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(54) **APPARATUS FOR SIMULATING INSERTION OF AN ELONGATED INSTRUMENT INTO A STRUCTURE INCLUDING A PULLEY AND A PULLEY POSITION SENSING ARRANGEMENT**

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(57) **ABSTRACT**

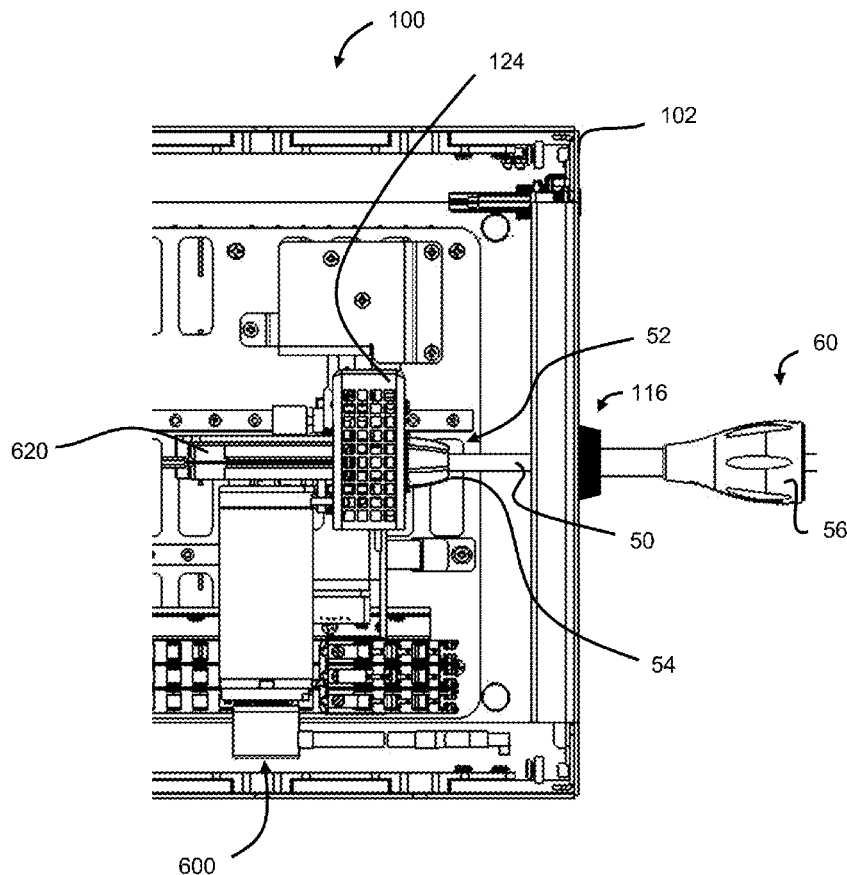
The present disclosure relates to an apparatus for simulating insertion of an inner elongated instrument attached to a tether into a structure through an outer elongated instrument. The apparatus has a carriage for mounting the outer elongated instrument, for translation according to a translation of the outer elongated instrument. The apparatus has a pulley for anchoring a tether and rotating according to a longitudinal translation of the tether into the outer elongated instrument. The apparatus has a feedback force actuator for applying an adjustable resistive force to a translation of the carriage according to the sensed longitudinal position of the carriage and resistance characteristics of the structure, and for further applying an adjustable resistive force to a rotation of the pulley according to the sensed angular position of the pulley and the resistance characteristics. The present disclosure also relates to a medical insertion simulator comprising such an apparatus.

