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(54) ACTIVE DRIVE MECHANISM FOR SIMULTANEOUS ROTATION AND TRANSLATION

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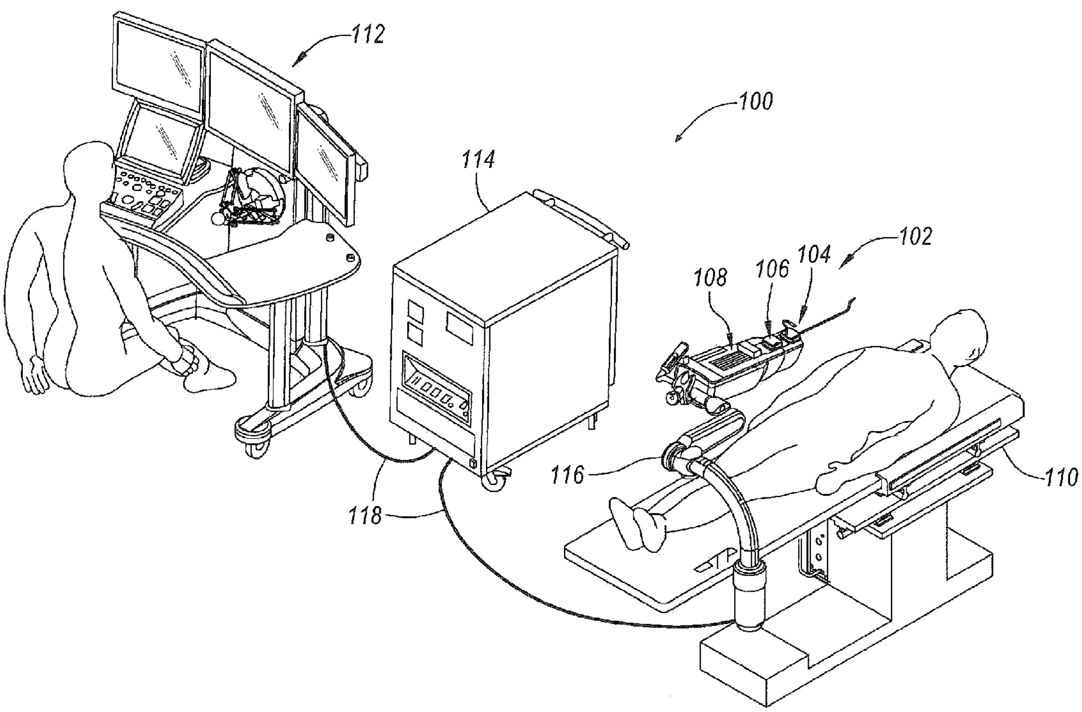
(57) **ABSTRACT**

An exemplary drive apparatus is disclosed having a roller assembly configured to impart axial motion to the elongate member along a first continuous surface configured to maintain contact with the elongate member during axial motion. The drive apparatus may further include a roller support configured to rotate the roller assembly, thereby imparting rotational motion to the elongate member. The roller support may be configured to rotate the roller assembly about a second continuous surface configured to maintain contact with the roller support during rotational motion. Moreover, the roller assembly and roller support may be configured to impart axial and rotational motion independently of one another, such that a first one of the roller assembly and the roller support imparts their associated motion regardless of a presence or absence of motion by the other of the roller assembly and the roller support.



