more distal joints to cause translation of the one or more distal joints based on the first position of the one or more sensorized joints.

20. The system of claim 19, further comprising a stabilizing apparatus that is transitionable between an unlocked state and a locked state.
21. The system of claim 20, wherein the stabilizing apparatus is configured to be in the locked state when the powered actuation unit actuates the one or more distal joints to cause the translation.
22. The system of claim 21, wherein the one or more distal joints are configured to be manipulated about a remote pivot point.
23. The system of claim 22, wherein the remote pivot point is configured to align with a trocar through which the elongate body is inserted during a procedure.
24. A system for minimally invasive surgery, comprising:

a medical instrument comprising:

an elongate body having a proximal portion and a distal portion comprising one or more distal joints, and

an end-effector; and

a control assembly comprising:

a handle configured to couple to the proximal portion of the medical instrument and manipulate the medical instrument, wherein the handle comprises one or more sensorized joints, and

an instrument actuator interface configured to be reversibly coupled to the handle,

wherein the system is configured to be selectively operated in a first control mode or a second control mode, and wherein selecting between the first control mode and the second control mode comprises modifying a movement range associated with the one or more sensorized joints.

25. The system of claim 24, wherein:

the first control mode is a fulcrum-effect mode, wherein a first input of the handle is configured to manipulate the end-effector of the medical instrument, and

the second control mode is a fulcrum corrected mode, wherein a movement of the one or more sensorized joints of the handle is enabled, such that manipulation of the handle causes the movement of the one or more sensorized joints which results in a corresponding distal movement of the one or more distal joints at least: about a predefined pivot point or in a predefined three-dimensional space.

26. The system of claim 25, wherein, in the first control mode, the first input or a second input is configured to roll the elongate body about a longitudinal axis of the medical instrument.

27. A system for performing minimally invasive surgery, comprising:

a control assembly comprising:

a handle pivotally coupled to a bedside apparatus, wherein the handle comprises one or more sensorized joints, and

an instrument actuator interface; and

a medical instrument couplable to the handle and manipulatable by the handle, the medical instrument comprising:

an elongate body having a proximal portion and a distal portion comprising one or more distal joints, and

wherein, in a fulcrum-effect mode, mechanical movement of the handle coupled to the proximal portion of the medical instrument causes movement of the medical instrument about a pivot point, and

wherein, in a fulcrum corrected mode:

the pivot point is between the one or more sensorized joints of the handle and the one or more distal joints of the medical instrument, and

actuation of the handle causes a movement of the one or more sensorized joints causing the instrument actuator interface to map the movement to a corresponding distal movement in the one or more distal joints at least about the pivot point.

28. A method for performing minimally invasive surgery, comprising:

in a fulcrum-effect mode:

receiving a first input at a handle coupled to a medical instrument, wherein the first input causes manual movement of the medical instrument about a pivot point, wherein the pivot point is between a distal portion of the medical instrument and a proximal portion of the medical instrument; and

in a fulcrum corrected mode:

activating a control at the handle, the control being configured to engage a sensor assembly and a powered actuation unit in communication with the medical instrument to perform an electronically assisted movement;

monitoring a position of one or more sensorized joints of the handle using the sensor assembly communicatively coupled to a controller; and

responsive to detecting, by the sensor assembly, a change in the position, causing the distal portion of the medical instrument to translate using the powered actuation unit, wherein the translation of the distal portion of the medical instrument is based on the position of the one or more sensorized joints.

29. The method of claim 28, wherein the one or more sensorized joints are proximal relative to the pivot point.

30. A handle configured to be installed at a bedside of a patient support apparatus and to perform a minimally invasive surgery, the handle comprising:

a first input mechanism configured to select a fulcrum-effect mode,

wherein the handle is configured to attach to a medical instrument that is mechanically movable about a pivot point; and

a second input mechanism configured to select a fulcrum corrected mode,

wherein selection of the second input mechanism is configured to activate a sensor assembly, a powered actuation unit, and a controller communicatively coupled to the powered actuation unit and the sensor assembly.

31. The handle of claim 30, wherein the first input mechanism comprises a first gripping portion of the handle; and the second input mechanism comprises a second gripping portion of the handle.

32. The handle of claim 30, wherein the first input mechanism comprises a button, a joystick, or a grip portion of the handle; and the second input mechanism comprises a second button.

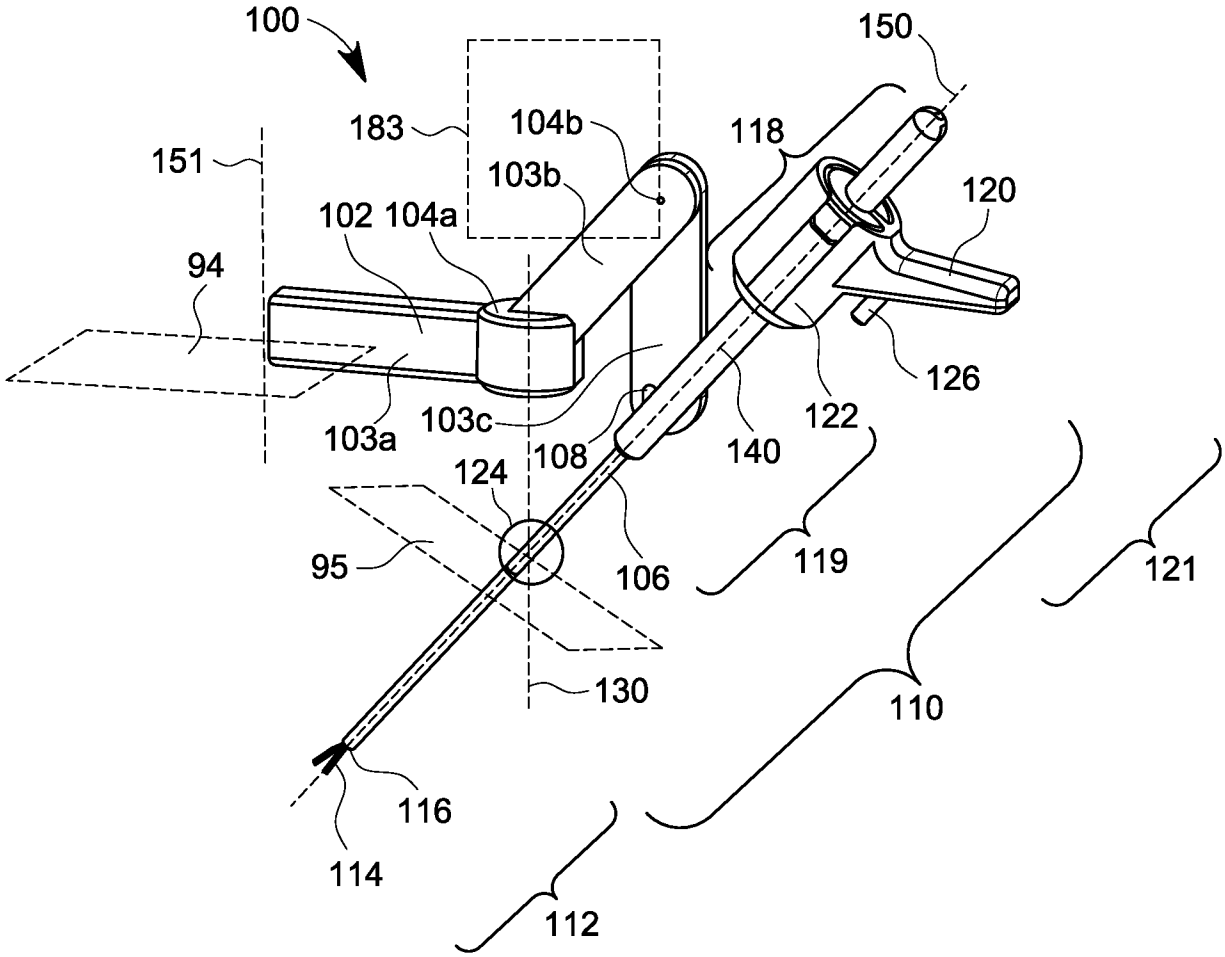
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FIG. 1A

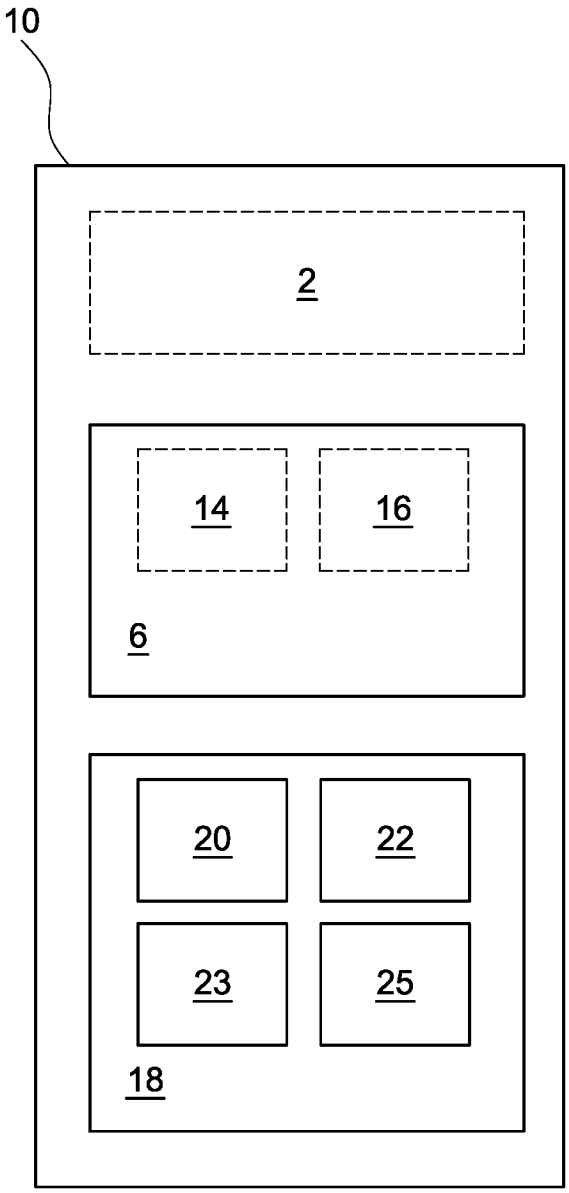

FIG. 1B

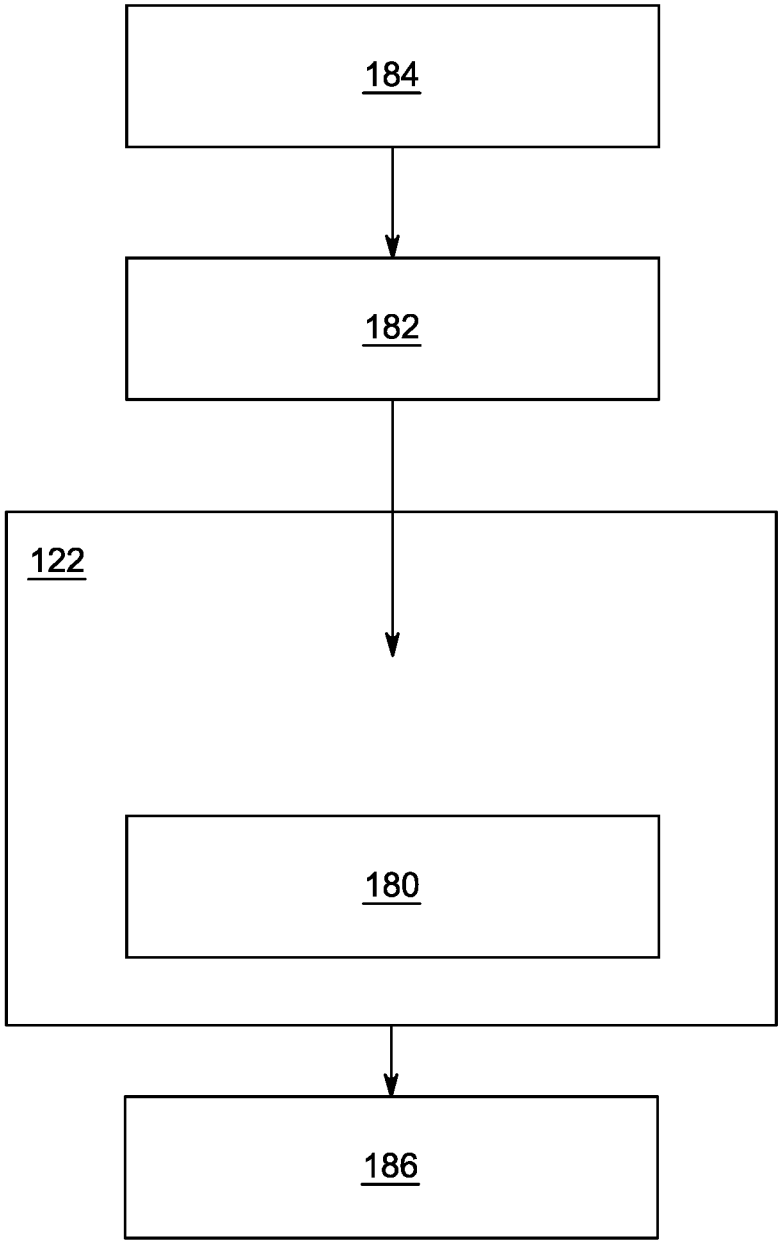

FIG. 1C

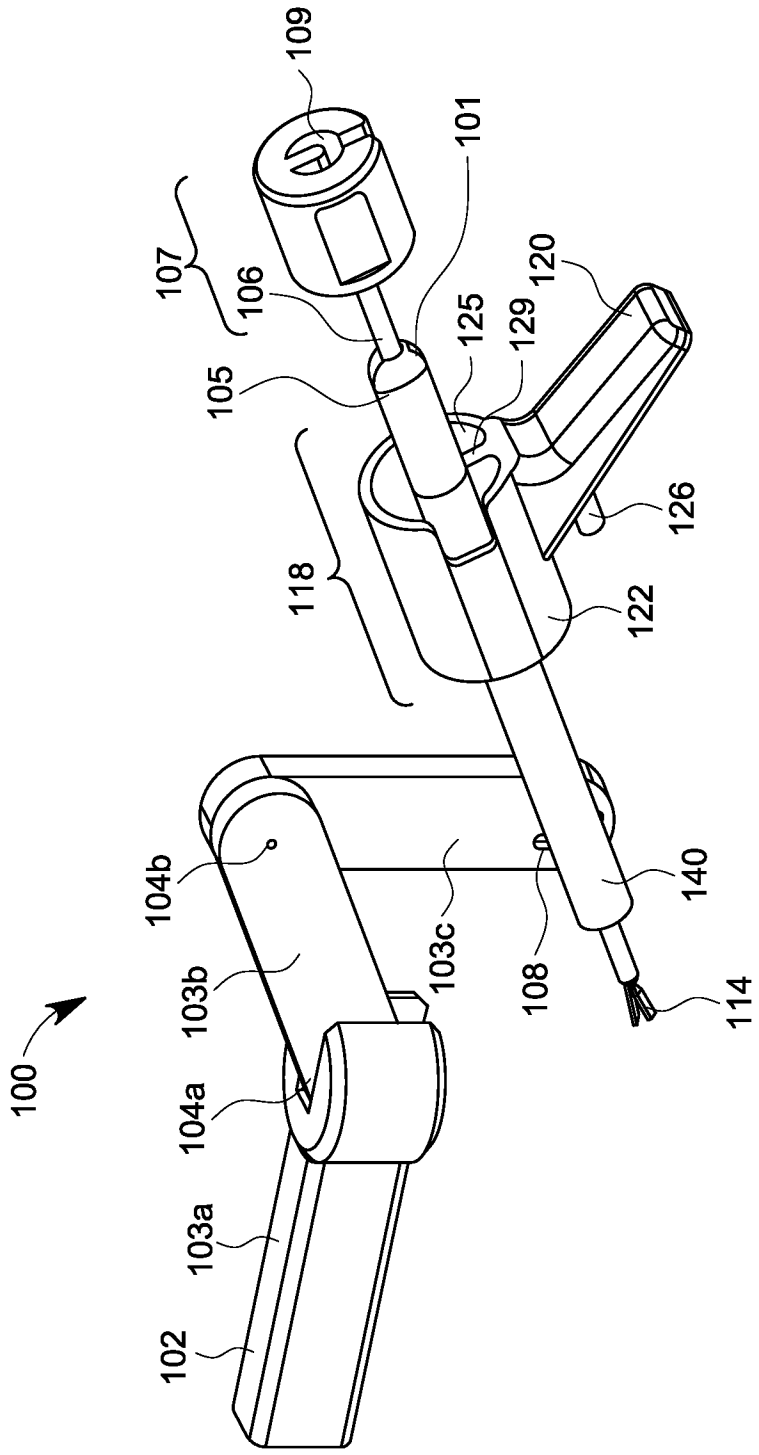
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FIG. 2