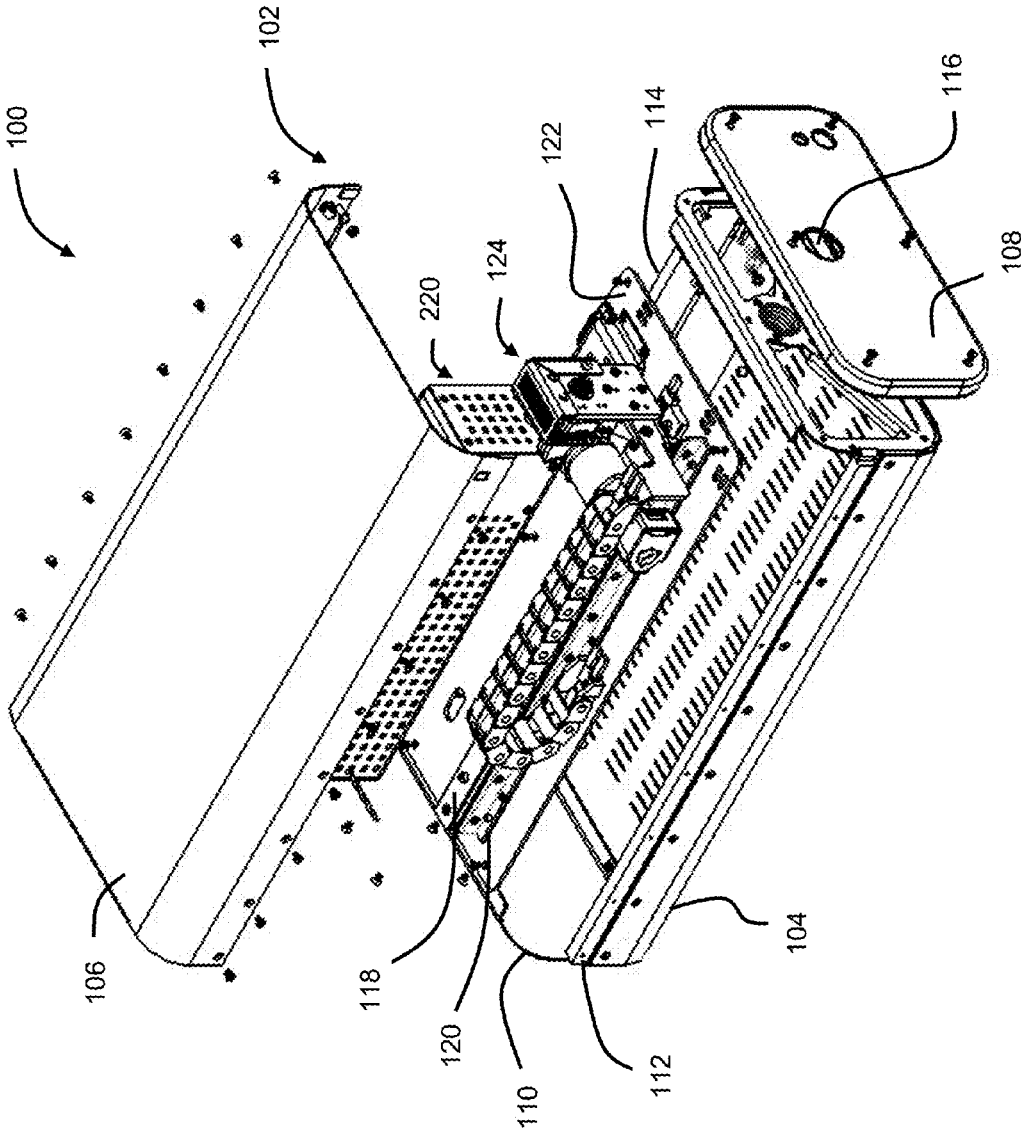
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**FIG. 1**