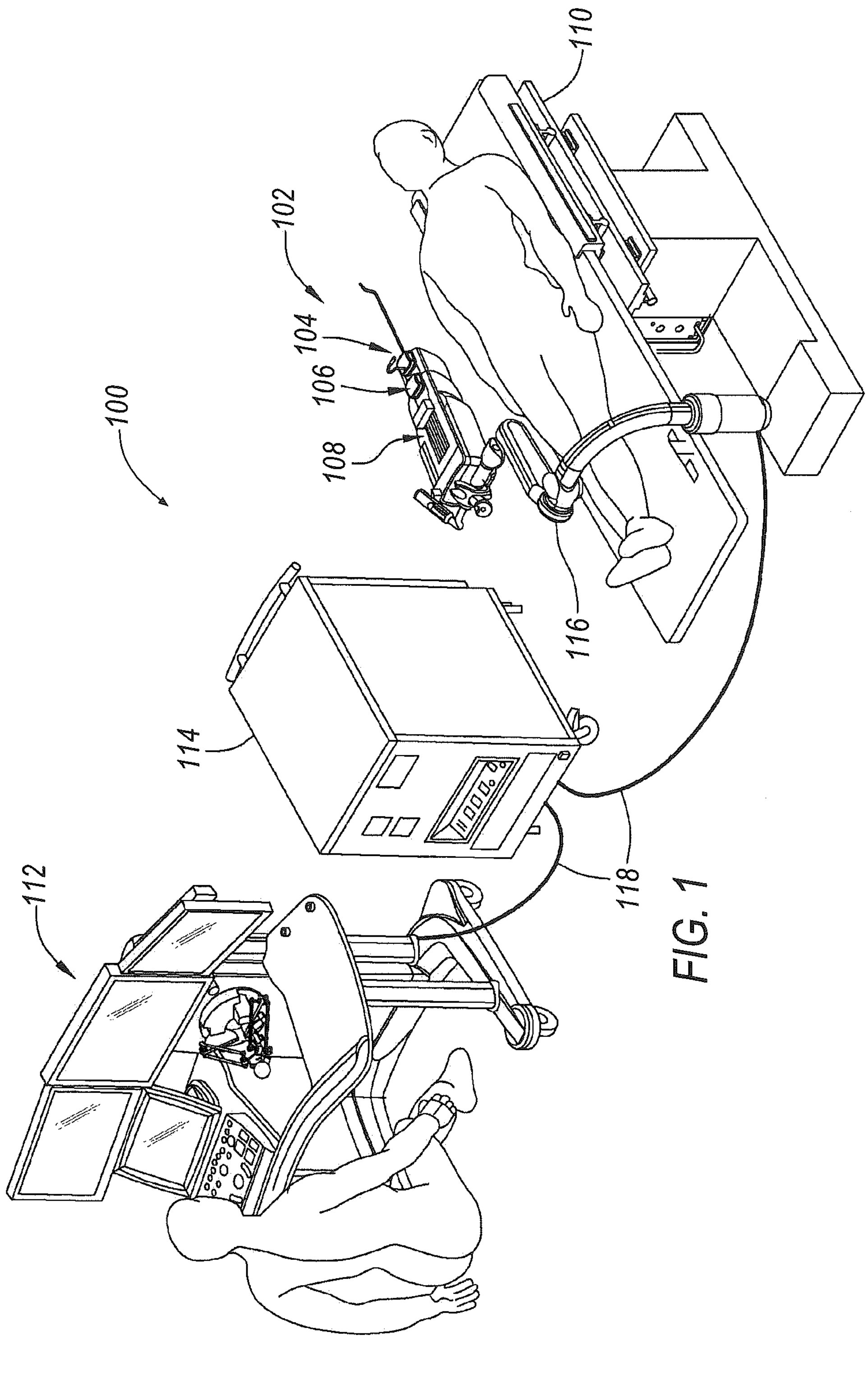


FIG. 1

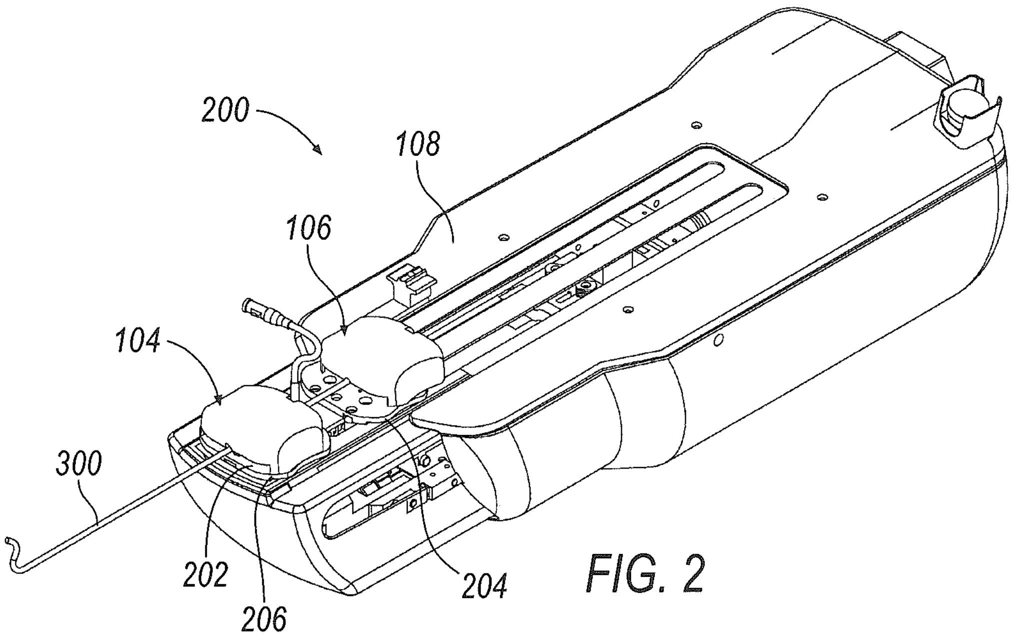


FIG. 2

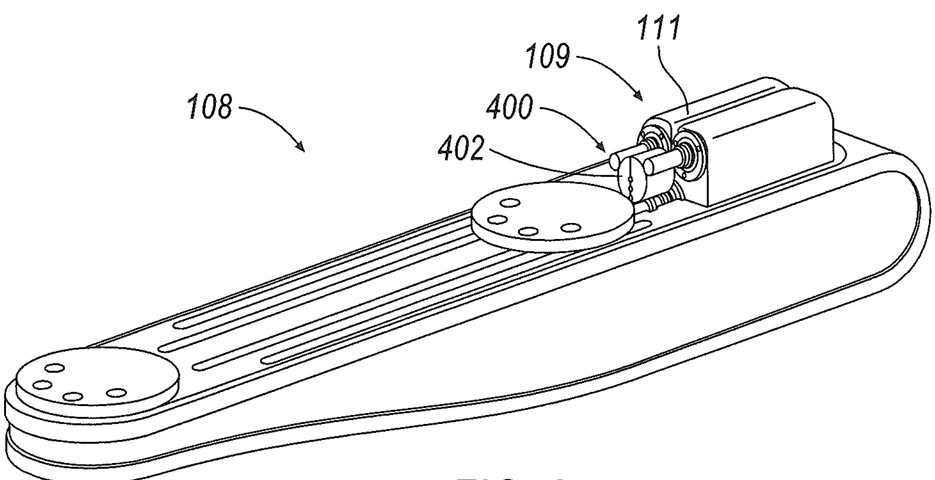


FIG. 3

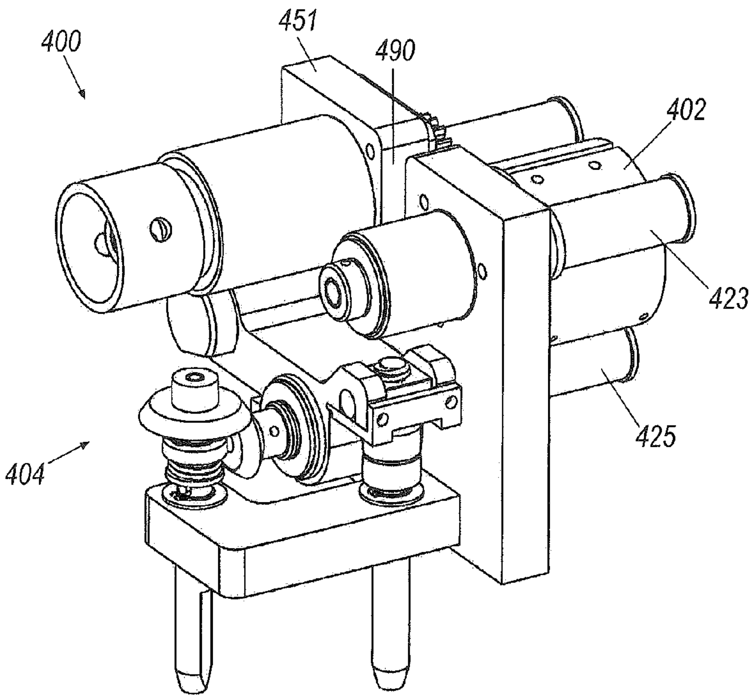


FIG. 4

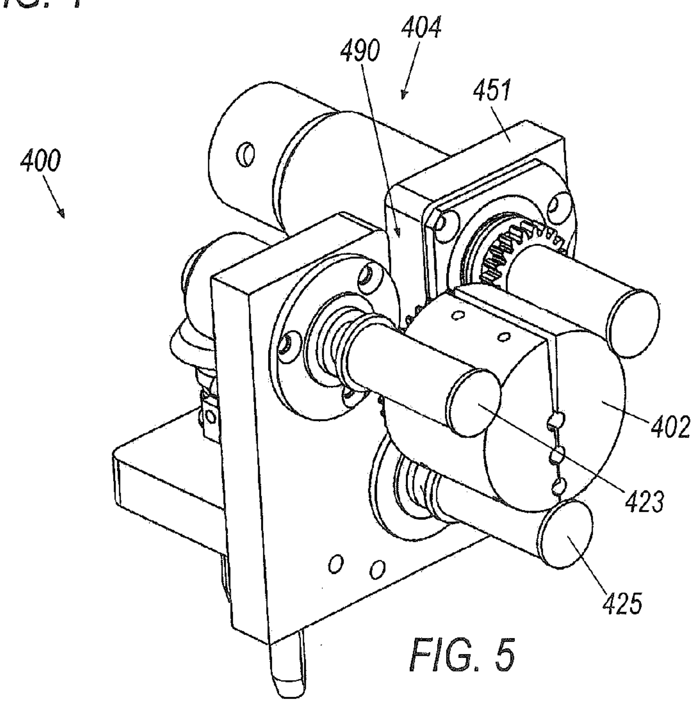


FIG. 5