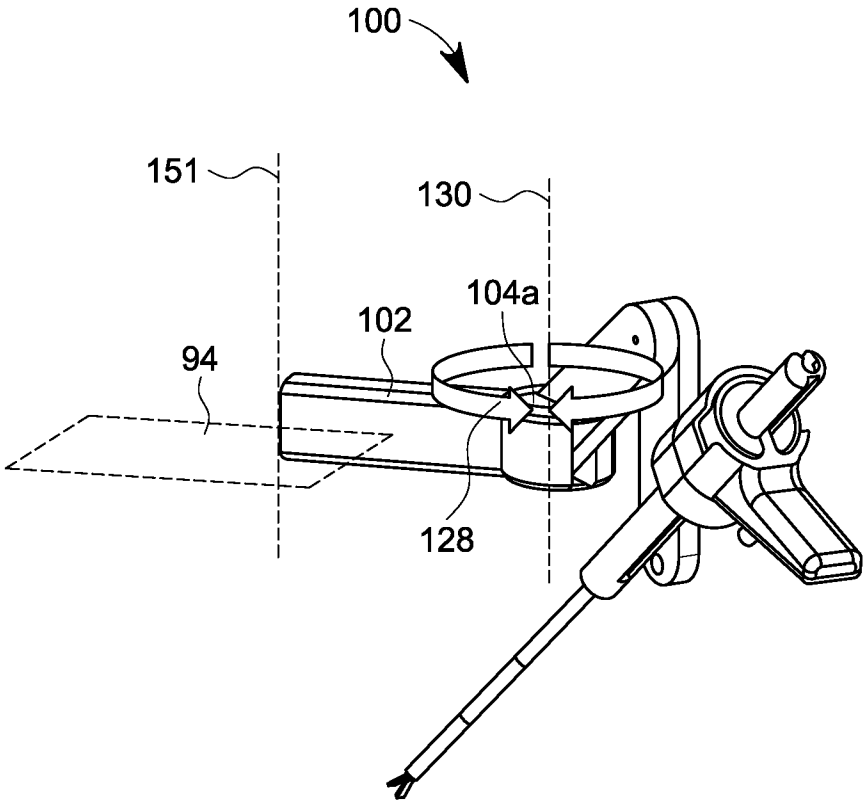

FIG. 3A

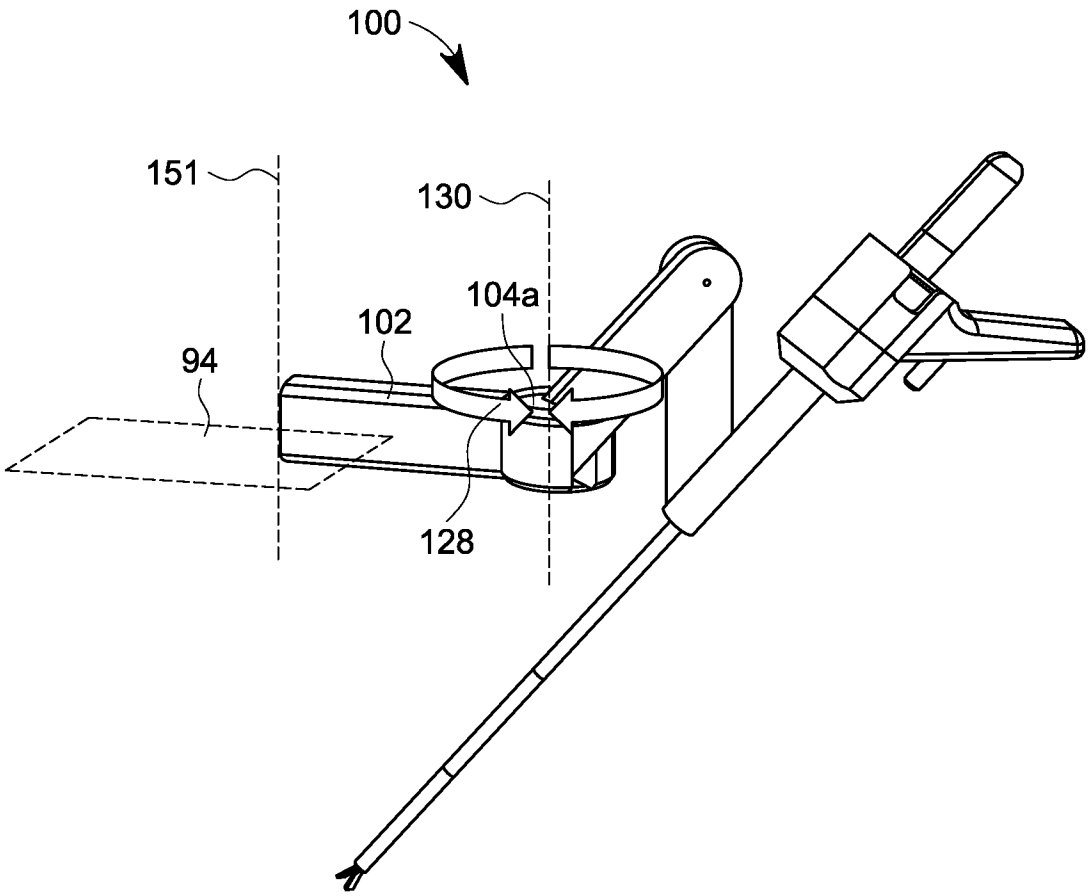

FIG. 3B

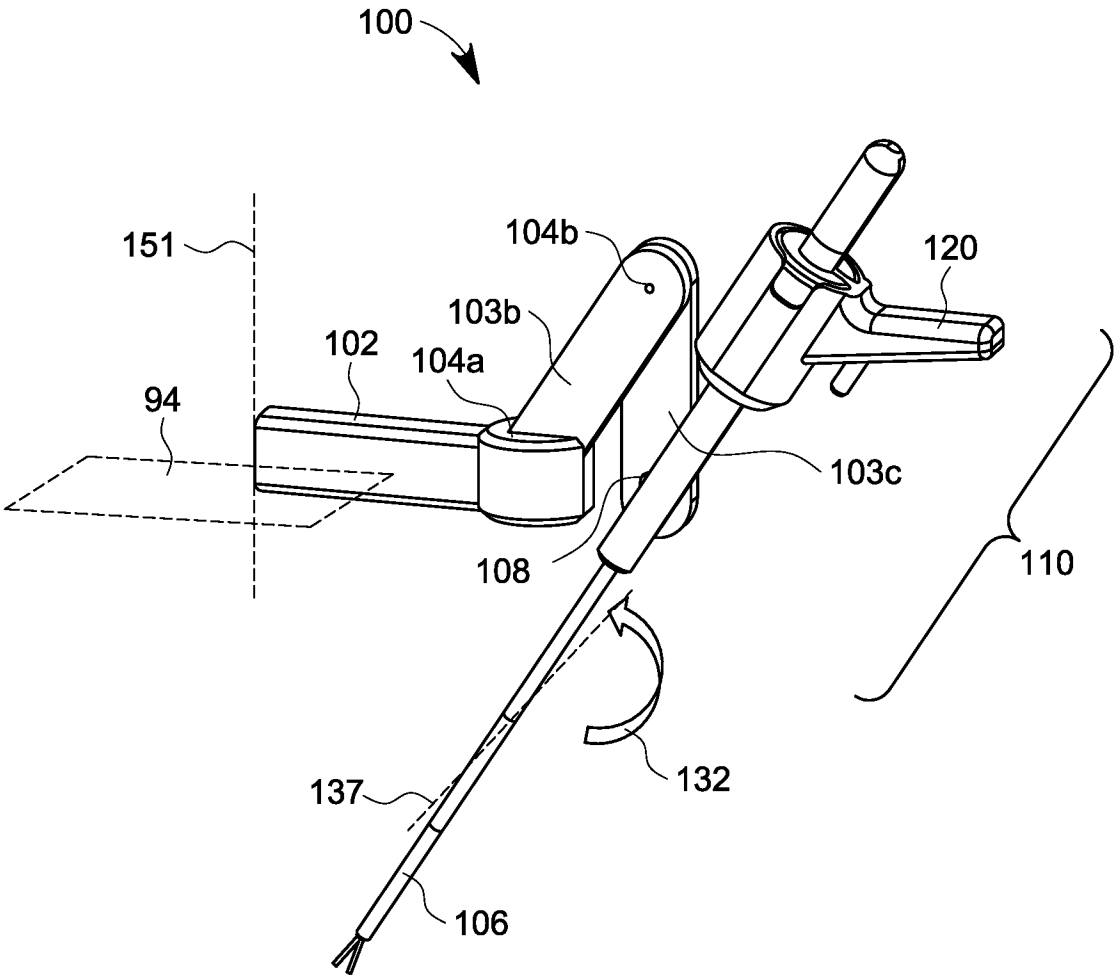

FIG. 4A

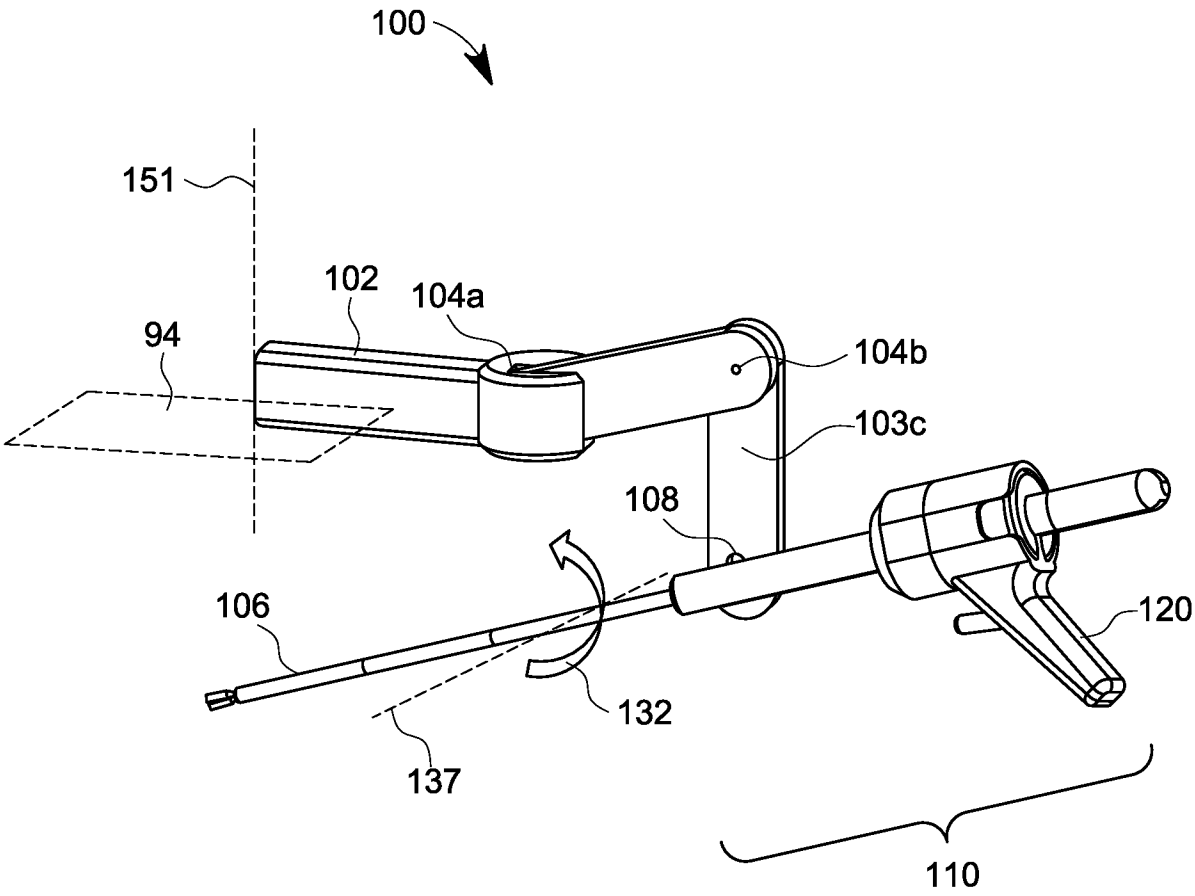

FIG. 4B

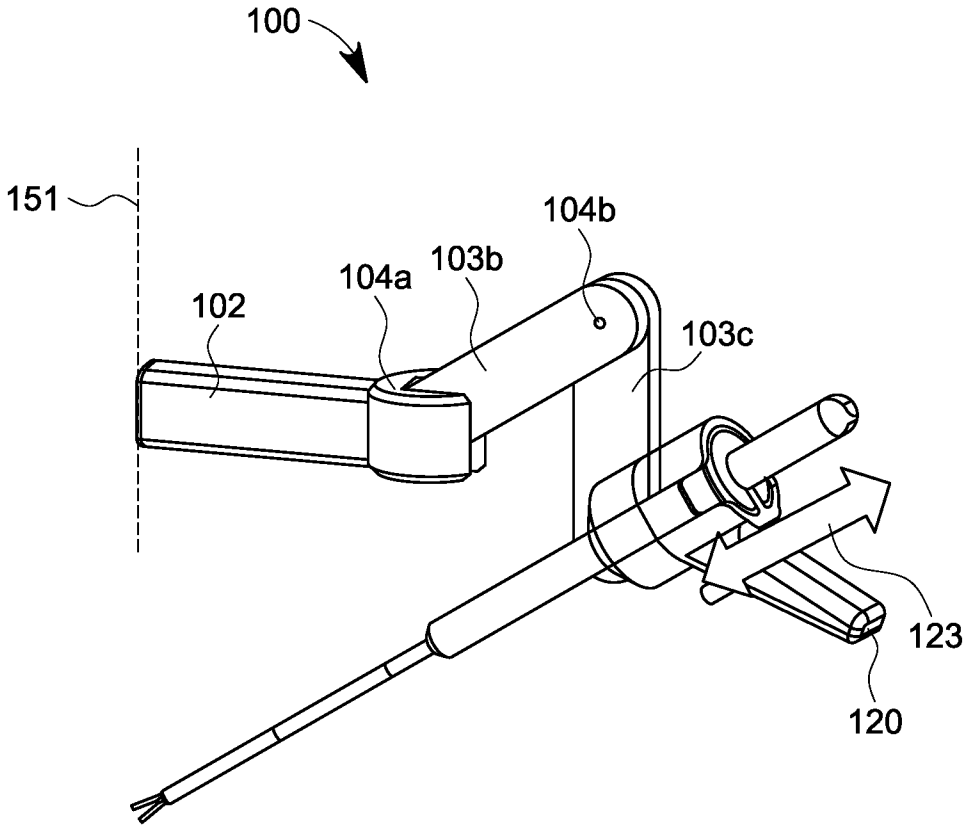

FIG. 5A

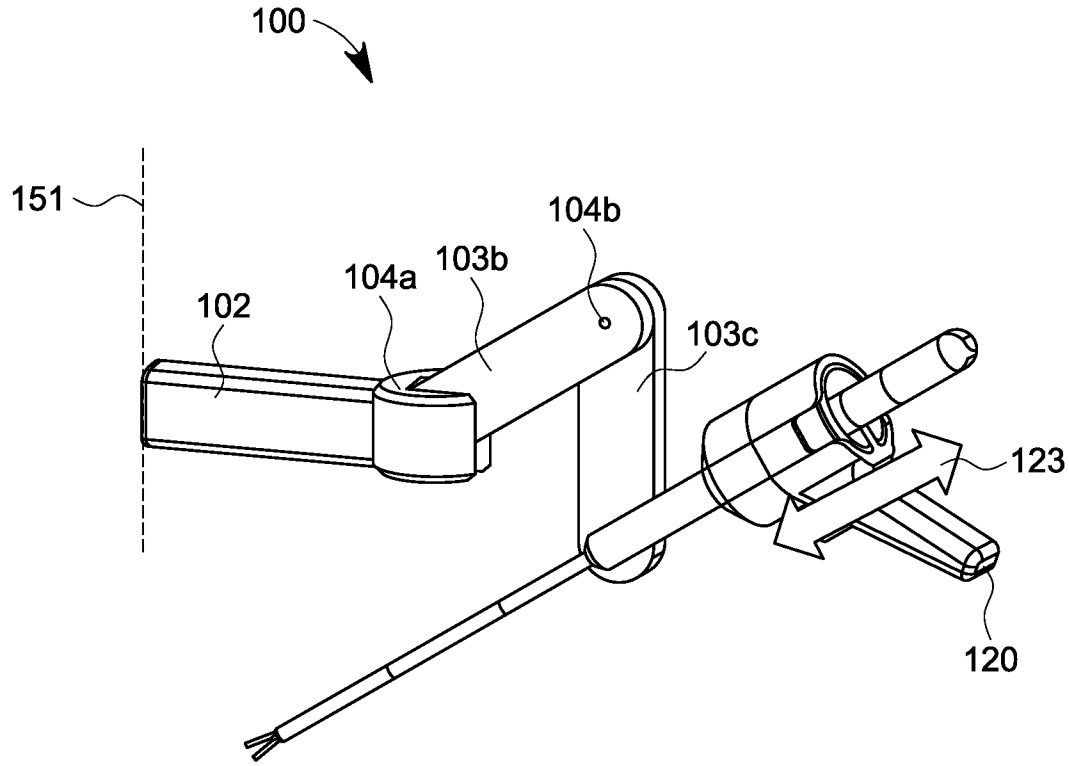