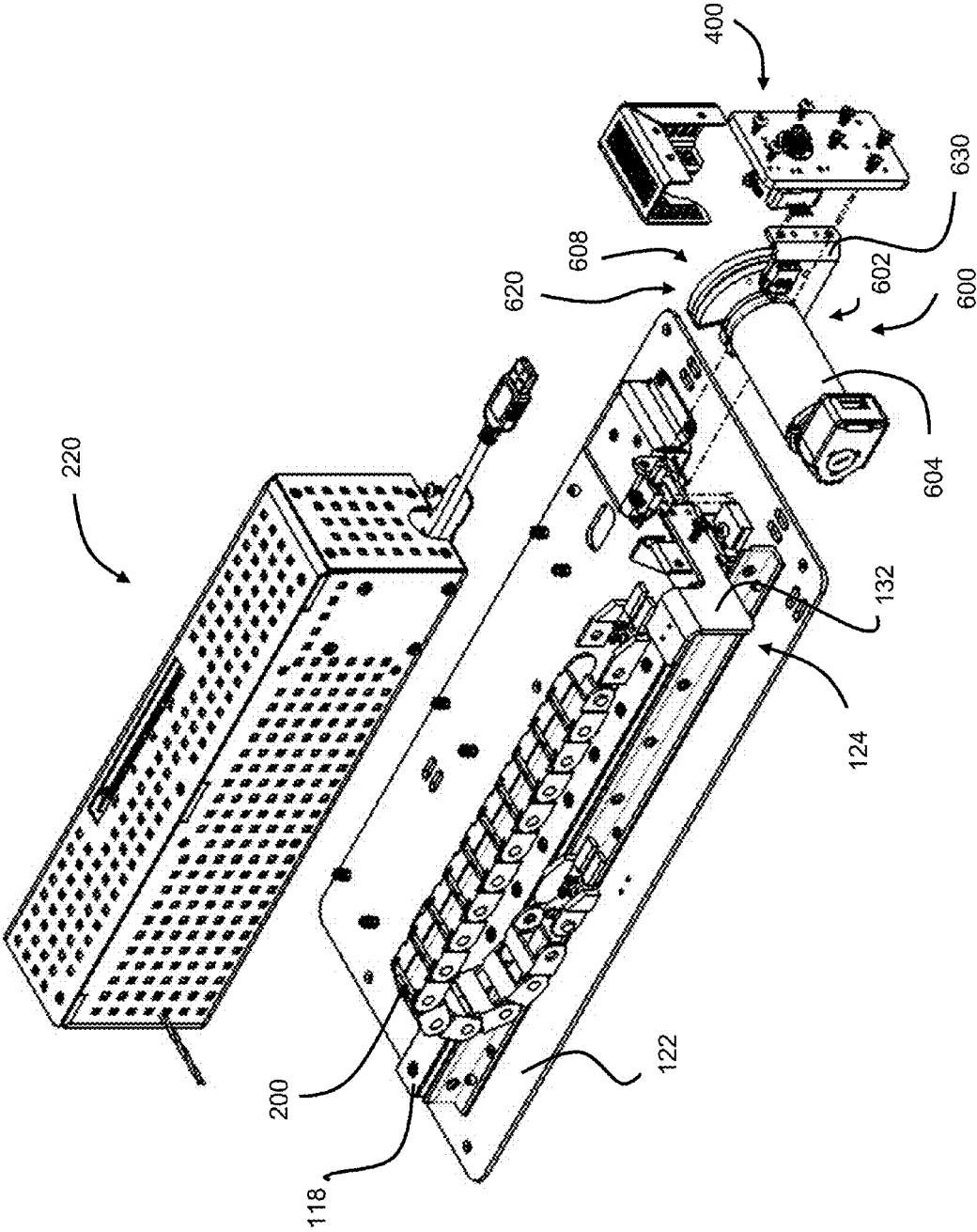