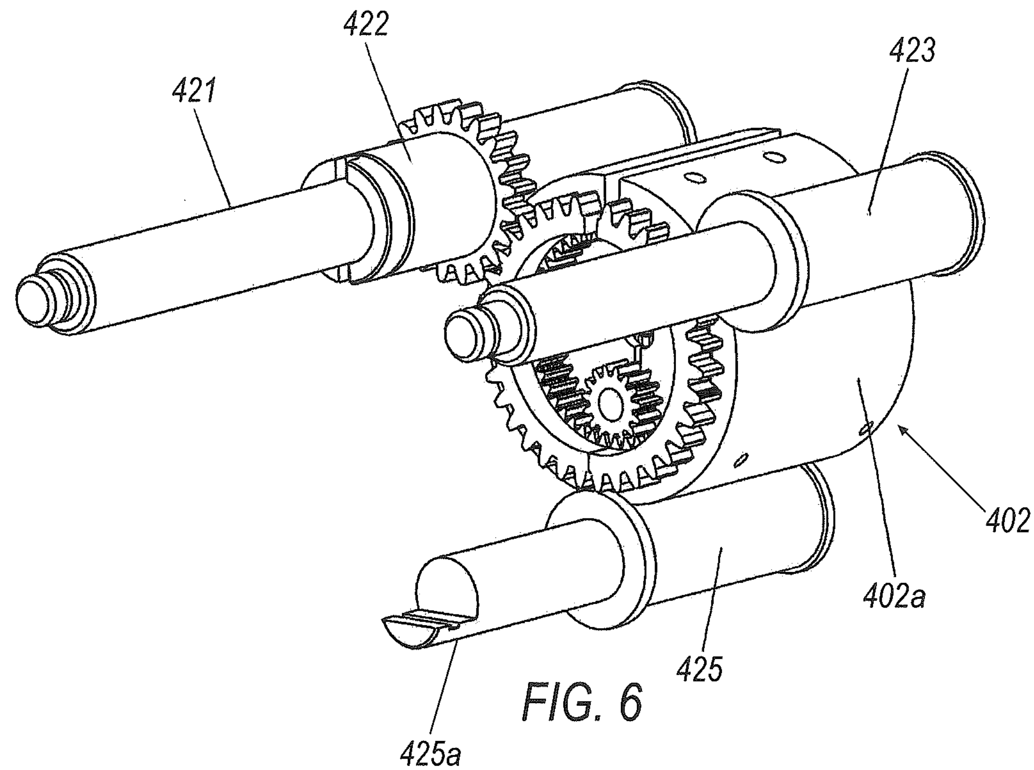


FIG. 6

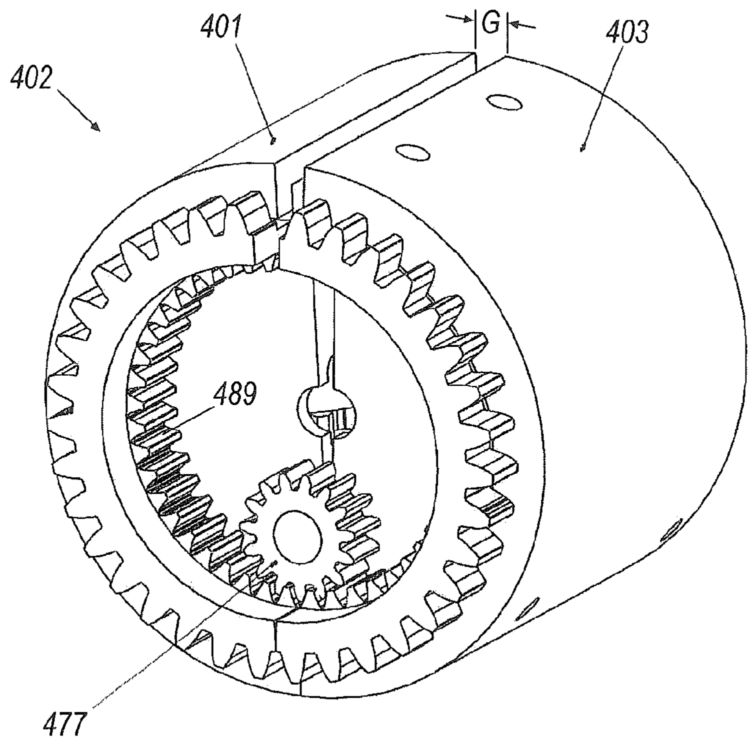


FIG. 7

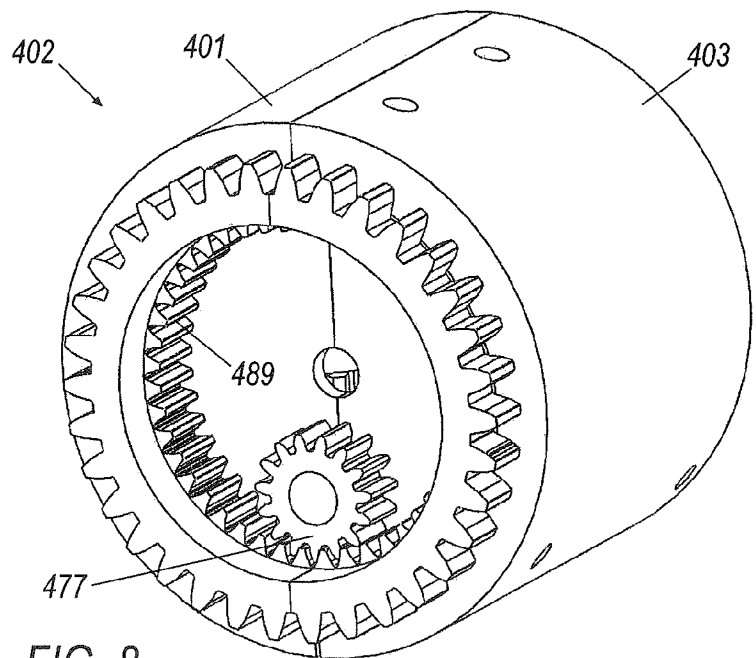


FIG. 8

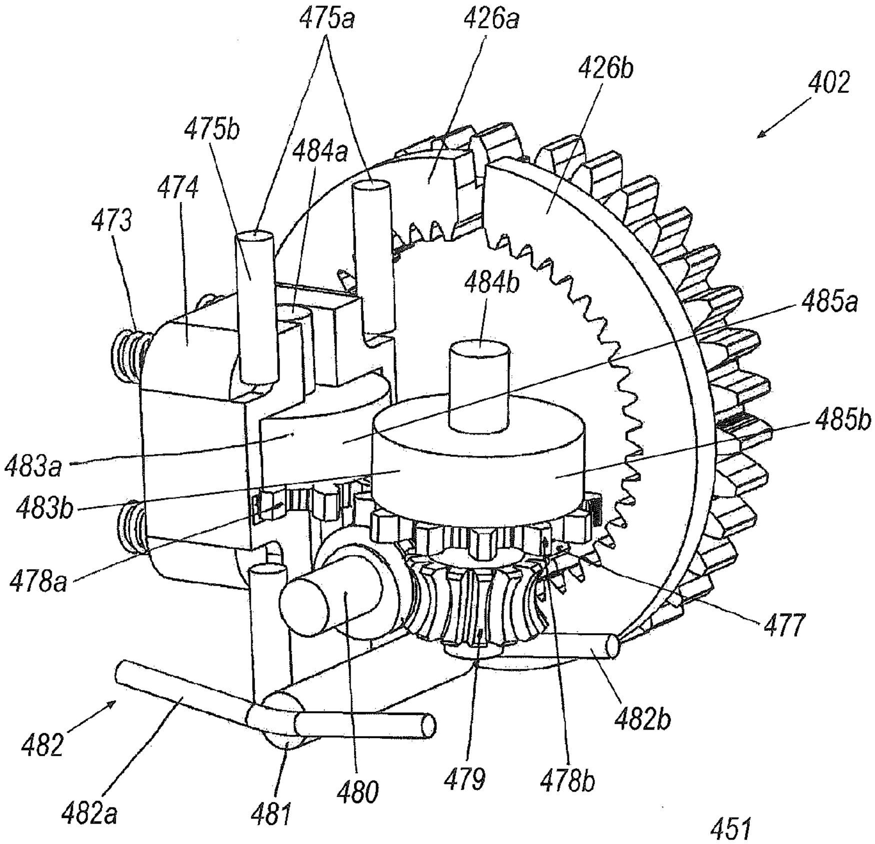

475a
426a
426b
402
475b
484a
474
473
484b
485a
485b
483a
483b
478a
477
482
482b
482a
481
480
479
478b