FIG. 5B

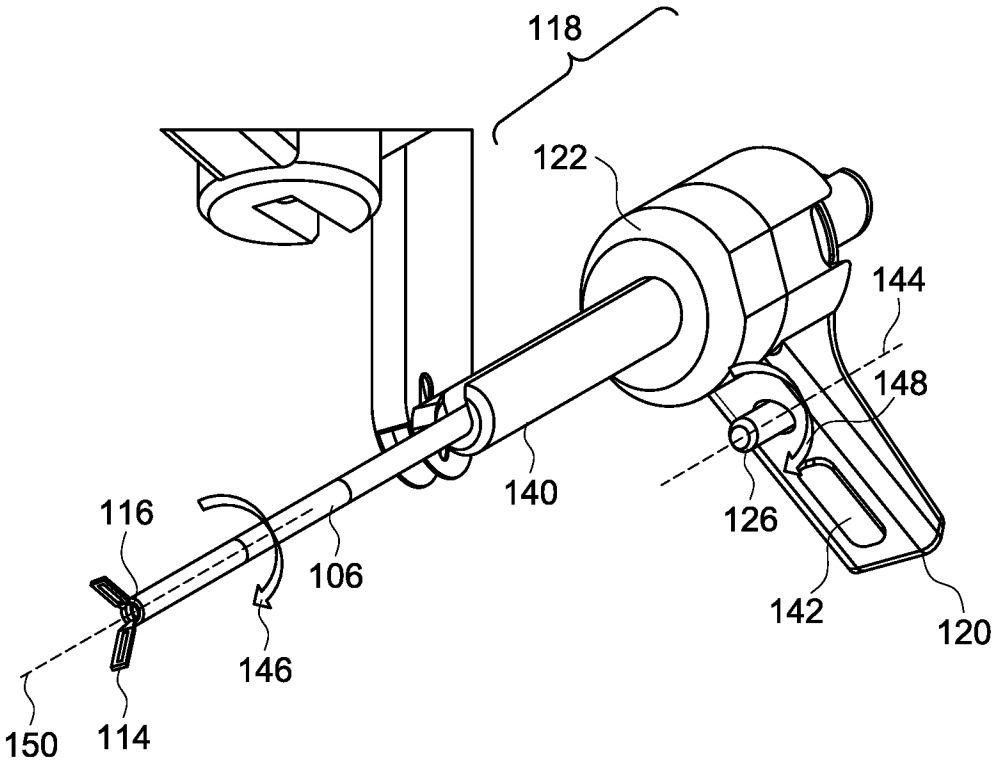

FIG. 6

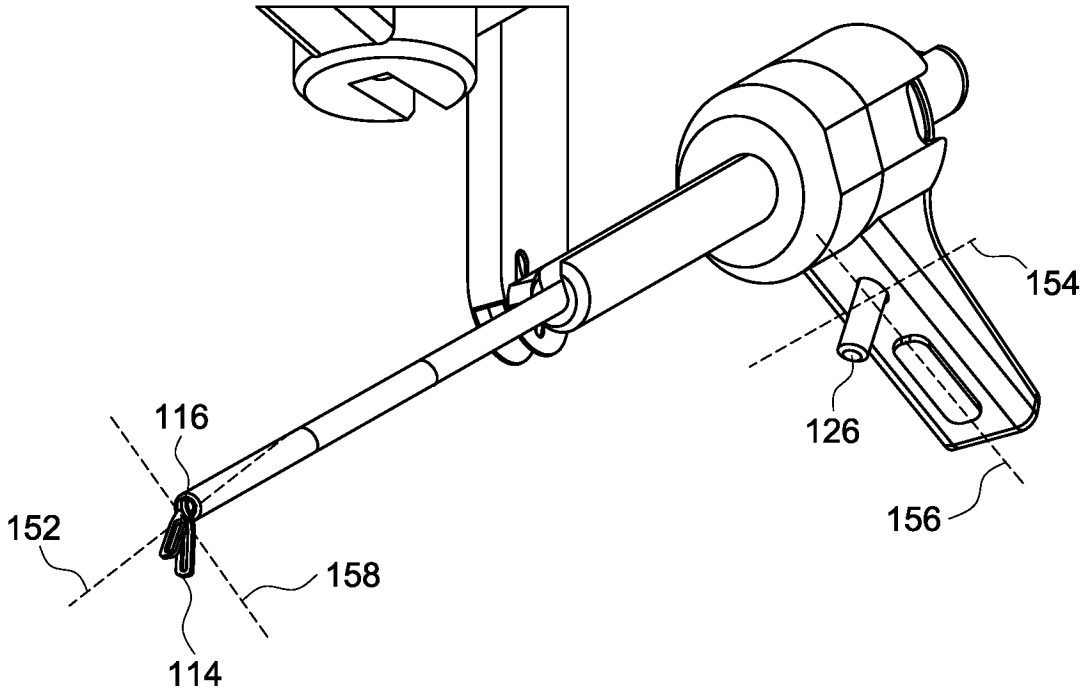

FIG. 7

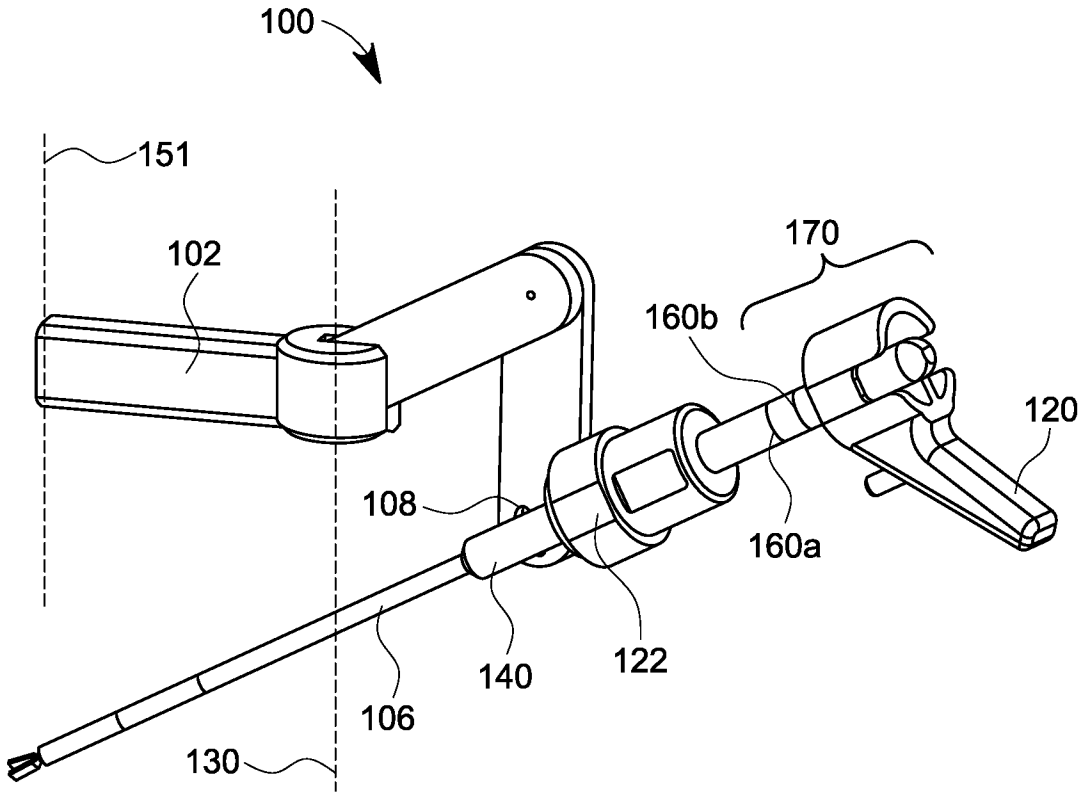

FIG. 8

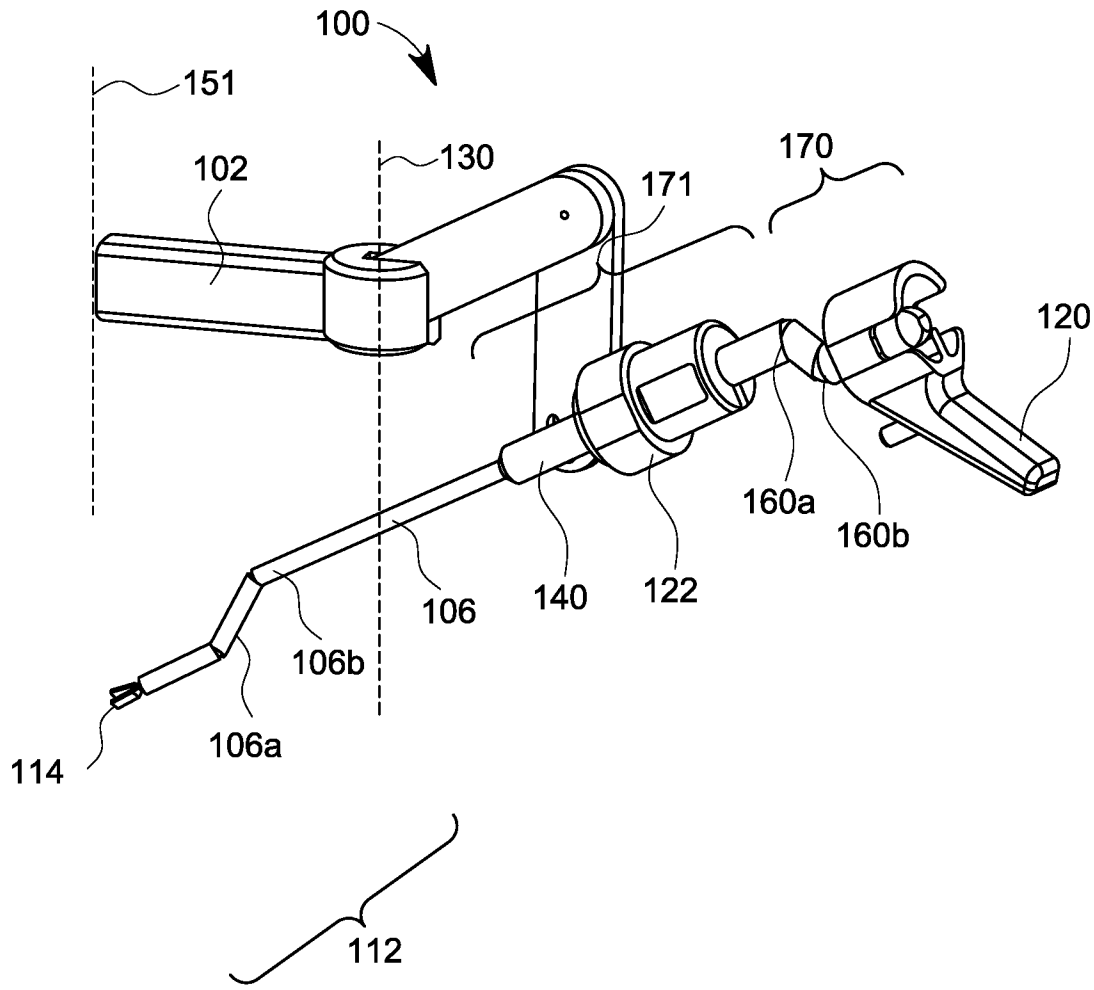
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FIG. 9