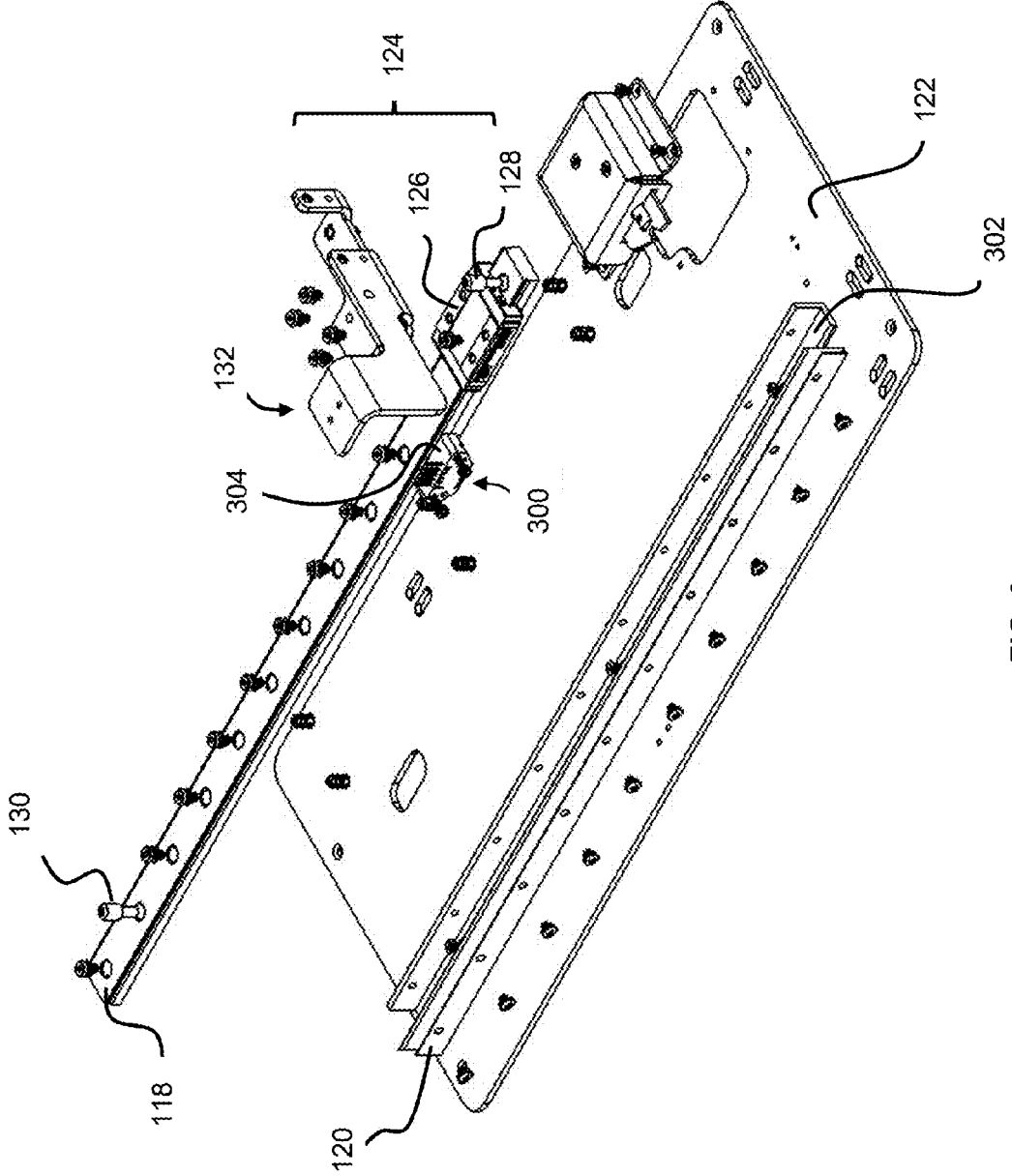