FIG. 9

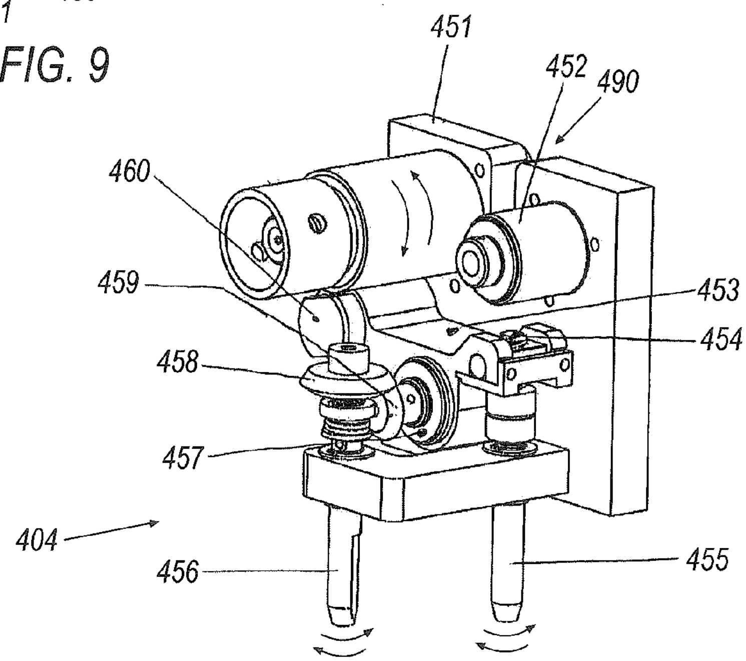

451
452
490
460
459
453
454
458
457
404
456
455

FIG. 10

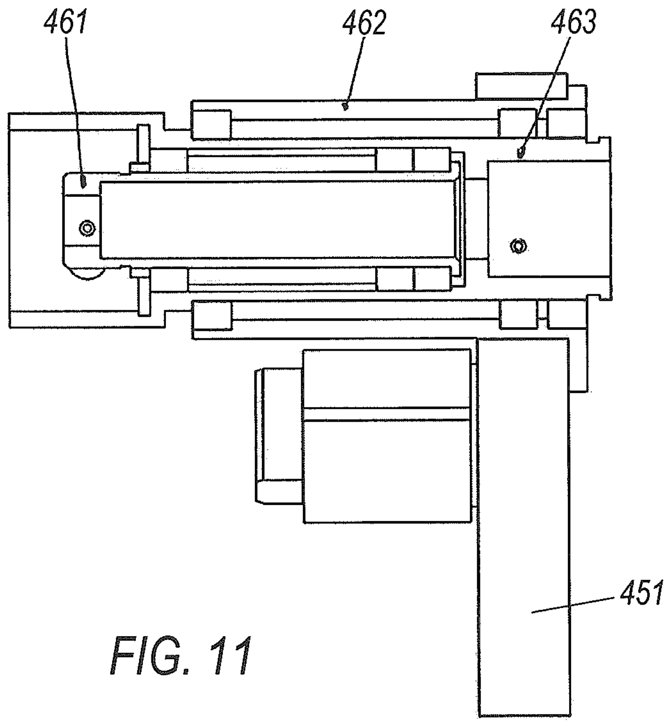


FIG. 11

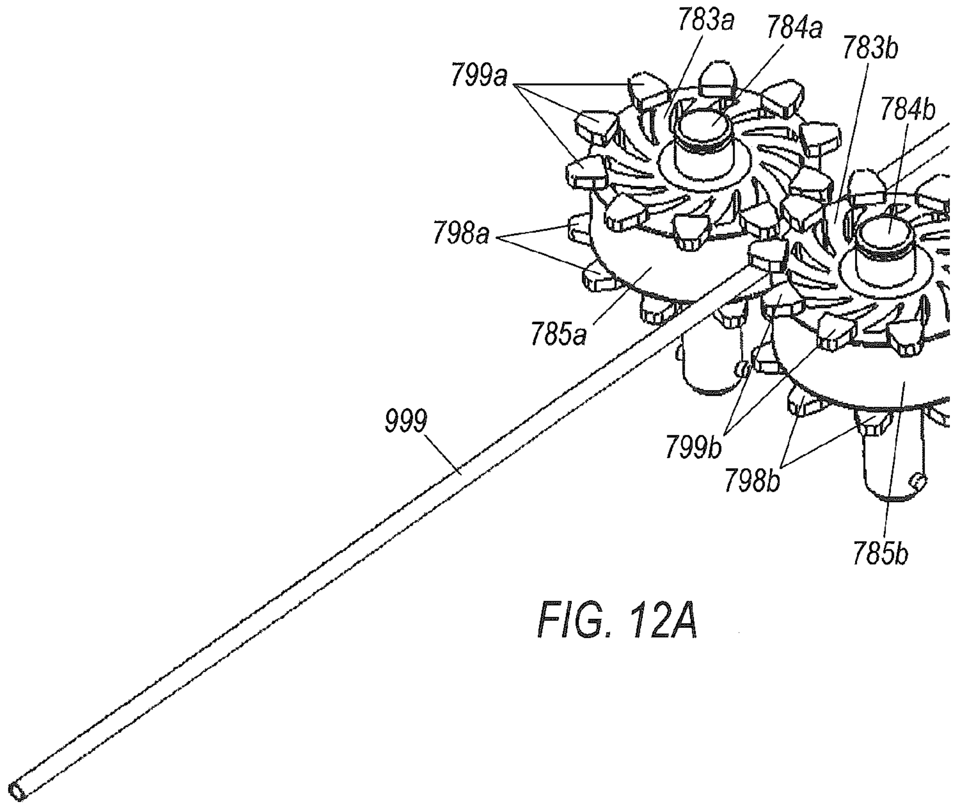


FIG. 12A

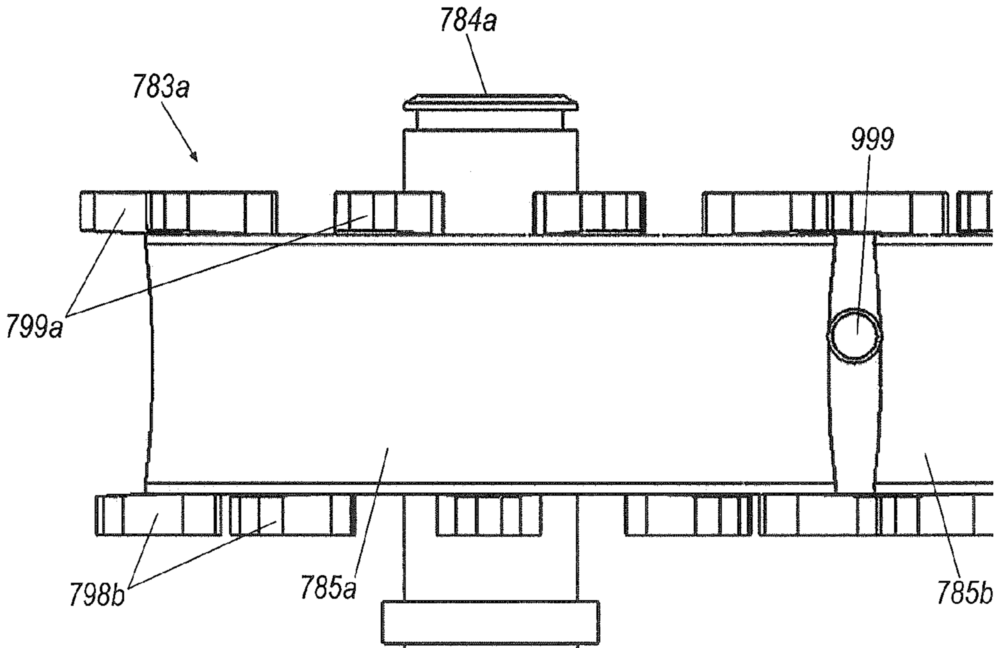


FIG. 12B

ACTIVE DRIVE MECHANISM FOR SIMULTANEOUS ROTATION AND TRANSLATION

BACKGROUND

[0001] Robotic interventional systems and devices are well suited for performing minimally invasive medical procedures as opposed to conventional techniques wherein the patient's body cavity is open to permit the surgeon's hands access to internal organs. However, advances in technology have led to significant changes in the field of medical surgery such that less invasive surgical procedures, in particular, minimally invasive surgery (MIS), are increasingly popular.

[0002] MIS is generally defined as surgery that is performed by entering the body through the skin, a body cavity, or an anatomical opening utilizing small incisions rather than large, open incisions in the body. With MIS, it is possible to achieve less operative trauma for the patient, reduced hospitalization time, less pain and scarring, reduced incidence of complications related to surgical trauma, lower costs, and a speedier recovery.

[0003] Special medical equipment may be used to perform MIS procedures. Typically, a surgeon inserts small tubes or ports into a patient and uses endoscopes or laparoscopes having a fiber optic camera, light source, or miniaturized surgical instruments. Without a traditional large and invasive incision, the surgeon is not able to see directly into the patient. Thus, the video camera serves as the surgeon's eyes. The images of the interior of the body are transmitted to an external video monitor to allow a surgeon to analyze the images, make a diagnosis, visually identify internal features, and perform surgical procedures based on the images presented on the monitor.

[0004] MIS devices and techniques have advanced to the point where an insertion and rolling motion of components of an elongated component such as a catheter instrument, e.g., a catheter sheath and associated guidewire, are generally controllable by selectively operating rollers or other mechanisms for generally gripping the component. Some known mechanisms use gripping devices capable of infinite motion for translation, e.g., a roller, may require complex catheter component loading procedures, or may not be compatible with replaceable components adapted for a sterile operating environment.