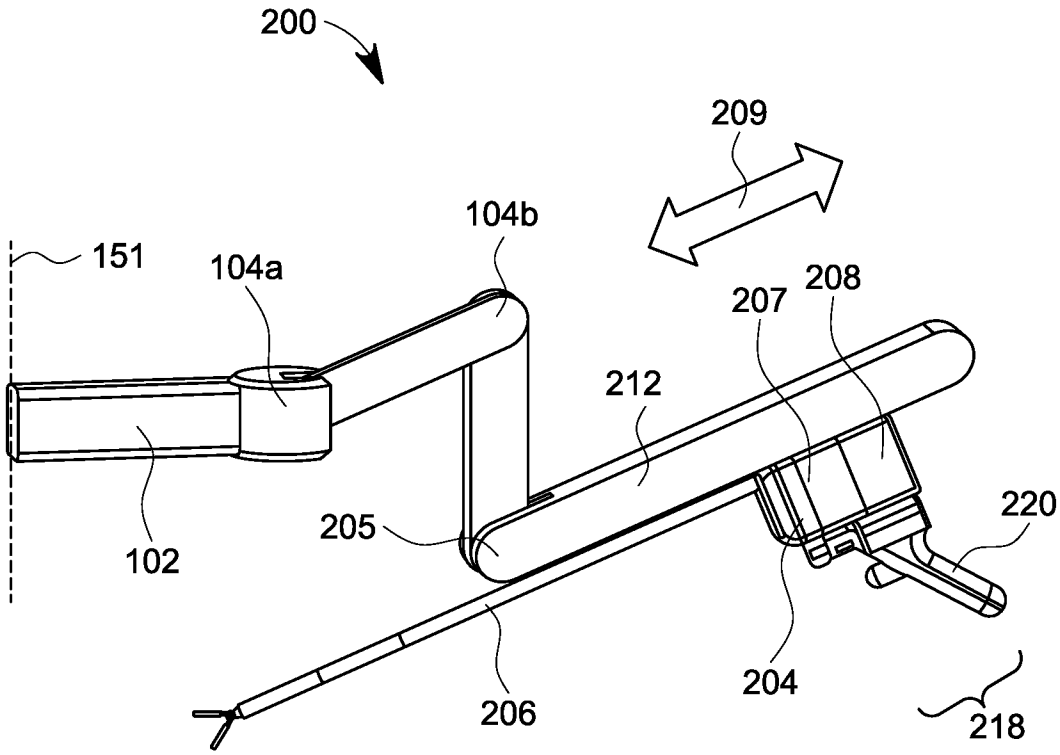

FIG. 10A

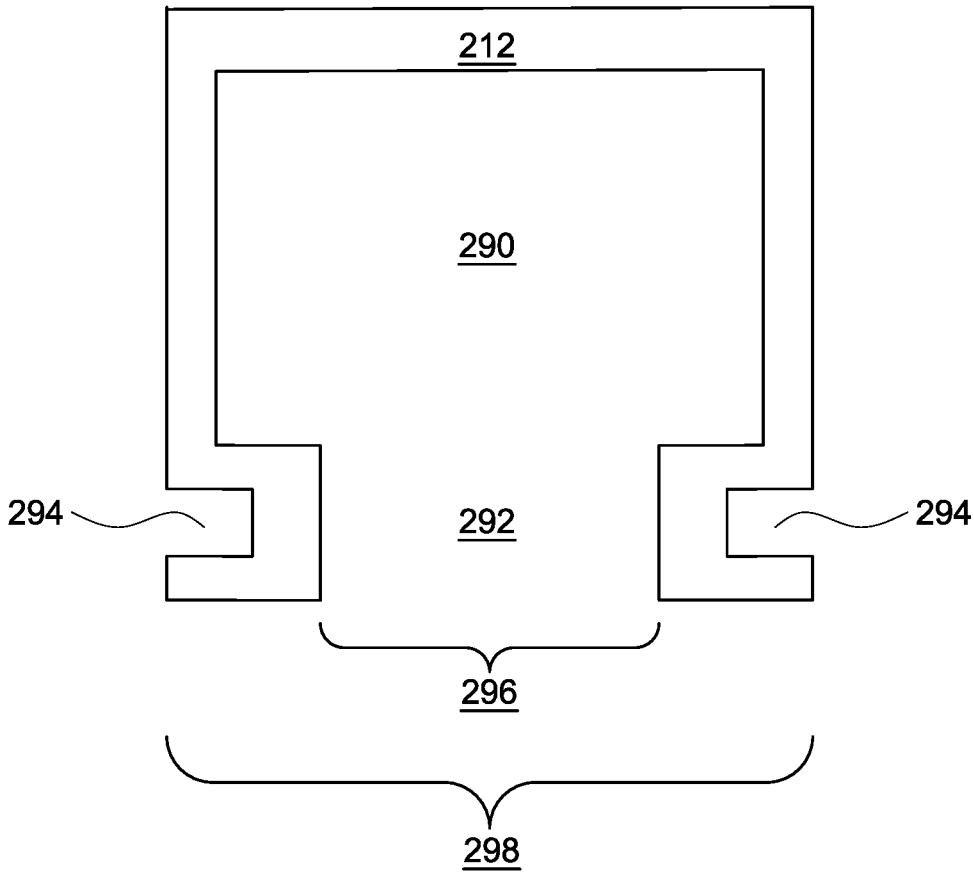

FIG. 10B

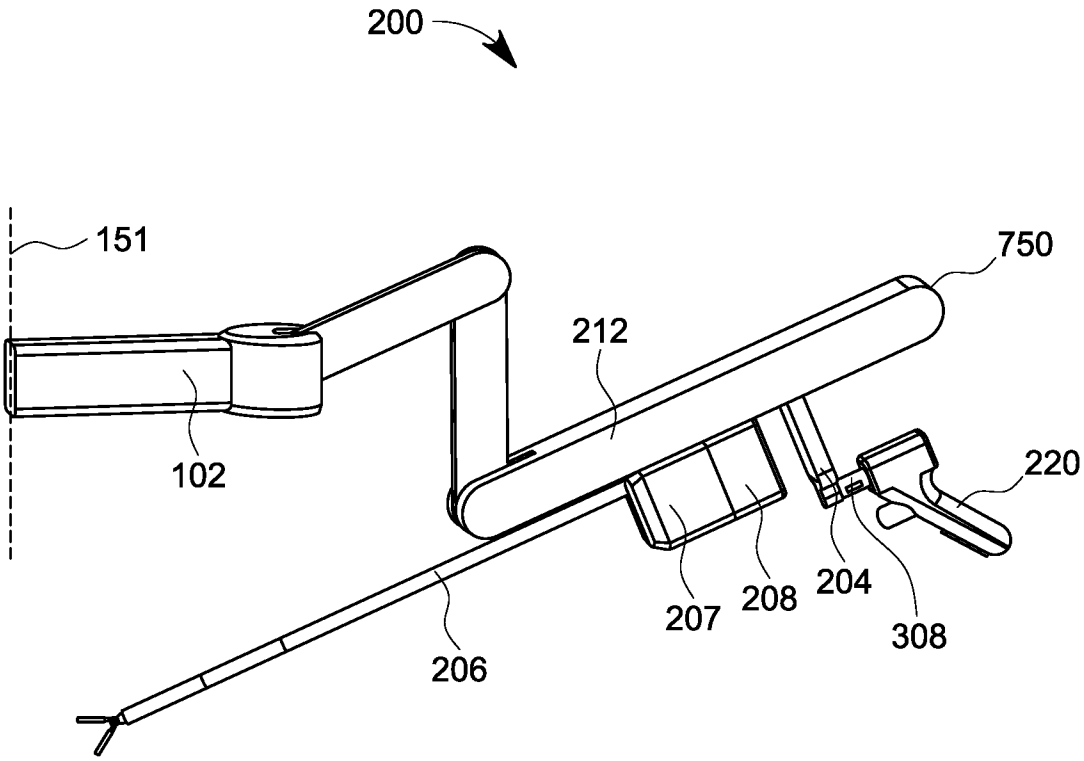

FIG. 11

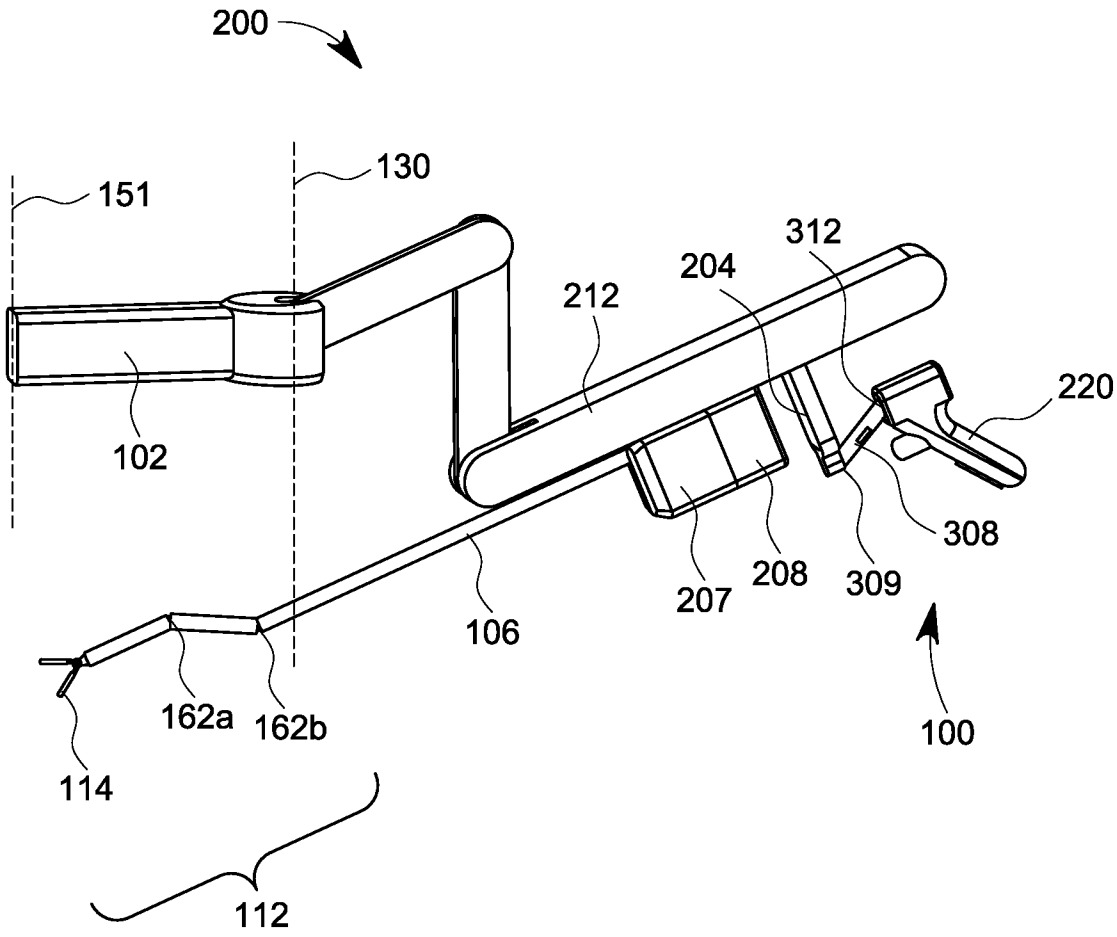
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FIG. 12

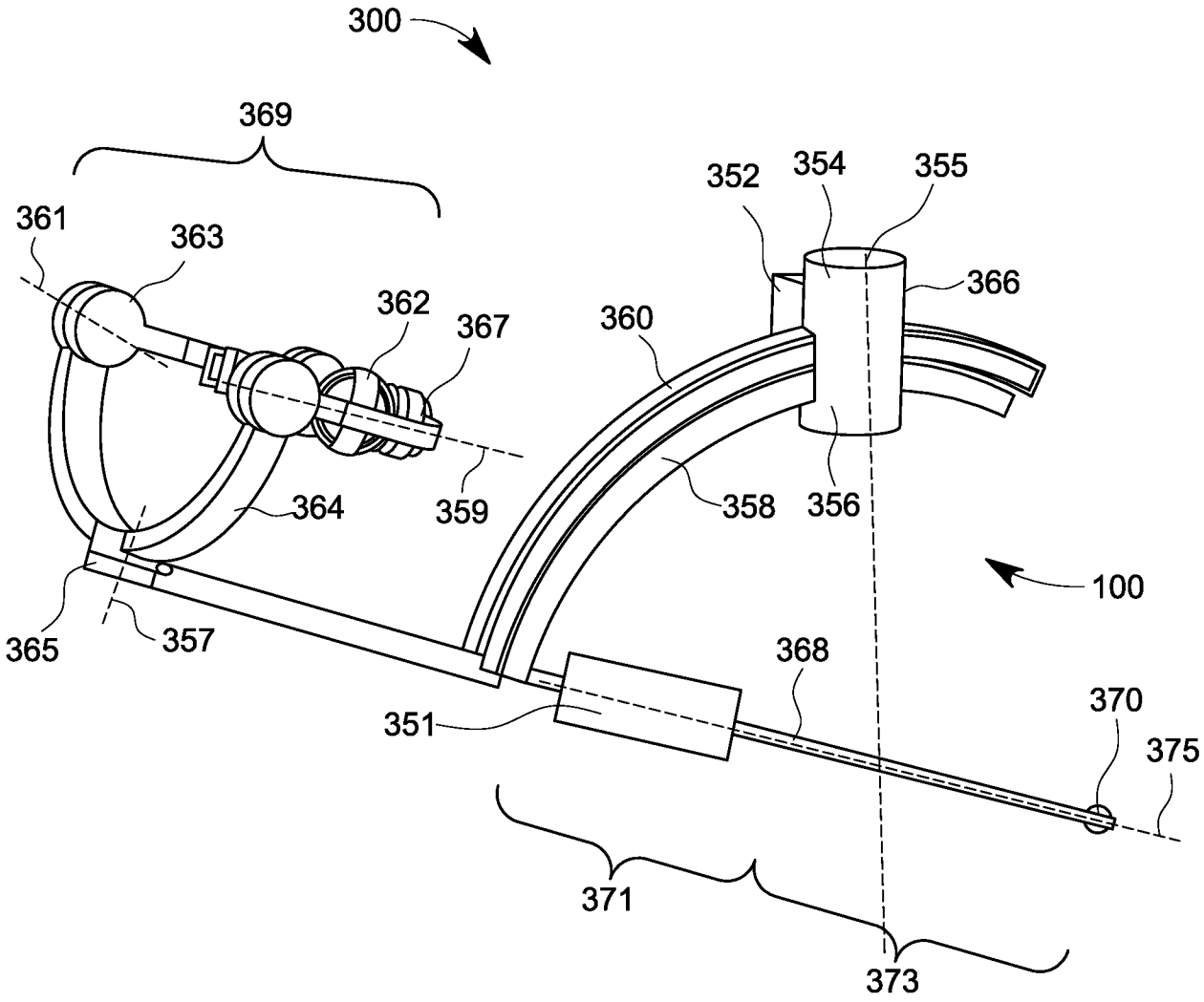
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FIG. 13