FIG. 2



**FIG. 3**

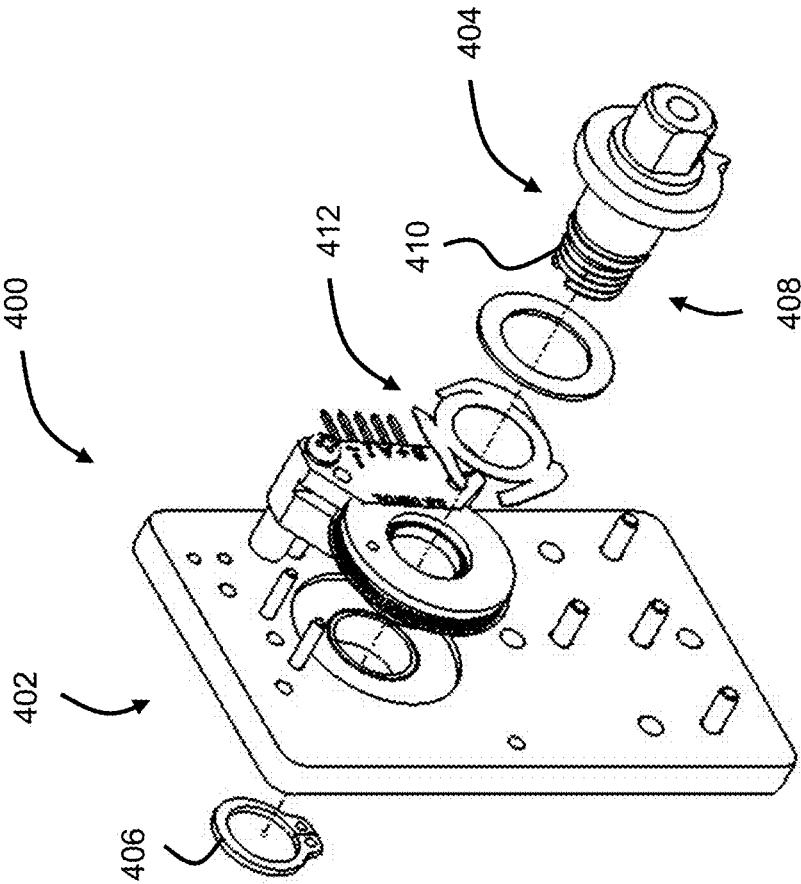


FIG. 4