[0005] Accordingly, there is a need in the art for systems and methods for inserting and rolling catheter components that address or solve the above problems.

SUMMARY

[0006] An exemplary drive apparatus is disclosed having a roller assembly configured to impart axial motion to the elongate member along a first continuous surface configured to maintain contact with the elongate member during axial motion. The drive apparatus may further include a roller support configured to rotate the roller assembly, thereby imparting rotational motion to the elongate member. The roller support may be configured to rotate the roller assembly about a second continuous surface configured to maintain contact with the roller support during rotational motion. Moreover, the roller assembly and roller support may be configured to impart axial and rotational motion independently of one another, such that a first one of the roller assembly and the roller support imparts their associated motion regardless of a presence or absence of motion by the other of the roller assembly and the roller support.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] While the claims are not limited to the illustrated embodiments, an appreciation of various aspects is best gained through a discussion of various examples thereof. Referring now to the drawings, illustrative embodiments are shown in detail. Although the drawings represent the embodiments, the drawings are not necessarily to scale and certain features may be exaggerated to better illustrate and explain an innovative aspect of an embodiment. Further, the embodiments described herein are not intended to be exhaustive or otherwise limiting or restricting to the precise form and configuration shown in the drawings and disclosed in the following detailed description. Exemplary embodiments of the present invention are described in detail by referring to the drawings as follows.

[0008] FIG. **1** is an illustration of a robotically controlled surgical system, according to one exemplary illustration;

[0009] FIG. **2** is an illustration of an exemplary catheter assembly of the surgical system of FIG. **1**;

[0010] FIG. **3** is another exemplary illustration of an exemplary catheter assembly of the surgical system of FIG. **1**;

[0011] FIG. **4** is a rear perspective view of an exemplary drive apparatus for an elongated member, e.g., a guidewire for a catheter;

[0012] FIG. **5** is a front perspective view of the exemplary drive apparatus of FIG. **4**;

[0013] FIG. **6** is a rear perspective view of the exemplary drive apparatus of FIG. **4**, with a support plate removed;

[0014] FIG. **7** is a rear perspective view of a disposable device for the exemplary drive apparatus of FIG. **4**, with the disposable device in an open position;

[0015] FIG. **8** is a rear perspective view of the split clamp assembly of FIG. **7**, with the disposable device in a closed position;

[0016] FIG. **9** is a front perspective view of the disposable device of FIG. **7**, with the disposable device in an open position and shown without a split housing;

[0017] FIG. **10** is a rear perspective view of a drive mechanism for the exemplary drive apparatus of FIG. **4**;

[0018] FIG. **11** is a section view of the exemplary drive mechanism taken through line **11-11** in FIG. **10**;

[0019] FIG. **12**A is a perspective view of another roller assembly with an elongated member, according to an exemplary illustration; and

[0020] FIG. **12**B is a front perspective view of the exemplary roller assembly of FIG. **12**A.

DETAILED DESCRIPTION

[0021] Referring now to the drawings, illustrative embodiments are shown in detail. Although the drawings represent the embodiments, the drawings are not necessarily to scale and certain features may be exaggerated to better illustrate and explain an innovative aspect of an embodiment. Further, the embodiments described herein are not intended to be exhaustive or otherwise limit or restrict the invention to the precise form and configuration shown in the drawings and disclosed in the following detailed description.

[0022] Referring to FIG. **1**, a robotically controlled surgical system **100** is illustrated in which an apparatus, a system, and/or method may be implemented according to various exemplary illustrations. System **100** may include a robotic catheter assembly **102** having a robotic or first or outer steerable complement, otherwise referred to as a sheath instrument **104** (generally referred to as "sheath" or "sheath instrument") and/or a second or inner steerable component, otherwise referred to as a robotic catheter or guide or catheter instrument **106** (generally referred to as "catheter" or "catheter instrument"). Catheter assembly **102** is controllable using a robotic instrument driver **108** (generally referred to as "instrument driver"). During use, a patient is positioned on an operating table or surgical bed **110** (generally referred to as "operating table") to which robotic instrument driver **108** may be coupled or mounted. In the illustrated example, system **100** includes an operator workstation **112**, an electronics rack **114** and associated bedside electronics box (not shown), a setup joint mounting brace **116**, and instrument driver **108**. A surgeon is seated at operator workstation **112** and can monitor the surgical procedure, patient vitals, and control one or more catheter devices. Operator workstation **112** may include a computer monitor to display a three dimensional object, such as a catheter instrument or component thereof, e.g., a guidewire, catheter sheath. Moreover, catheter instrument **502** may be displayed within or relative to a three dimensional space, such as a body cavity or organ, e.g., a chamber of a patient's heart. In one example, an operator uses a computer mouse to move a control point around the display to control the position of catheter instrument.

[0023] System components may be coupled together via a plurality of cables or other suitable connectors **118** to provide for data communication, or one or more components may be equipped with wireless communication components to reduce or eliminate cables **118**. Communication between components may also be implemented over a network or over the interne. In this manner, a surgeon or other operator may control a surgical instrument while being located away from or remotely from radiation sources, thereby decreasing radiation exposure. Because of the option for wireless or networked operation, the surgeon may even be located remotely from the patient in a different room or building.

[0024] Referring now to FIG. **2**, an exemplary instrument assembly **200** is shown, including sheath instrument **104** and the associated guide or catheter instrument **106** mounted to mounting plates **202**, **204** on a top portion of instrument driver **108**. During use, catheter instrument **106** is inserted within a central lumen of sheath instrument **104** such that instruments **104**, **106** are arranged in a coaxial manner. Although instruments **104**, **106** are arranged coaxially, movement of each instrument **104**, **106** can be controlled and manipulated independently. For this purpose, motors within instrument driver **108** are controlled such that carriages coupled to each of the instruments **104**, **160** may allow the instruments **104**, **106** to be driven forwards and backwards along the driver **108**, e.g., with mounting plates securing the instruments to the driver **108** on bearings. As a result, a catheter **300** coupled to guide catheter instrument **106** and sheath instrument **104** can be controllably manipulated while inserted into the patient, as will be further illustrated. Additional instrument driver **108** motors (not shown in FIG. **2**) may be activated to control bending of the catheter as well as the orientation of the distal tips thereof, including tools mounted at the distal tip. Sheath catheter instrument **106** is configured to move forward and backward for effecting an axial motion of the catheter, e.g., to insert and withdraw the catheter from a patient, respectively.

[0025] Referring now to FIG. **3**, another exemplary instrument **109** is illustrated mounted on theexemplary instrument driver **108**. The instrument **109** includes a cover **111** and a drive apparatus **400** partially extending out of the cover, as will be described further in regard to FIGS. **4-11**. More specifically, as will be described further, the drive apparatus **400** may include a disposable portion **402** which extends out of the housing **111**, while an associated drive mechanism (not seen in FIG. **3**) remains within the housing **111**. Accordingly, the drive mechanism (not shown in FIG. **3**) may generally be reused for surgical procedures, while the disposable portion **402** may part of a sterile environment associated with a surgical procedure and may be disposed of afterwards. Moreover, as will be described further below the disposable portion **402** may be formed of relatively cost-effective materials and may be of a generally small relative size, minimizing a length of the elongate member that must be allowed for the drive mechanism **400** to properly "grip" the elongate member, and increasing cost-effectiveness of the system **100** overall.

[0026] During use the instrument **109** may be used to manipulate an elongate member included in the catheter assembly **102**, e.g., a catheter guidewire (not shown in FIG. **3**). Alternatively, the instrument **109** may be employed to manipulate a catheter sheath (not shown in FIG. **3**). Although a single instrument **109** is illustrated in FIG. **3**, in another exemplary illustration two instruments **109** may be employed in which a first instrument **109** is used to insert and roll a guidewire, which guidewire is inserted within a central lumen of a second instrument **109** (not shown in FIG. **3**) such that the two instruments **109** are arranged in a coaxial manner, substantially as described above regarding the instruments **104**, **106**. Additionally, the instruments **109** may generally insert and rotate the associated elongate member, i.e., the guidewire and catheter sheath, independently, as described above regarding the instruments **104**, **106**. Accordingly, while the exemplary illustrations herein may generally focus on the insertion and rotation of a guidewire for a catheter, the instrument **109** may be used for insertion and rotation of any elongate member that is convenient.