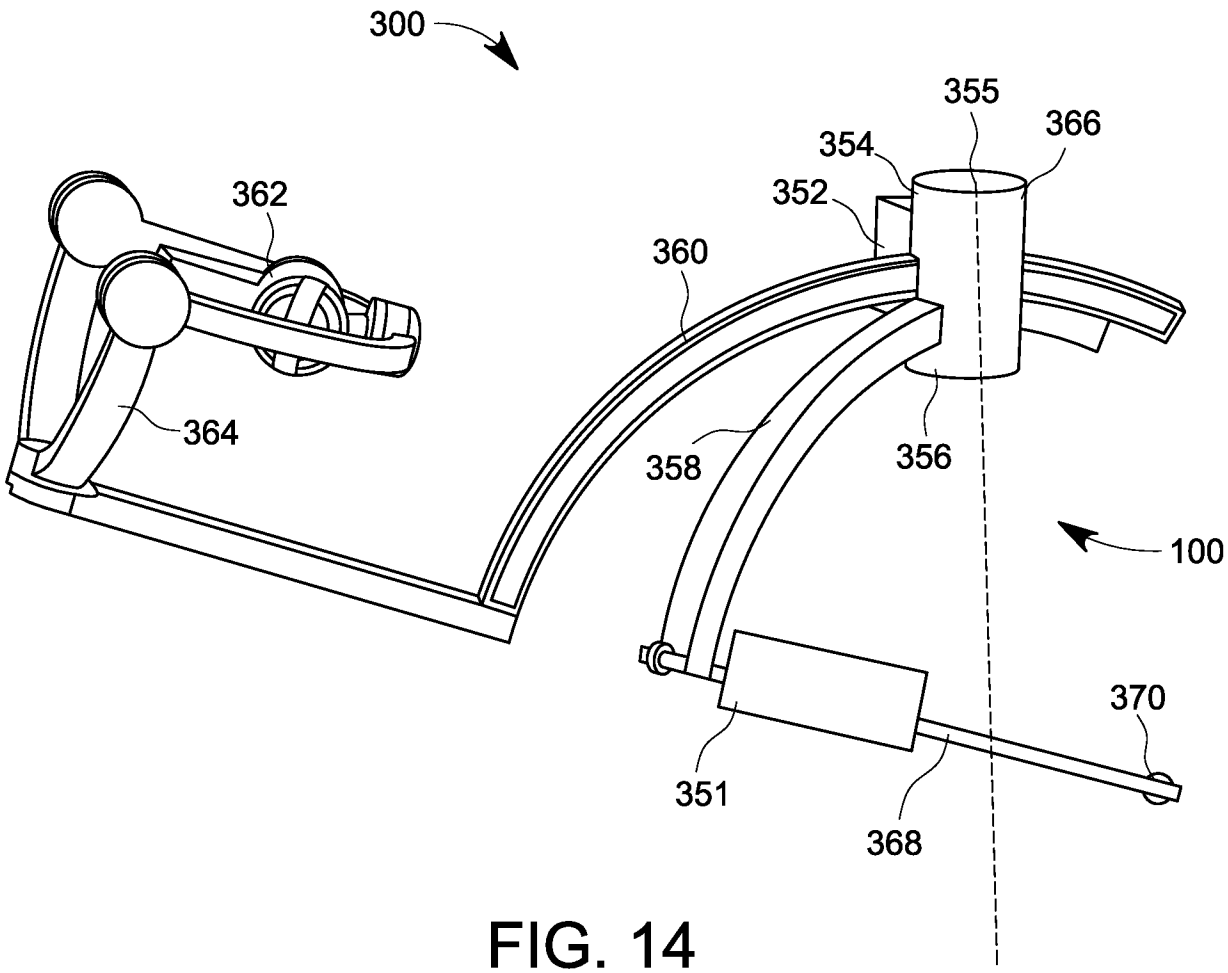

FIG. 14

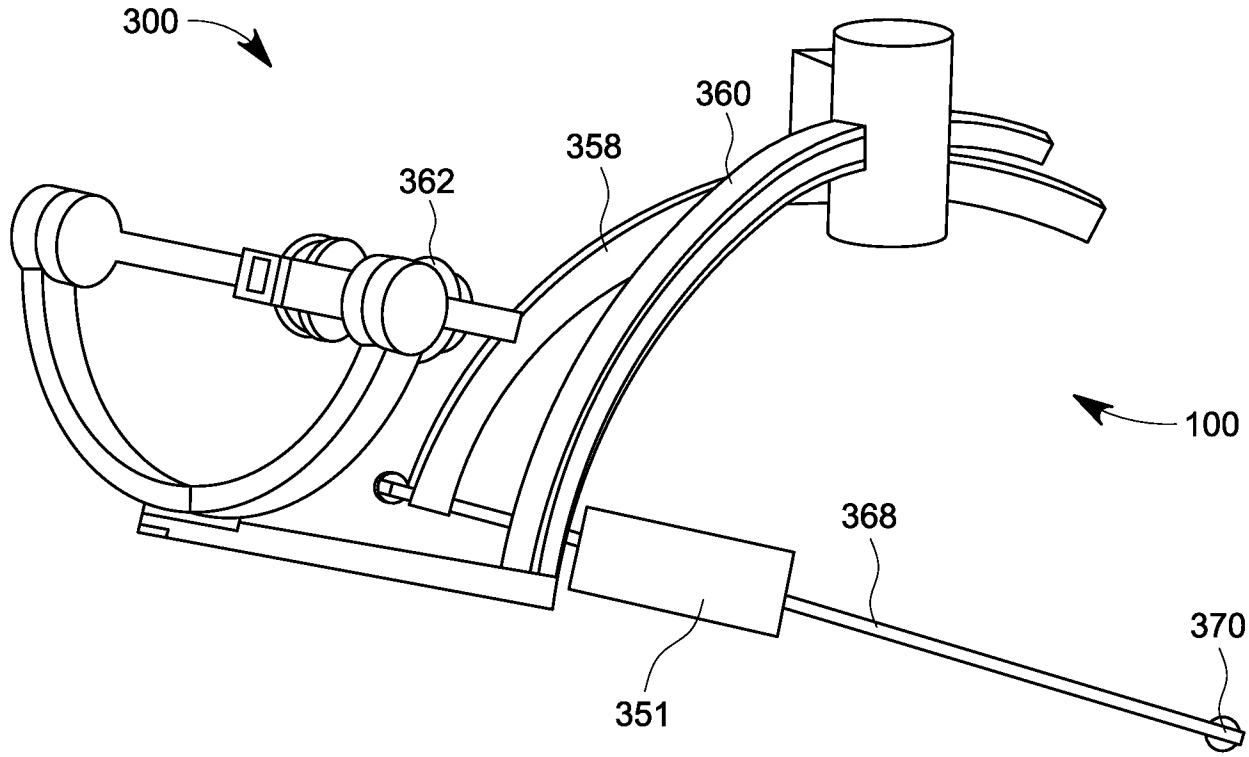

FIG. 15

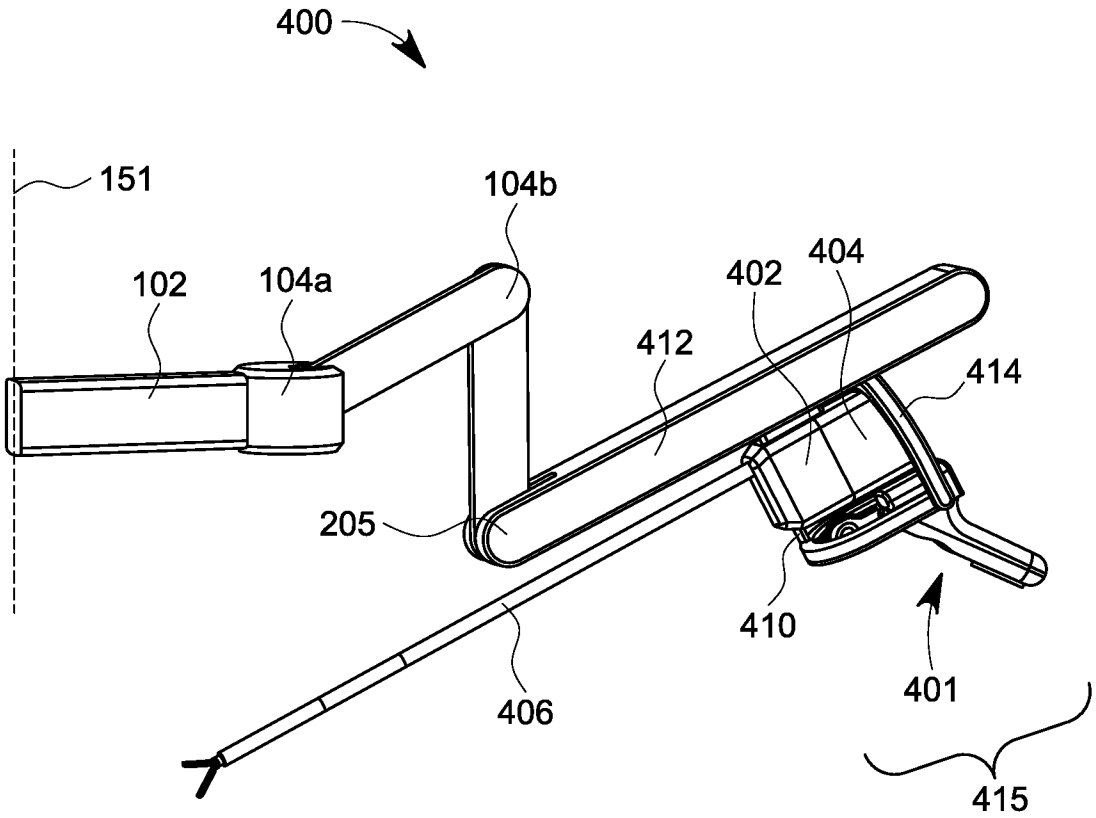

FIG. 16

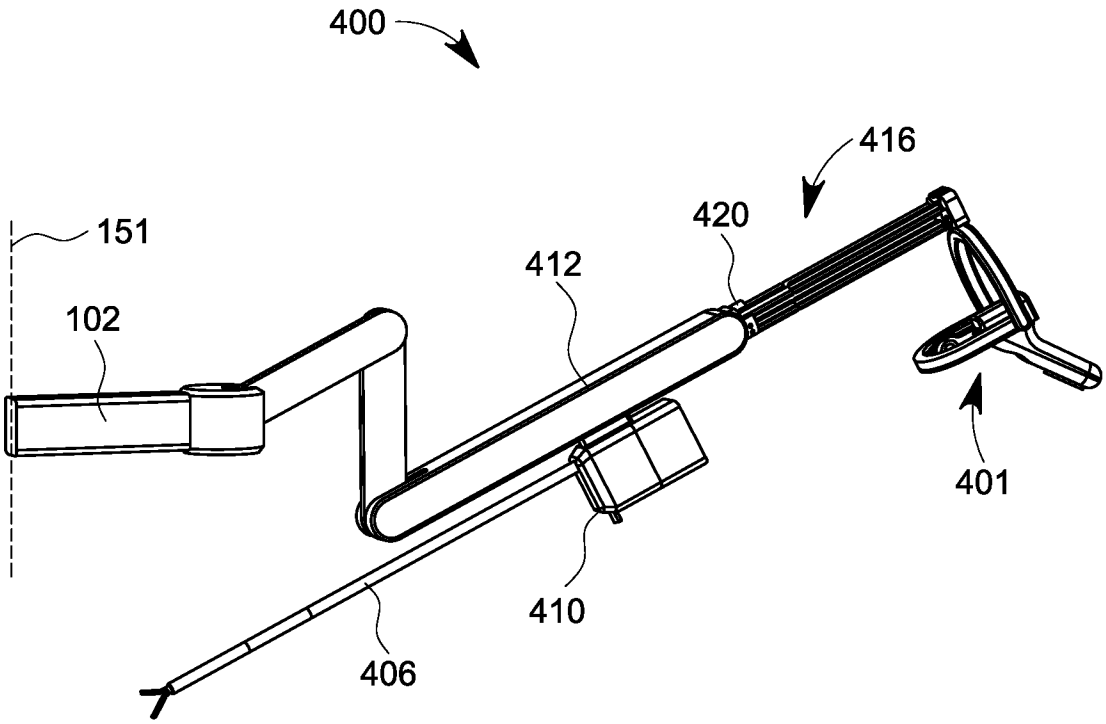

FIG. 17

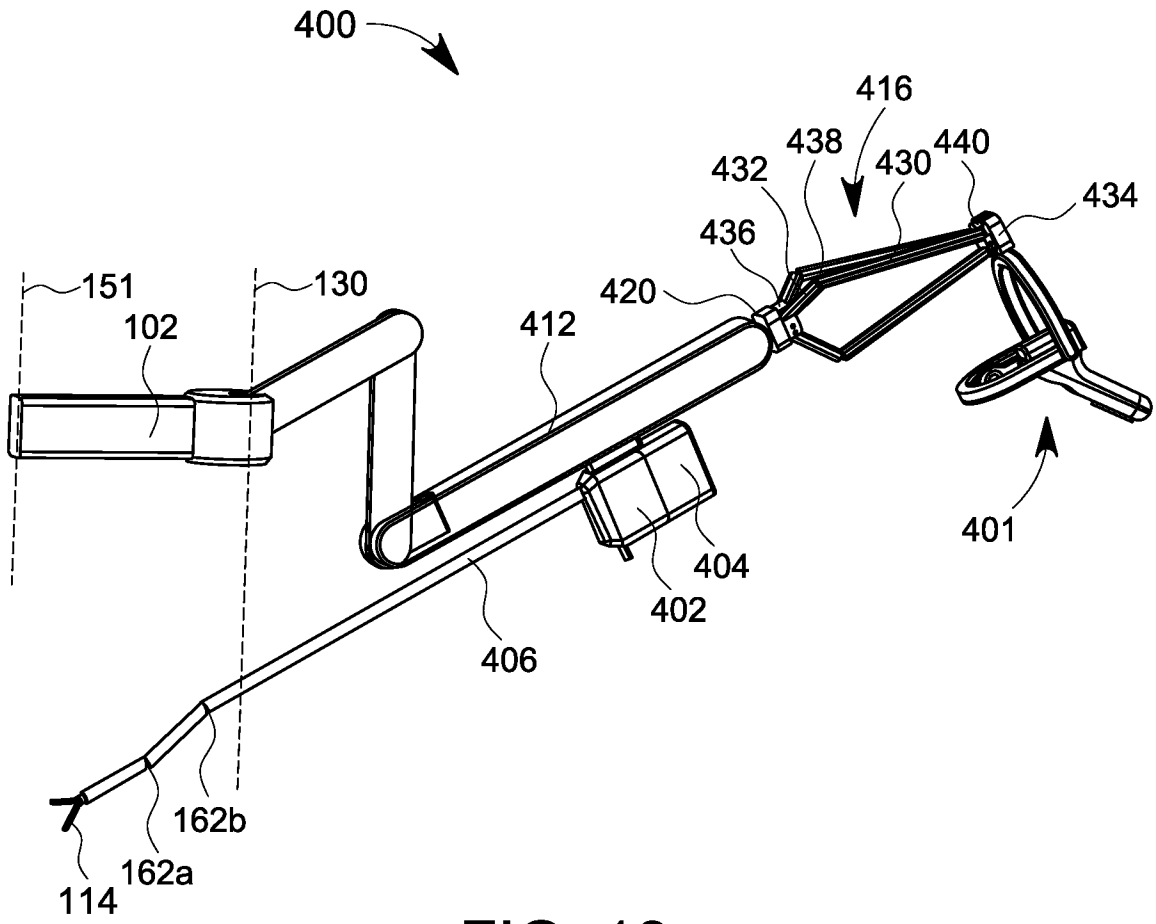
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FIG. 18