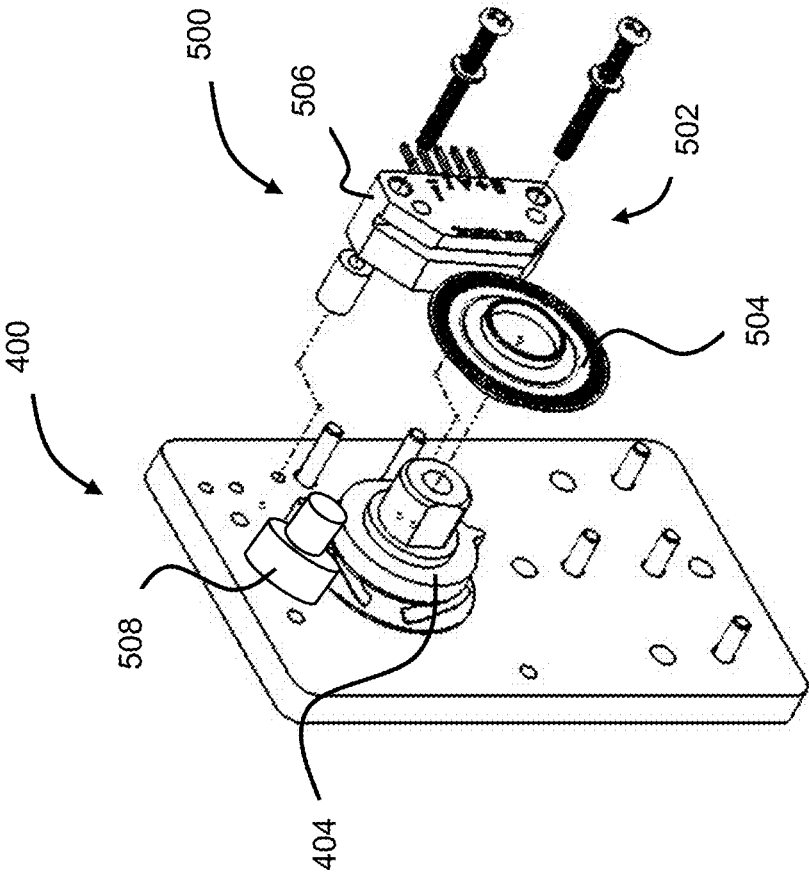
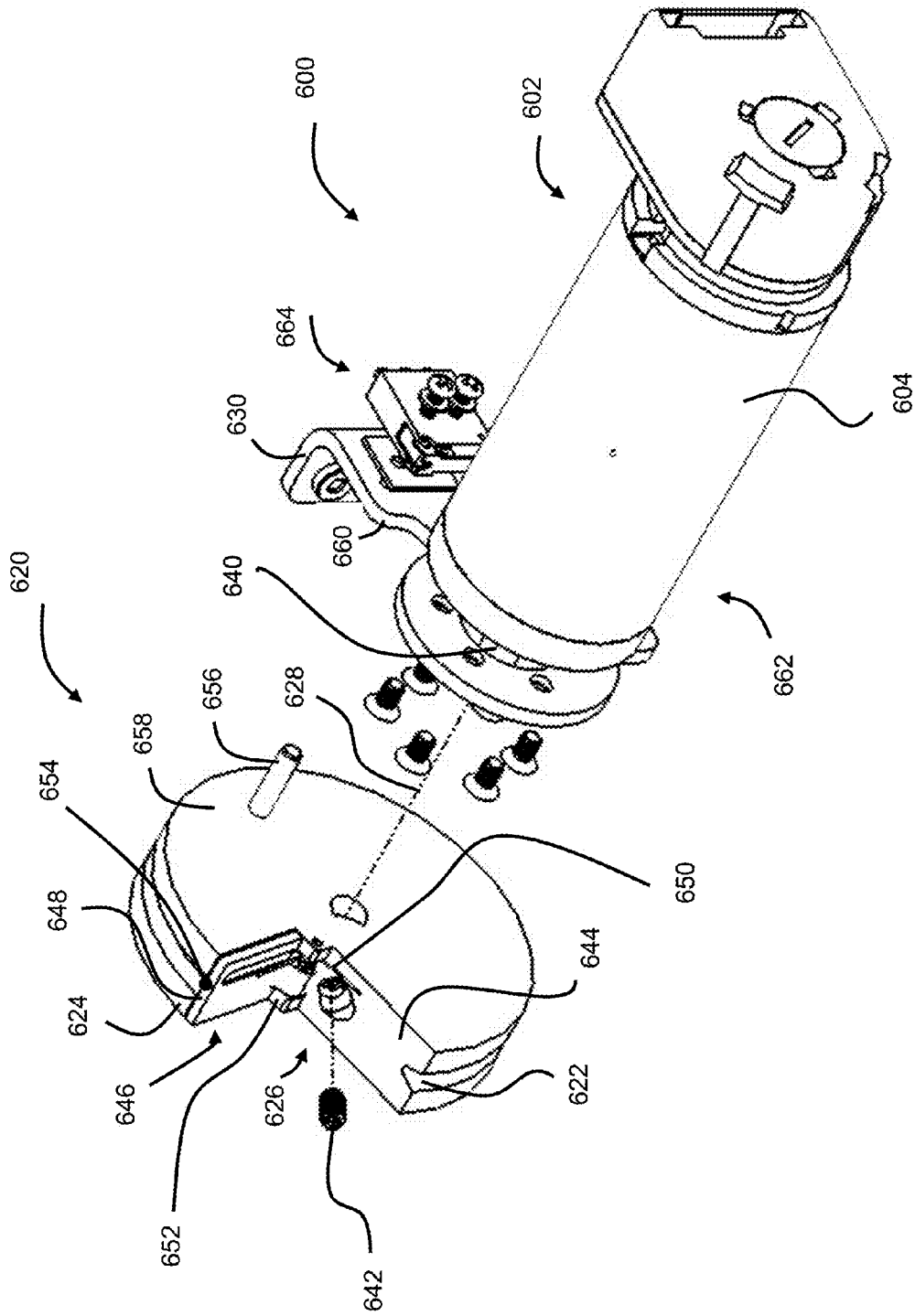