[0027] Turning now to FIGS. **4-11**, exemplary drive apparatus **400** is illustrated in further detail. As noted above, the drive apparatus **400** may include a disposable mechanism **402** for contacting and driving an elongate member, e.g., a guidewire or catheter. An associated drive mechanism **404** may generally be configured to be kept separate from the disposable mechanism **402**, at least to an extent allowing the drive mechanism **404** to be kept out of a sterile environment associated with the elongate member and surgical procedure. As best seen in FIGS. **4-6**, the disposable mechanism **402** may be supported between two idle rollers **421**, **423**, and a driving roller **425** which is configured to rotate the disposable mechanism **402** to impart rotational motion to the elongate member, as will be described further below. Moreover, the idle roller **421** may include a driving gear **422** for selectively imparting axial motion, i.e., insertion or retraction, of an elongate member, as will also be further described below.

[0028] The disposable portion **402** may include a roller assembly, e.g., comprising one or more rollers **483** that are configured to impart axial motion to the elongate member along a first continuous surface. For example, as best seen in FIG. **9**, a roller **483***a* and a second roller **483***b* each define generally cylindrical surfaces **485***a*, **485***b* that are configured to maintain contact with the elongate member during axial motion, i.e., caused by rotation of the rollers **483**. The drive apparatus **400** may further include a roller support configured to rotate the roller assembly, i.e., at least one of the rollers **483**, thereby imparting rotational motion to the elongate member. For example, as will be described further below, the rollers **483** may generally be supported within the clamps **401**, **403** of the disposable portion, e.g., via a saddle **474** or by the clamps **401**, **403** themselves, such that the rollers **483** may be rotated about an axis defined by the elongate member. Moreover, the roller support may be configured to rotate the roller assembly about a second continuous surface configured to maintain contact with the roller support during rotational motion, thereby permitting generally any magnitude of rotational motion. Moreover, the roller assembly and roller support may be configured to impart axial and rotational motion independently of one another, such that a first one of the roller assembly and the roller support imparts their associated motion regardless of a presence or absence of motion by the other of the roller assembly and the roller support. More specifically, as will be described further below the rollers **483** may generally rotate about their respective spindles to provide axial motion, regardless of whether the spindles themselves are being rotated about the axis of the elongate member. It should be noted that while one set of rollers **483** is shown, multiple sets of rollers could be incorporated, e.g., in series, to provide additional traction on the elongate member for axial and rotational movement thereof.

[0029] Turning now to FIG. **7**, the disposable drive mechanism **402** may include a left clamp **401** and a right clamp **403**, as best seen in FIG. **7**. The left and right clamps **401**, **403** may be connected to each other with a compliant member **482** configured to maintain the left and right clamps **401**, **403** together in an open position as illustrated in FIG. **7**. More specifically, in the open position the left and right clamps **401**, **403** are held together along a lower portion and are spaced apart by a gap G along an upper portion of the clamps **401**, **403**. In one exemplary illustration, the compliant member **482** includes first and second memory wires **482***a*, **482***b*, e.g., nitinol wires, which generally act similar to a spring in holding the clamps together in the open configuration shown in FIG. **7**. The memory wires **482***a*, **482***b* may generally provide a locating feature for the roller assembly, thereby generally positioning the rollers **483***a*, **483***b* within the clamps **401**, **403**, as best seen in FIG. **9**.

[0030] Referring now to FIG. **9**, the disposable mechanism **402** is illustrated with the left and right clamps **401**, **403** (not shown in FIG. **9**) removed. The disposable drive mechanism **402** includes a roller assembly, e.g., having one or more rollers **483***a*, **483***b* for imparting axial motion to the elongate member. As shown in FIG. **9**, two rollers **483***a*, **483***b* may be configured to receive an elongate member (not shown in FIG. **9**) therebetween. More specifically, the rollers **483** may each rotate about corresponding spindles **484***a*, **484***b*. Moreover, as will be described further below the rollers **483***a*, **483***b* may each have a plurality of geared teeth **478***a*, **478***b* which are meshingly engaged such that the rotation of the rollers **483***a*, **483***b* is generally coordinated. The rollers **483***a*, **483***b* may each be generally round, thereby defining respective continuous surfaces **485***a*, **485***b* about the generally cylindrical rollers **483** for engaging the elongate member. More specifically, an axial movement of any distance may be applied by the rollers **483***a*, **483***b*, since the rollers **483***a*, **483***b* may continuously turn about the spindles **484** without limitation. Accordingly, axial motion of the elongate member is not limited by any range of motion of any component of the drive apparatus **400**, allowing the drive apparatus **400** to provide an axial movement in either direction of any magnitude while maintaining constant contact with the elongate member, i.e., by way of the generally looped or continuous surfaces **485***a*, **485***b* of the rollers **483***a*, **483***b*.

[0031] The roller assembly may be supported in a roller support configured to rotate the rollers about an axis perpendicular to the spindles **484** of the rollers **483**. For example, the spindle **484***a* of the roller **483***a* may be supported in a saddle **474** that is engaged with an interior surface of one of the clamps **401**, **403** (not shown in FIG. **9**) by way of a plurality of springs **473**. Radially inward movement of the saddle **474** away from the interior surface may be limited by stop pins **475**, which may engage an interior side of the saddle **474** to generally limit radially inward movement of the saddle **474** and the roller **483***a*, thereby limiting force applied by the roller **483***a* to the elongate member when the elongate member is positioned between the rollers **483***a*, **483***b*. The spindle **484***b* of the other roller **483***b* may be supported in the corresponding one of the clamps **401**, **403** (not shown in FIG. **9**). Accordingly, the spindle **484***b* may be generally fixed within the clamps **401**, **403** while the spindle **484***a* may be movable by way of the springs **473** to provide a clamping force upon the elongate member.

[0032] The disposable device **402** may further comprise gear halves **426***a*, **426***b* which define an inner toothed surface **489** engaging a drive pinion **477** (see FIGS. **7** and **8**). The drive pinion **477** may be engaged with a worm gear **479** by way of worm **480**, wherein the worm **480** is fixed for rotation with the drive pinion **477**. A location shaft **481** may be provided to assist with locating the above components within the clamps **401**, **403**, as will be described further below. Additionally, a compliant element **482** may be provided which generally provides a spring force urging the clamps **401**, **403** toward an open position, e.g., as seen in FIG. **7**.

[0033] The driving mechanism **404**, as best seen in FIGS. **10** and **11**, may include a front plate **451** having a channel **490** through which an elongate member may be received during operation. The driving mechanism may further include a right idle roll rotational assembly **452** which corresponds to right idle roller **423** (see FIGS. **4-6**). Additionally, a lever **453** is located on the front plate **451** by way of a pivot shaft **460**, about which the lever **453** may be pivoted by way of a threaded member **454**, which may be a driving screw. The driving mechanism **404** may include driving shafts **455** and **456**, which may be received within corresponding drive mechanisms (not shown) associated with the instrument driver **108** supporting the instrument **109** (see FIG. **3**). A driving roll rotational assembly **457** supports bevel gears **458** and **459**, which are engaged to transfer rotational motion of the driving shaft **456** to driving roller **425** (see FIGS. **4** and **5**). A left idle roll bushing **461** and driving gear bushing **463** may be supported in a housing **462** mounted to the support plate **451**, as will be described further below.

[0034] The drive apparatus **400** may generally integrate a plurality of actuating mechanisms together. The drive apparatus **400** may include a mechanism for opening and closing to facilitate loading and unloading of an elongate member, e.g., a guidewire or a catheter. As will be described further below, the clamps **401**, **403** may generally be opened to allow top loading of an elongate member, and may thereby facilitate loading of the elongate member without requiring threading the elongate member axially through the drive apparatus **400**. The drive apparatus may also include a mechanism for inserting and retracting the elongate member, i.e., in an axial direction. Moreover, the drive apparatus **400** also includes a mechanism for imparting rotational motion to the elongate member. Additionally, as will be described further below, the drive apparatus **400** may provide axial motion and rotational motion simultaneously, and in an "infinite" manner. More specifically, as will be seen below the insertion and rotational motion is provided by continuous drive surfaces, e.g., the generally round or looped roller surfaces **485***a*, **485***b* and the toothed gear engagement between the drive pinion **477** and gear halves **426***a*, **426***b*. Accordingly, a generally continuous axial or rotational motion may be provided without releasing the elongate member during the motion. In other words, the rotational and insertion motions are not limited by any range of motion of the drive apparatus **400** or components thereof. Moreover, the rotational and axial motion may be provided independent of the other, i.e., one of or both of the rotational and axial motion may be applied to the elongate member at any given time.