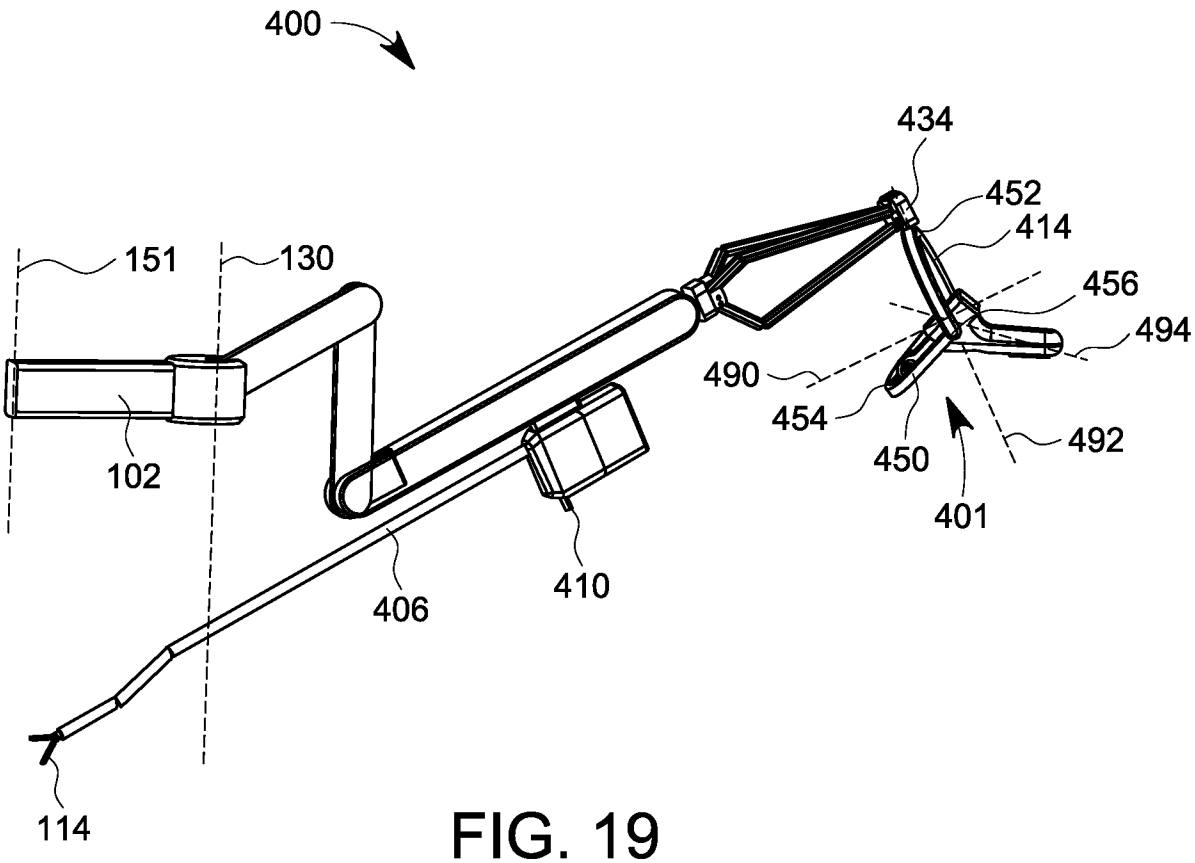
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FIG. 19

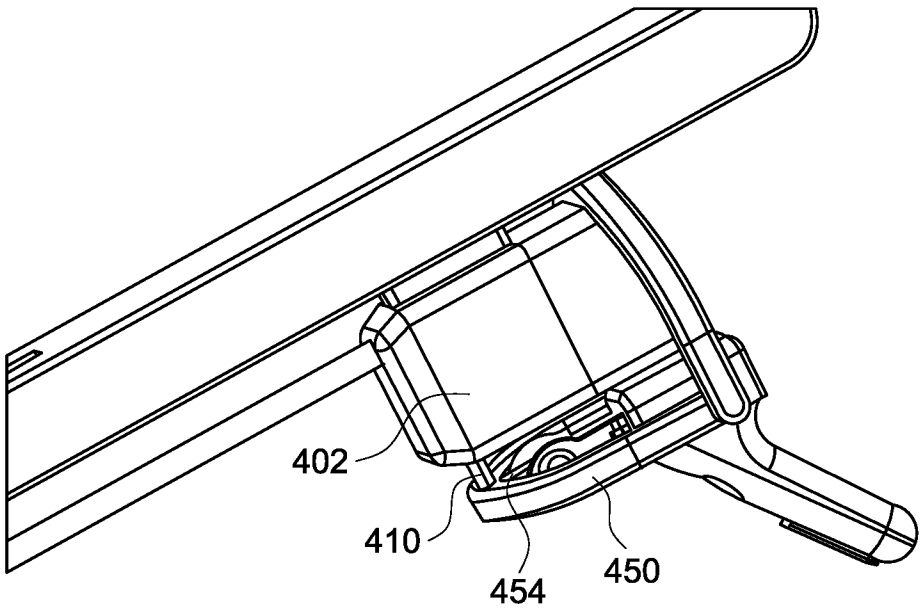

FIG. 20

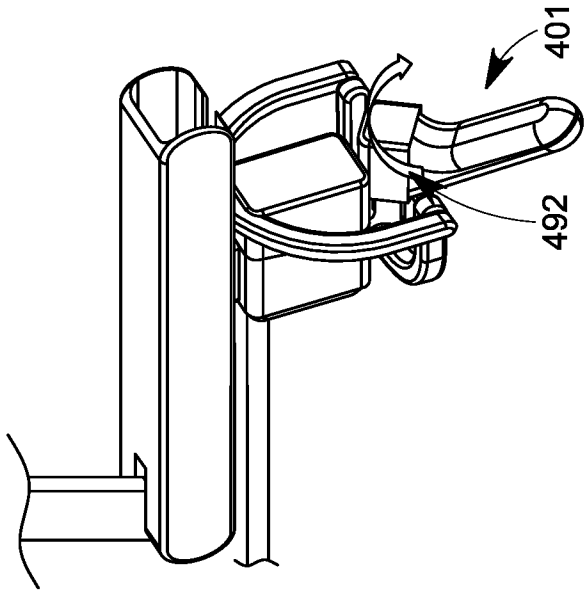

FIG. 21B

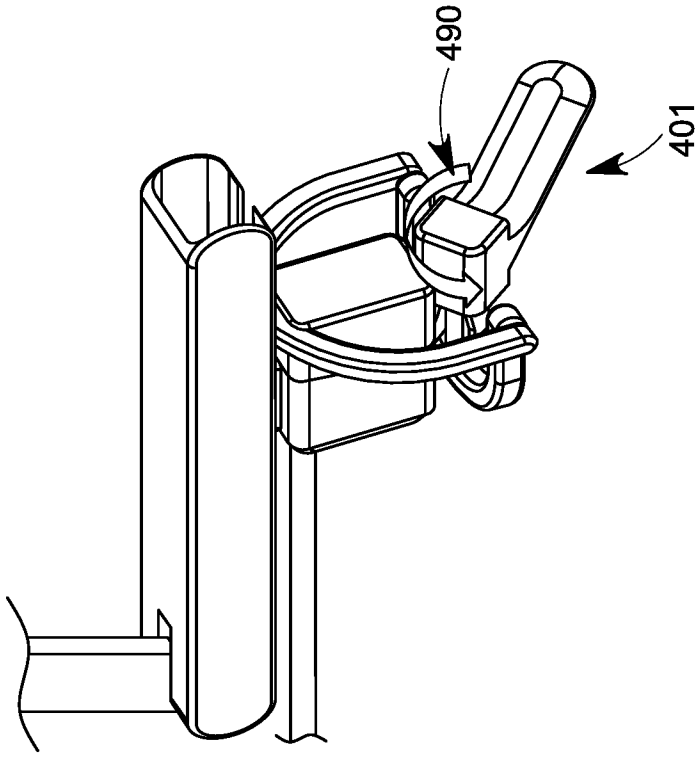

FIG. 21A

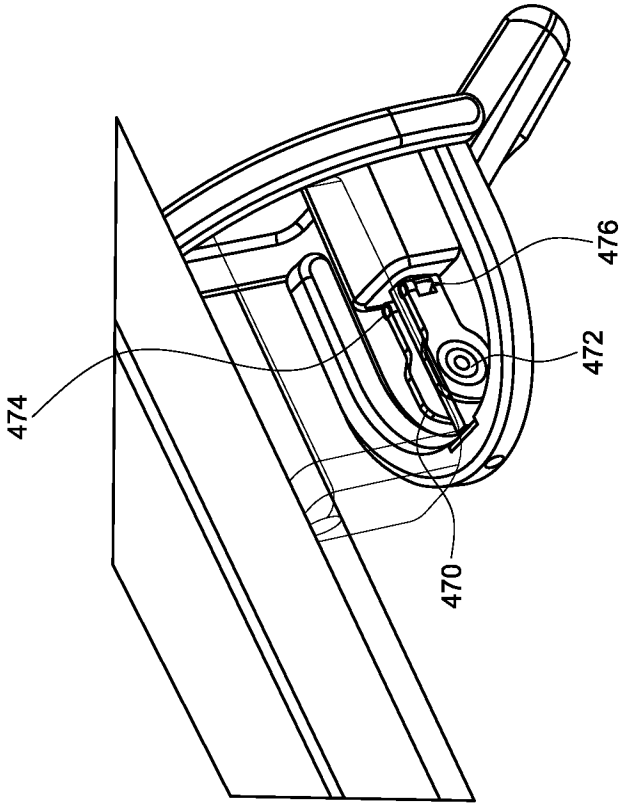

FIG. 22B

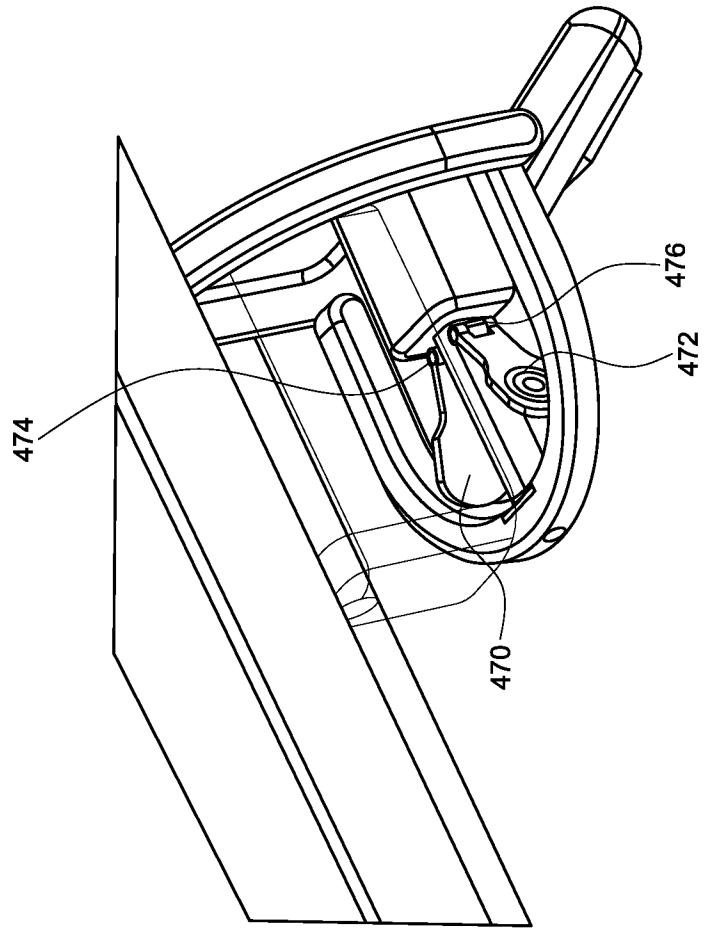

FIG. 22A

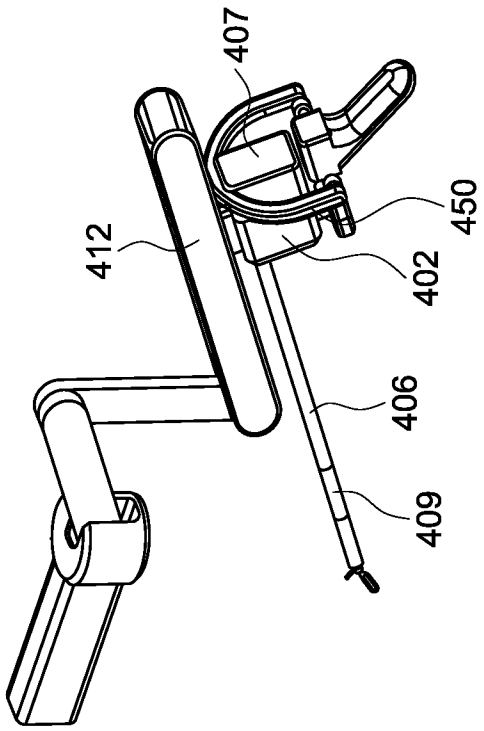

FIG. 23A

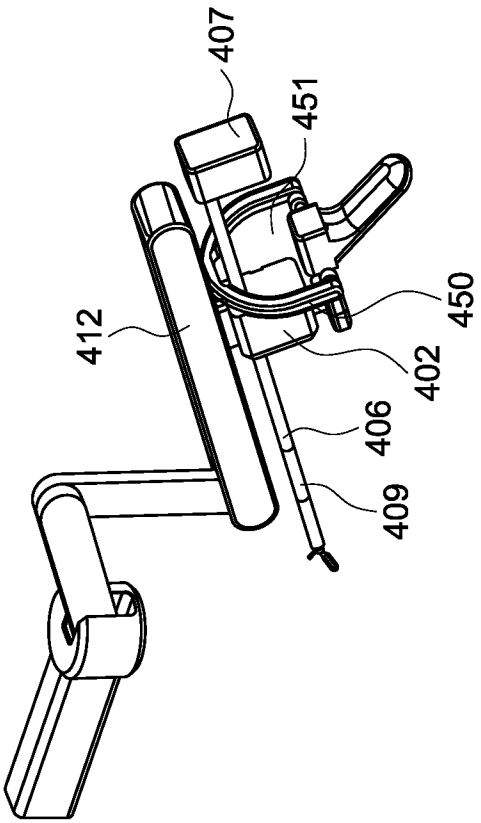

FIG. 23B

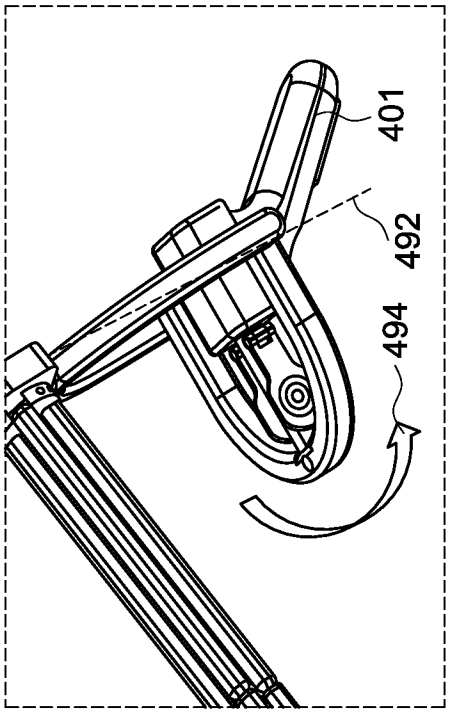

FIG. 24B

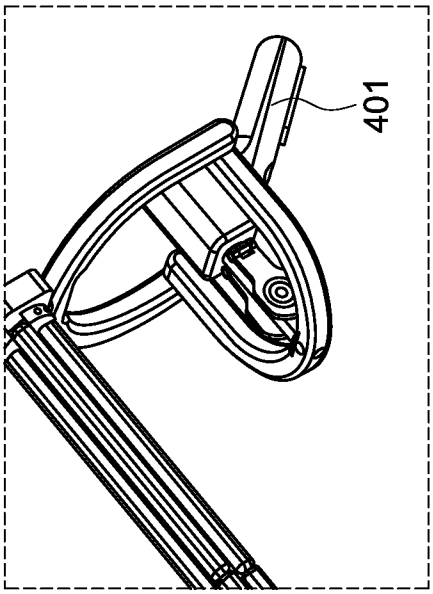

FIG. 24A

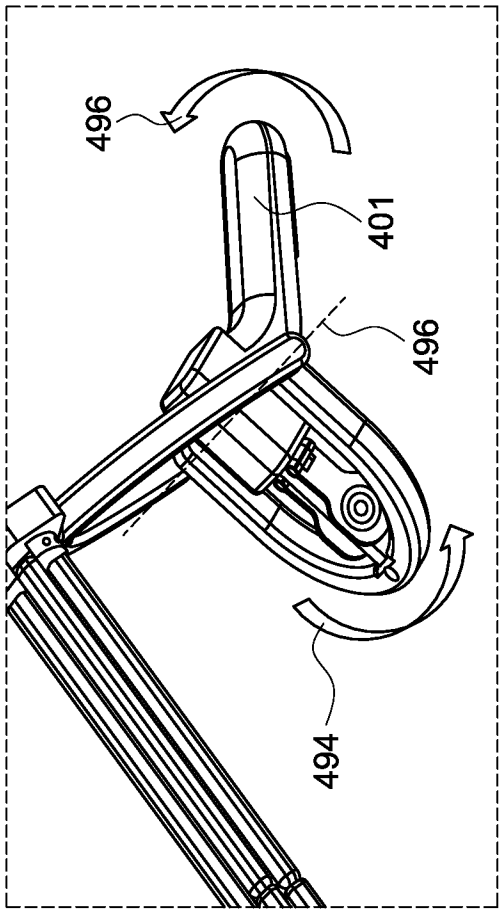

FIG. 24C

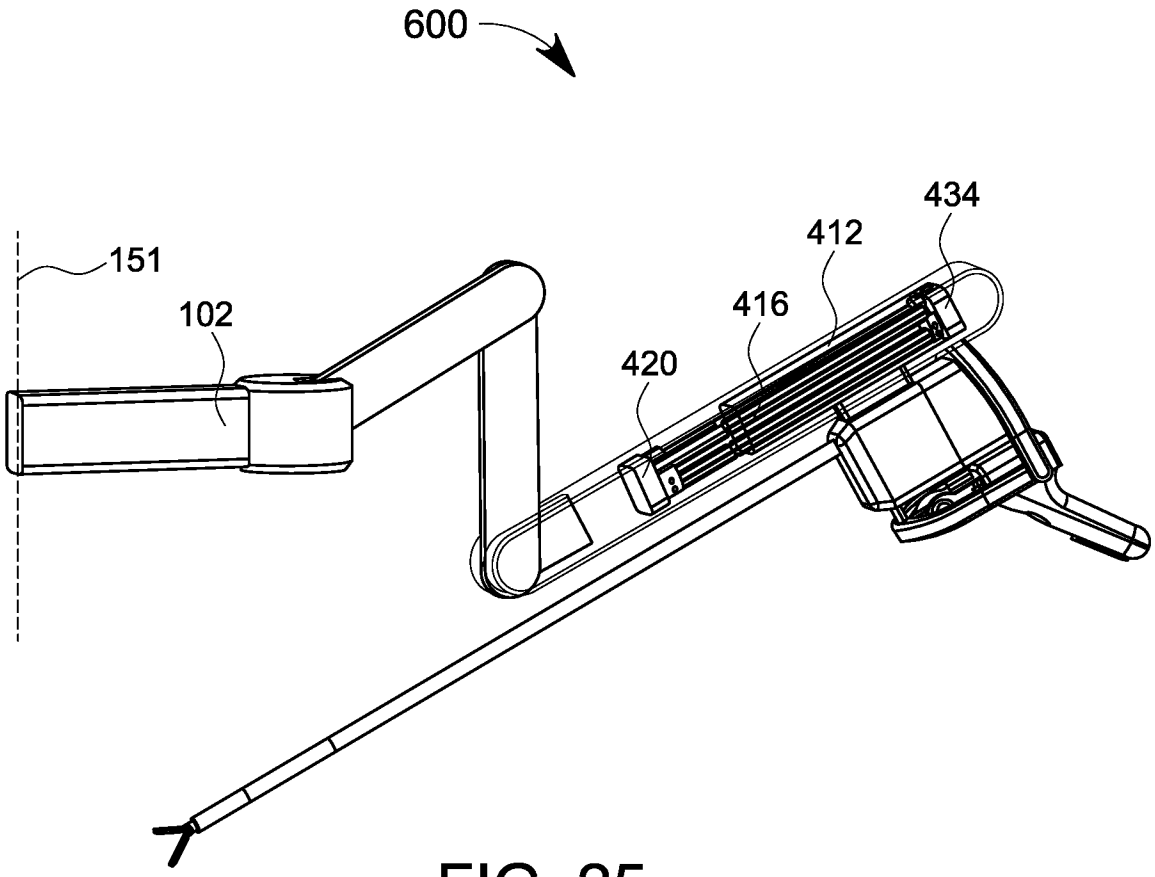

FIG. 25

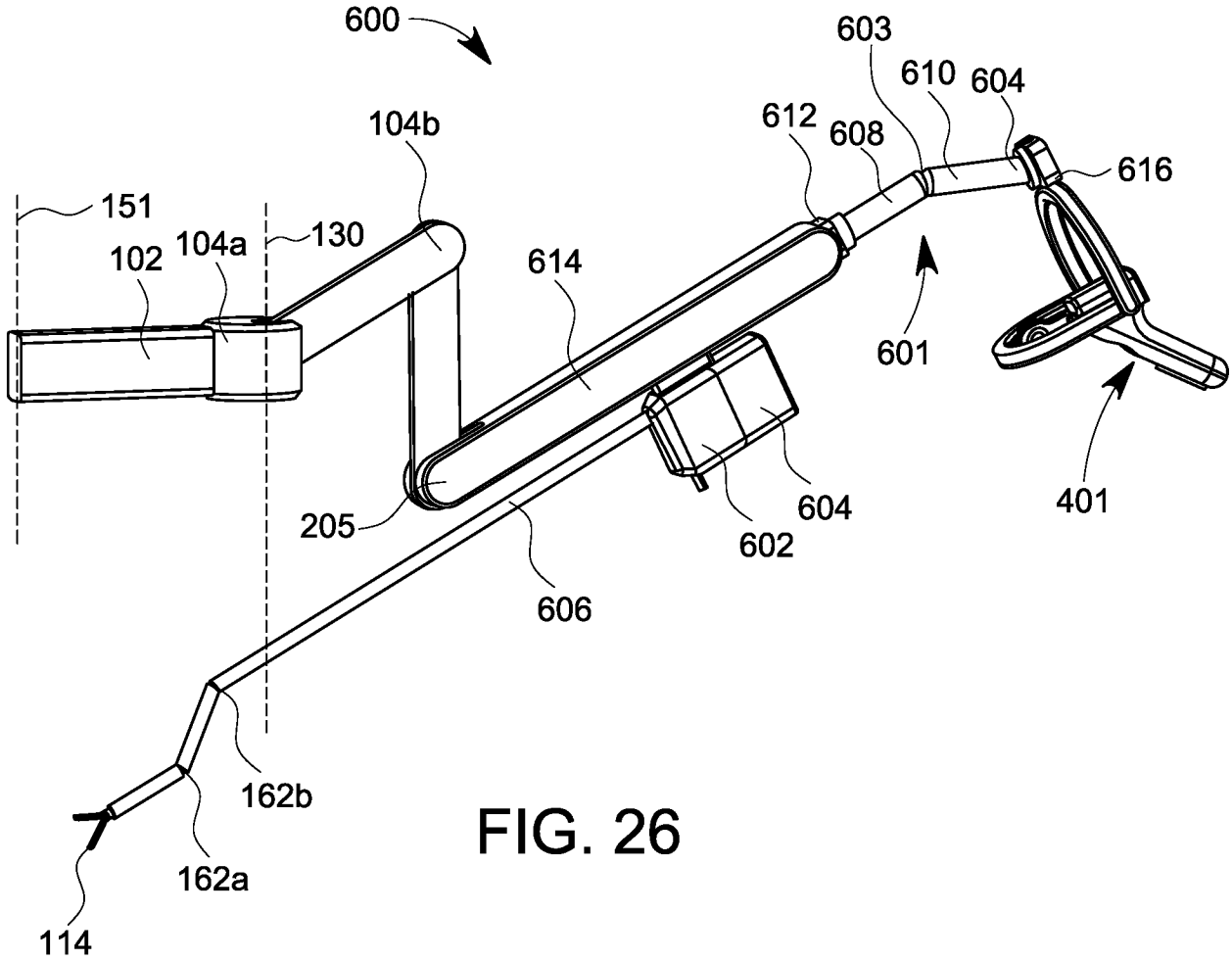
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FIG. 26