[0035] Referring now to FIGS. **6** and **7**, the use and operation of the drive apparatus **400** will be described in further detail. Initially the drive apparatus **400** may be in the open position, i.e., where the disposable portion **402** defines a gap G between the clamps **401**, **403** as best seen in FIG. **7**. While the disposable portion **402** is in the open position, the elongate member, e.g., a guidewire or catheter (not shown in FIG. **6** or **7**), may be placed between the rollers **483***a*, **483***b* supported from below by the compliant members **482**. An end portion **425***a* of driving roller **425** (see FIG. **6**), may be located in the driving roll assembly **457** and can be moved up and down by rotation of the lever **453**, which rotates about the pivot shaft **460**, as best seen in FIG. **7**. The lever **453** may be actuated by threaded member **454**. Accordingly, the driving roller **425** may selectively open and close the disposable portion **402**. More specifically, when the driving roller **425** is in an upper position as defined by the pivoting of the lever **453**, the disposable portion **402** will be closed, as seen in FIG. **8**. When the driving roller **425** is moved downward to a lower position, the driving roller **425** generally allows the compliant element **482** to urge the clamps **401**, **403** apart at the upper portion, defining the gap G as best seen in FIG. **7**. Upon movement of the driving roller **425** upward, the disposable portion **402** is forced to close. For example, an engagement portion **425***b* of the driving roller **425** may come into contact with one or both clamps **401**, **403**, thereby forcing the clamps **401**, **403** together at the upper portion, closing the gap G as seen in FIG. **8**.

[0036] Upon closure of the disposable portion **402**, the elongate member may be held between the rollers **483***a*, **483***b* with a force that is generally limited by springs **473**, as best seen in FIG. **9**. More specifically, the springs **483** may generally act upon an inner surface of one of the clamps **401**, **403** (not shown in FIG. **9**), urging the roller **483***a* which is supported in the saddle **474** toward the other roller **483***b*. Accordingly, a desired force of the rollers **483***a*, **483***b* may be adjusted based upon the spring force imparted by the springs **473**.

[0037] Turning now to FIGS. **6** and **10**, a rotational motion imparted by the drive apparatus **400** to an elongate member will be described in further detail. The roller **425** may be rotated via the shaft **456**, e.g., though bevel gears **458** and **459**, as best seen in FIG. **10**. Rotation of the driving roller **425** in turn rotates the disposable portion **402** via friction between the engagement portion **425***b* of the roller **425** and an outer surface **402***a* of the disposable portion **402**, as best seen in FIG. **6**. Motion may be imparted to the disposable portion via other mechanisms as well. Merely as an example, motion may be transferred from the roller **425** to the disposable portion **402** with a using corresponding toothed surfaces on the roller **425** and the disposable portion **402**, similar to a geared arrangement.

[0038] Turning now to FIGS. **9-11**, the axial motion of the drive apparatus **400** is described in further detail. FIG. **11** illustrates a cross section of the holders for left idle roller **423** and driving gear **422** (see FIG. **3**). More specifically, left idle roll **423** is located by bushing **461** and driving gear **422** is located by bushing **463**. The bushing **463** may have a driving mechanism (not shown) for selectively rotating the driving gear **422**. Rotation of the driving gear **422** (see FIG. **3**), which is engaged with an outer toothed surface of gear halves**426***a*, **426***b*, will thereby rotate the gear halves **426***a*, **426***b*. The gear halves **426***a*, **426***b* when in the closed position (i.e., as in FIG. **8**) may form a gear that rotates in response to the driving gear **422** (see FIG. **6**). The gear halves **426***a*, **426***b* in turnactuates gear **477** as best seen in FIGS. **7** and **8**. The gear **477** is located on the worm **480**, as illustrated in FIG. **9**. Rotation of the worm **480** in turn drives worm gear **479**. The worm gear **479** actuates one of the rollers **483***b*. The other roller **483***a* rotates in response to the roller **483***b*, as they are connected with the corresponding gears**478***a*, **478***b*. The surfaces**485***a*, **485***b* of the rollers **483***a*, **483***b* may generally be designed to ensure substantially slipless contact with the elongate member, such that the turning of the rollers **483***a*, **483***b* imparts axial motion directly to the elongate member.

[0039] To enact simultaneous axial and rotational motion of the elongate member, shaft **456** (see FIG. **10**) and drive gear **422** (see FIG. **6**) may be driven simultaneously. Moreover, the instrument **109** may include interfaces for the shaft **456** and drive gear **422** that allow for selective rotation of each, facilitating independent axial and rotational motion. Rotational speeds of the components of the drive apparatus **400** can be optimized as needed to suit any given application, e.g., by altering the interfaces between the various rotational parts, e.g., by adjusting the geared arrangements to ensure reasonable rotational speeds of the components based upon typical axial and rotational movement for the given application.

[0040] Turning now to FIGS. **12**A and **12**B, another set of exemplary rollers **783***a*, **783***b* is illustrated with an elongate member **999**, e.g., a guidewire. The rollers **783***a*, **783***b* may each define generally cylindrical continuous surfaces **785***a*, **785***b*, and may rotate about spindles **784***a*, **784***b*, e.g., similar to rollers **483***a*, **483***b*. Moreover, the rollers **783***a*, **783***b* may each define a plurality of upper teeth **799***a*, **799***b*, as well as a plurality of lower teeth **789***a*, **798***b*. The upper teeth **799***a* of the roller **783***a* may generally mesh with the upper teeth **799***b* of the roller **783***b*, and the lower teeth **798***a* of the roller **783***a* may generally mesh with the lower teeth **798***b* of the roller **783***b*, thereby generally preventing an elongate member received between the rollers **783***a*, **783***b*, e.g., guidewire **999**, from slipping out between the rollers **783***a*, **783***b*. Moreover, the upper and lower teeth **799**, **798** may still allow for top loading of an elongate member such as the guidewire **999**. For example, at least one of the rollers **783***a*, **783***b* may be supported in a saddle, e.g., as described above regarding roller **483***a*, which allows enough lateral displacement of the roller **783***a* or **783***b* to be moved to temporarily open a gap between the upper teeth **799** through which the elongate member can be laid between the rollers **783***a*, **783***b*.

[0041] Operator workstation **112**, electronics rack **114** and/or drive apparatus **400** may include a computer or a computer readable storage medium implementing the operation of drive and implementing the various methods and processes described herein, e.g., process **1300**. In general, computing systems and/or devices, such as the processor and the user input device, may employ any of a number of computer operating systems, including, but by no means limited to, versions and/or varieties of the Microsoft Windows® operating system, the Unix operating system (e.g., the Solaris® operating system distributed by Oracle Corporation of Redwood Shores, Calif.), the AIX UNIX operating system distributed by International Business Machines of Armonk, N.Y., the Linux operating system, the Mac OS X and iOS operating systems distributed by Apple Inc. of Cupertino, Calif., and the Android operating system developed by the Open Handset Alliance.

[0042] Computing devices generally include computer-executable instructions, where the instructions may be executable by one or more computing devices such as those listed above. Computer-executable instructions may be compiled or interpreted from computer programs created using a variety of programming languages and/or technologies, including, without limitation, and either alone or in combination, Java™, C, C++, Visual Basic, Java Script, Perl, etc. In general, a processor (e.g., a microprocessor) receives instructions, e.g., from a memory, a computer-readable medium, etc., and executes these instructions, thereby performing one or more processes, including one or more of the processes described herein. Such instructions and other data may be stored and transmitted using a variety of computer-readable media.

[0043] A computer-readable medium (also referred to as a processor-readable medium) includes any non-transitory (e.g., tangible) medium that participates in providing data (e.g., instructions) that may be read by a computer (e.g., by a processor of a computer). Such a medium may take many forms, including, but not limited to, non-volatile media and volatile media. Non-volatile media may include, for example, optical or magnetic disks and other persistent memory. Volatile media may include, for example, dynamic random access memory (DRAM), which typically constitutes a main memory. Such instructions may be transmitted by one or more transmission media, including coaxial cables, copper wire and fiber optics, including the wires that comprise a system bus coupled to a processor of a computer. Common forms of computer-readable media include, for example, a floppy disk, a flexible disk, hard disk, magnetic tape, any other magnetic medium, a CD-ROM, DVD, any other optical medium, punch cards, paper tape, any other physical medium with patterns of holes, a RAM, a PROM, an EPROM, a FLASH-EEPROM, any other memory chip or cartridge, or any other medium from which a computer can read.

[0044] Databases, data repositories or other data stores described herein may include various kinds of mechanisms for storing, accessing, and retrieving various kinds of data, including a hierarchical database, a set of files in a file system, an application database in a proprietary format, a relational database management system (RDBMS), etc. Each such data store is generally included within a computing device employing a computer operating system such as one of those mentioned above, and are accessed via a network in any one or more of a variety of manners. A file system may be accessible from a computer operating system, and may include files stored in various formats. An RDBMS generally employs the Structured Query Language (SQL) in addition to a language for creating, storing, editing, and executing stored procedures, such as the PL/SQL language mentioned above.

[0045] In some examples, system elements may be implemented as computer-readable instructions (e.g., software) on one or more computing devices (e.g., servers, personal computers, etc.), stored on computer readable media associated therewith (e.g., disks, memories, etc.). A computer program product may comprise such instructions stored on computer readable media for carrying out the functions described herein.

[0046] The drive apparatus **400** may advantageously use disposable materials in the construction of the disposable mechanism **402**, e.g., an injection molded plastic material. Additionally, the disposable mechanism is relatively short in an axial direction associated with the elongate member, minimizing wasted length, i.e., the portion of the elongate member that must be gripped or held by the drive apparatus **400** during operation. The minimal length of the drive apparatus **400** may generally be due in part to the containment of the driving mechanisms of the disposable portion **402** within the clamps **401**, **403**. Additionally, the drive apparatus employs separate driving mechanisms, e.g., rollers **483***a*, **483***b* and the toothed gear engagement between the drive pinion **477** and gear halves **426***a*, **426***b*, that allow for independent control of the axial motion and rotational motion. Moreover, the drive apparatus mechanism **400** provides generally "infinite" motion due to the looped or round surfaces of the rollers **483***a*, **483***b* and the toothed gear engagement between the drive pinion **477** and gear halves **426***a*, **426***b*, thereby allowing for application of any magnitude of axial or rotational motion without having to release the elongate member. Accordingly, axial and rotational motion of the elongate member are not limited by any range of motion of the drive apparatus **400**. Finally, the split clamps **401**, **403** of the disposable portion allows for top loading of the elongate member, such that the elongate member need not be threaded through the drive mechanism during installation of the elongate member.

[0047] The exemplary illustrations are not limited to the previously described examples. Rather, a plurality of variants and modifications are possible, which also make use of the ideas of the exemplary illustrations and therefore fall within the protective scope. Accordingly, it is to be understood that the above description is intended to be illustrative and not restrictive.

[0048] With regard to the processes, systems, methods, heuristics, etc. described herein, it should be understood that, although the steps of such processes, etc. have been described as occurring according to a certain ordered sequence, such processes could be practiced with the described steps performed in an order other than the order described herein. It further should be understood that certain steps could be performed simultaneously, that other steps could be added, or that certain steps described herein could be omitted. In other words, the descriptions of processes herein are provided for the purpose of illustrating certain embodiments, and should in no way be construed so as to limit the claimed invention.

[0049] Accordingly, it is to be understood that the above description is intended to be illustrative and not restrictive. Many embodiments and applications other than the examples provided would be upon reading the above description. The scope of the invention should be determined, not with reference to the above description, but should instead be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. It is anticipated and intended that future developments will occur in the arts discussed herein, and that the disclosed systems and methods will be incorporated into such future embodiments. In sum, it should be understood that the invention is capable of modification and variation and is limited only by the following claims.

[0050] All terms used in the claims are intended to be given their broadest reasonable constructions and their ordinary meanings as understood by those skilled in the art unless an explicit indication to the contrary in made herein. In particular, use of the singular articles such as "a," "the," "the," etc. should be read to recite one or more of the indicated elements unless a claim recites an explicit limitation to the contrary.

1. A drive apparatus for an elongated member, comprising:

a roller assembly configured to impart axial motion to the elongate member; and

a roller support configured to rotate the roller assembly, thereby imparting rotational motion to the elongate member;

wherein the roller assembly and roller support are configured to impart axial and rotational motion independently of one another, such that a first one of the roller assembly and the roller support imparts their associated motion regardless of a presence or absence of motion by the other of the roller assembly and the roller support.

2. The drive apparatus of claim **1**, further comprising a first continuous surface defined by a generally cylindrical roller included in the roller assembly.

3. The drive apparatus of claim **2**, wherein the roller support is configured to rotate about a second generally continuous surface.

4. The drive apparatus of claim **1** wherein the roller assembly is configured to maintain continuous grip of the elongate member in the axial and rotational direction.

5. The drive apparatus of claim **1**, further comprising a pair of clamps selectively surrounding the roller assembly and the roller support.

6. The drive apparatus of claim **5**, wherein the clamps selectively open to define a gap along an upper portion of the drive apparatus, allowing the elongate member to be received through the gap and within the rollers in a direction parallel to an axis of rotation of the rollers.

7. The drive apparatus of claim **5**, further comprising a driving roller supported in a support plate defining a channel configured to receive the elongated member when the elongated member is disposed in the roller assembly, the driving roller configured to rotate the clamps.

8. The drive apparatus of claim **5**, further comprising a saddle supporting the roller assembly within a housing defined by the pair of clamps.

9. The drive apparatus of claim **1**, wherein the roller assembly includes a pair of opposing rollers.

10. The drive apparatus of claim **9**, wherein the opposing rollers are engaged via a plurality of mating teeth, thereby coordinating a turning of the opposing rollers.

11. The drive apparatus of claim **5**, further comprising a drive pinion engaged with an inner toothed surface.

12. The drive apparatus of claim **11**, wherein the drive pinion is configured to rotate the first continuous surface about a spindle.

13. The drive apparatus of claim **1**, further comprising a drive mechanism and a disposable portion including the roller assembly and the roller support.

14. The drive apparatus of claim **13**, wherein the drive mechanism defines at least a portion of a sterile barrier with respect to the disposable portion.

15. A drive apparatus for an elongated member, comprising:

a roller assembly configured to impart axial motion to the elongate member along a first continuous surface configured to maintain contact with the elongate member during axial motion;

a roller support configured to rotate the roller assembly, thereby imparting rotational motion to the elongate member, the roller support configured to rotate the roller assembly about a second continuous surface configured to maintain contact with the roller support during rotational motion; and

a pair of clamps selectively surrounding the roller assembly and the roller support;

wherein the roller assembly and roller support are configured to impart axial and rotational motion independently of one another, such that a first one of the roller assembly and the roller support imparts their associated motion regardless of a presence or absence of motion by the other of the roller assembly and the roller support.

16. The drive apparatus of claim **15**, wherein the first continuous surface is defined by a generally cylindrical roller included in the roller assembly.

17. The drive apparatus of claim **15**, wherein the clamps selectively open to define a gap along an upper portion of the drive apparatus, allowing the elongate member to be received through the gap and within the rollers in a direction parallel to an axis of rotation of the rollers.

18. The drive apparatus of claim **15**, further comprising a drive pinion engaged with an inner toothed surface.

19. The drive apparatus of claim **18**, wherein the drive pinion is configured to rotate the first continuous surface about a spindle.

20. The drive apparatus of claim **15**, further comprising a drive mechanism and a disposable portion including the roller assembly and the roller support, wherein the drive mechanism defines at least a portion of a sterile barrier with respect to the disposable portion.

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