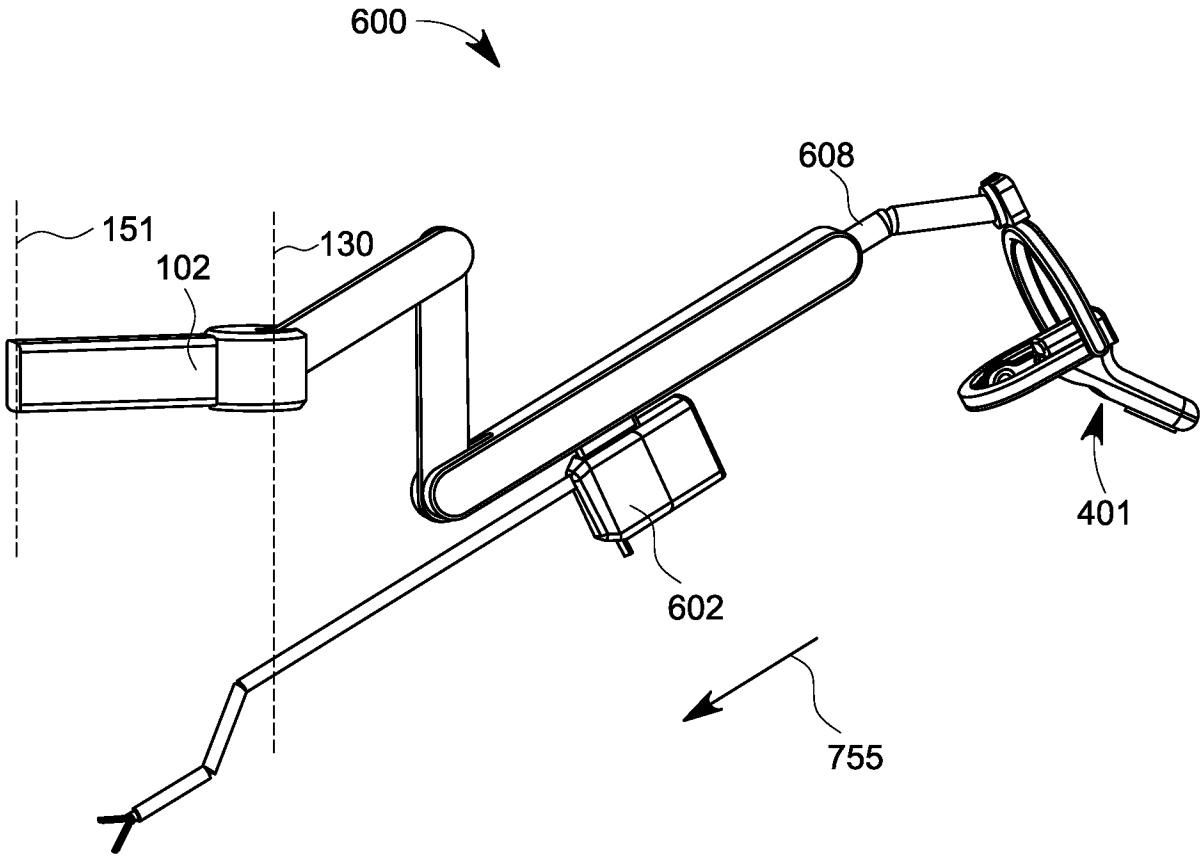

FIG. 27

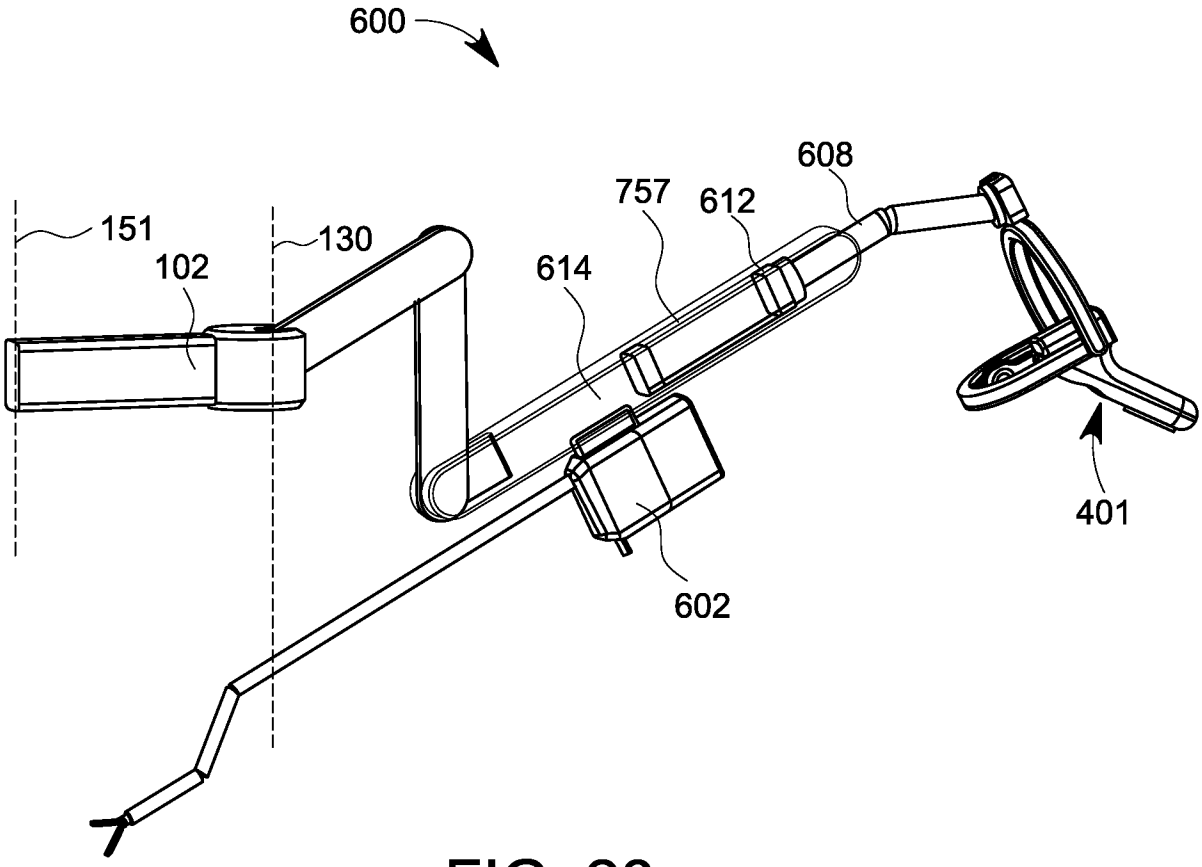

FIG. 28

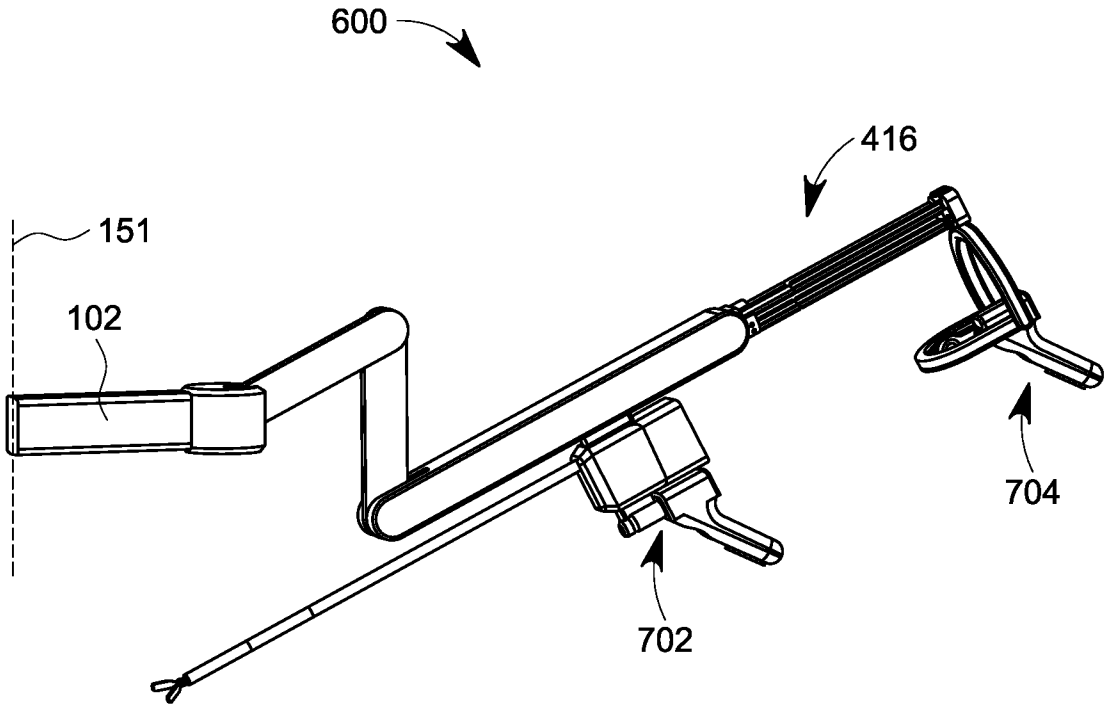

FIG. 29

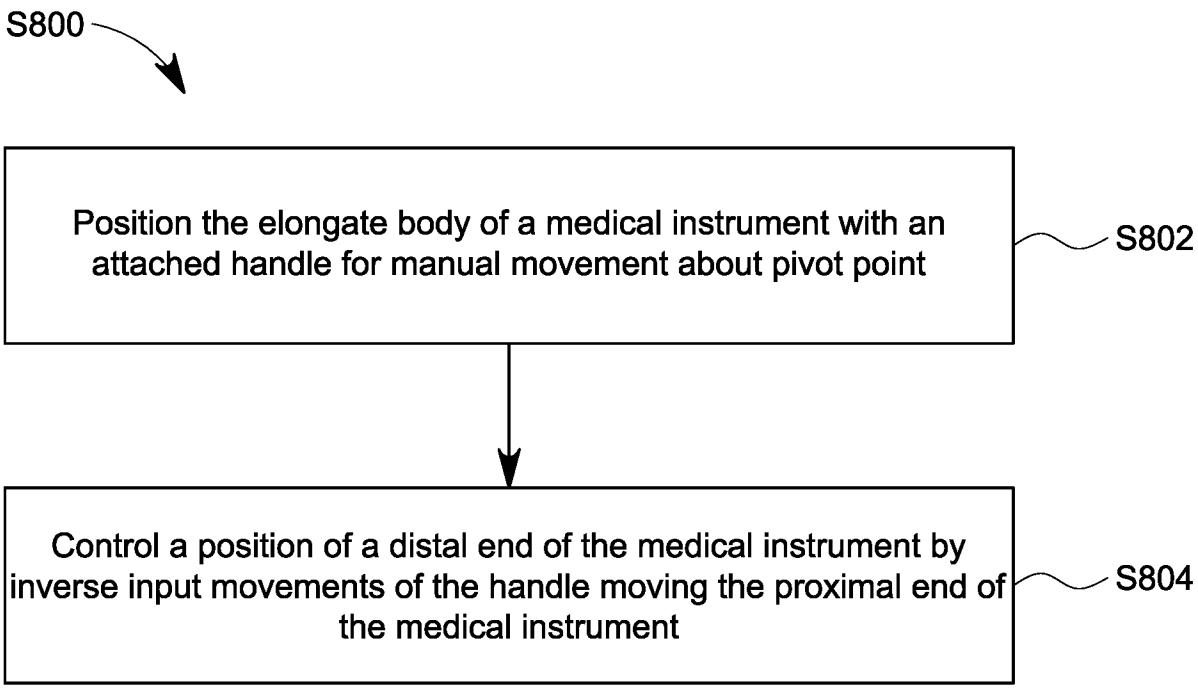
S800
Position the elongate body of a medical instrument with an attached handle for manual movement about pivot point
S802
Control a position of a distal end of the medical instrument by inverse input movements of the handle moving the proximal end of the medical instrument
S804

FIG. 30

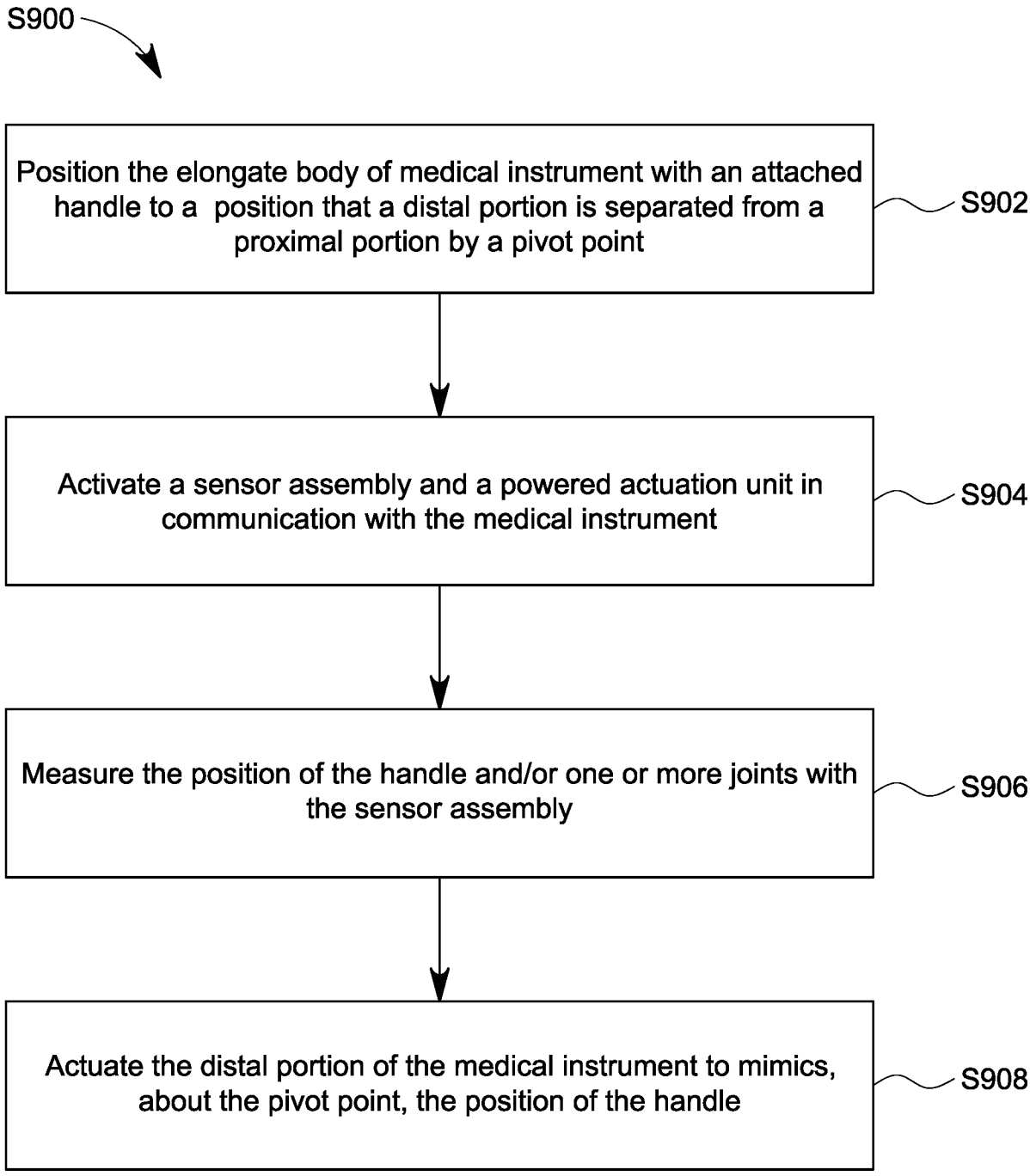
S900
Position the elongate body of medical instrument with an attached handle to a position that a distal portion is separated from a proximal portion by a pivot point
S902
Activate a sensor assembly and a powered actuation unit in communication with the medical instrument
S904
Measure the position of the handle and/or one or more joints with the sensor assembly
S906
Actuate the distal portion of the medical instrument to mimics, about the pivot point, the position of the handle
S908

FIG. 31

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2024/051452

A. CLASSIFICATION OF SUBJECT MATTER

IPC: ***A61B 34/00*** (2016.01) , ***A61B 34/30*** (2016.01) , ***A61B 90/50*** (2016.01)

CPC: A61B 34/30 (2020.01) , A61B 34/70 (2020.01) , A61B 90/50 (2020.01)

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)
IPC: ***A61B 34***+, ***A61B 90***+
CPC: ***A61B 34/30***, ***A61B 34/70***, ***A61B 90/50***

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

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)

Database: Questel Orbit
Keywords: fulcrum, "minimal invasive", pivot/rotate/roll, handle/sleeve, joint/arm/link, sens+/encod+, actuat+/interface, slid*/translat+/movable/extend+/retract+, distal/end/effector

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US6325808B1 (BERNARD, C. J. et al.) 4 December 2001 (04-12-2001) * figs. 1-5, 28; column 2, lines 31-32, 37-38, 51-56, 62-65, column 4, lines 21-25, 31-33, 49-55, column 5, lines 1, 19, 29-32, 39-40, 65-67, column 7, lines 19-22, 25-29, 34-37, 40-46, 59-61, column 8, lines 6-9, 13-16, column 9, lines 30-32, 41-45, column 11, lines 14-19, 41-48*	30-32
Y		1-27
Y	US20210369351A1 (KURODA, Y. et al.) 2 December 2021 (02-12-2021) * FIGs. 1-3; paras. [0116]-[0119], [0121], [0131]-[0135], [0141]-[0144]*	1-27
Y	WO2011002215A2 (CHOI, S. W. et al.) 6 January 2011 (06-01-2011) * FIGs. 1, 5, 7; paras. [16], [50]-[54], [60], [99]-[103], [124]*	1-27

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

*	Special categories of cited documents:	"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
"A"	document defining the general state of the art which is not considered to be of particular relevance	"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
"D"	document cited by the applicant in the international application	"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
"E"	earlier application or patent but published on or after the international filing date	"&"	document member of the same patent family
"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)		
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 22 May 2024 (22-05-2024)	Date of mailing of the international search report 22 May 2024 (22-05-2024)
Name and mailing address of the ISA/CA Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 819-953-2476	Authorized officer Li Lou Jiang

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN112716606A (SHI, H. et al.) 30 April 2021 (30-04-2021) * FIGs. 1-3; paras. [0030]-[0034]*	
A	US20170086932A1 (AULD, M. D. et al.) 30 March 2017 (30-03-2017) * FIGs. 4, 5; paras. [0076]-[0078]*	

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of the 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. ☒ Claim Nos.: 28 and 29
because they relate to subject matter not required to be searched by this Authority, namely:

Claims 28 and 29 are directed to a surgical method, which the International Searching Authority is not required to search under PCT Rule 39.1(iv).

2. ☐ Claim 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. ☐ Claim 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:

The claims are directed to a plurality of inventive concepts as follows:

Group A - Claims 1-29 are directed to a system for performing minimally invasive surgery (MIS) and a method for performing MIS, having the following features specific to this group: comprising a handle comprising one or more sensorized joints; and

Group B - Claims 30-32 are directed to a handle for performing minimally invasive surgery, having the following features specific to this group: comprising a second input mechanism configured to select a fulcrum corrected mode.

The claims cannot be considered to be one invention in the sense of being so linked to form a single general inventive concept because each of the groups possess different special technical features and these features do not share any technical relationship.

The claims must be limited to one inventive concept as set out in PCT Rule 13.

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 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 claim 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 claim 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.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2024/051452

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
US6325808B1	04 December 2001 (04-12-2001)	None	
US2021369351A1	02 December 2021 (02-12-2021)	US11612306B2	28 March 2023 (28-03-2023)
		CN111278344A	12 June 2020 (12-06-2020)
		CN111278344B	05 September 2023 (05-09-2023)
		EP3705018A1	09 September 2020 (09-09-2020)
		EP3705018A4	14 October 2020 (14-10-2020)
		JPWO2019087904A1	10 December 2020 (10-12-2020)
		JP7115493B2	09 August 2022 (09-08-2022)
		WO2019087904A1	09 May 2019 (09-05-2019)
WO2011002215A2	06 January 2011 (06-01-2011)	WO2011002215A3	28 April 2011 (28-04-2011)
		CN102469995A	23 May 2012 (23-05-2012)
		CN102469995B	11 March 2015 (11-03-2015)
		KR20110003229A	11 January 2011 (11-01-2011)
		KR101180665B1	07 September 2012 (07-09-2012)
CN112716606A	30 April 2021 (30-04-2021)	None	
US2017086932A1	30 March 2017 (30-03-2017)	US10258419B2	16 April 2019 (16-04-2019)