FIG. 5



**FIG. 6**

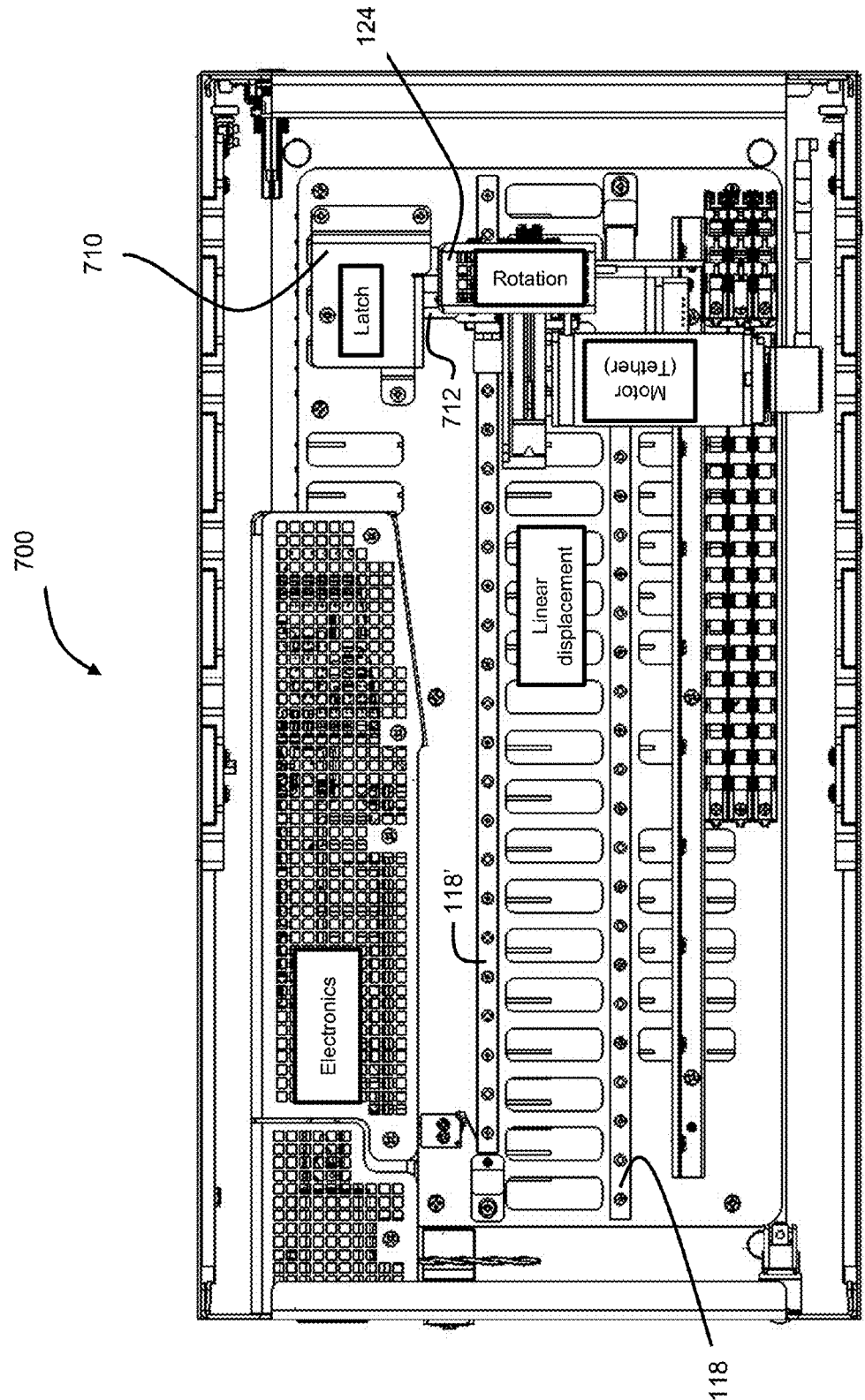


FIG. 7



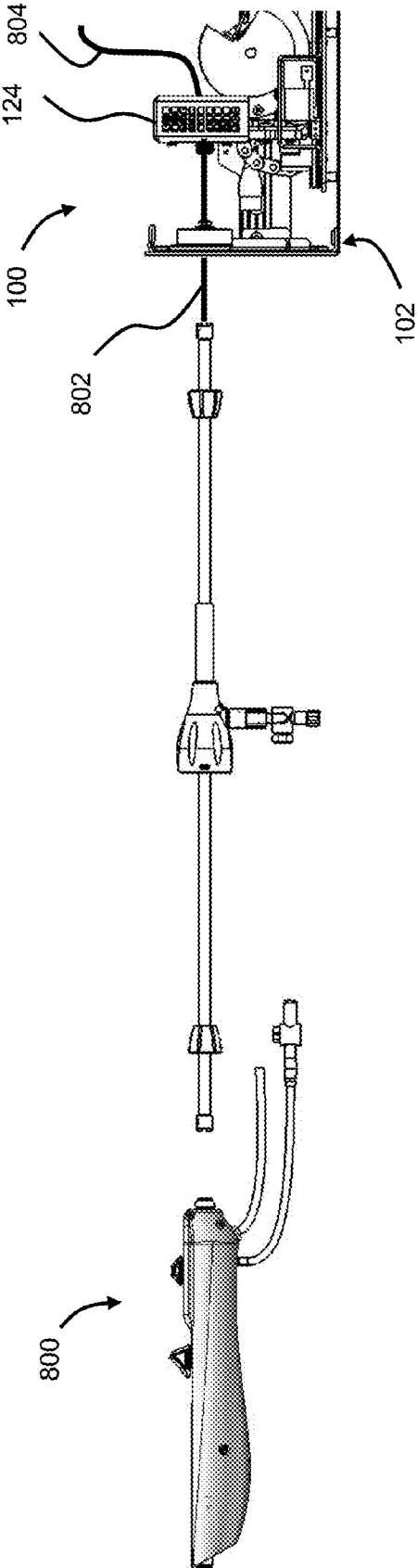
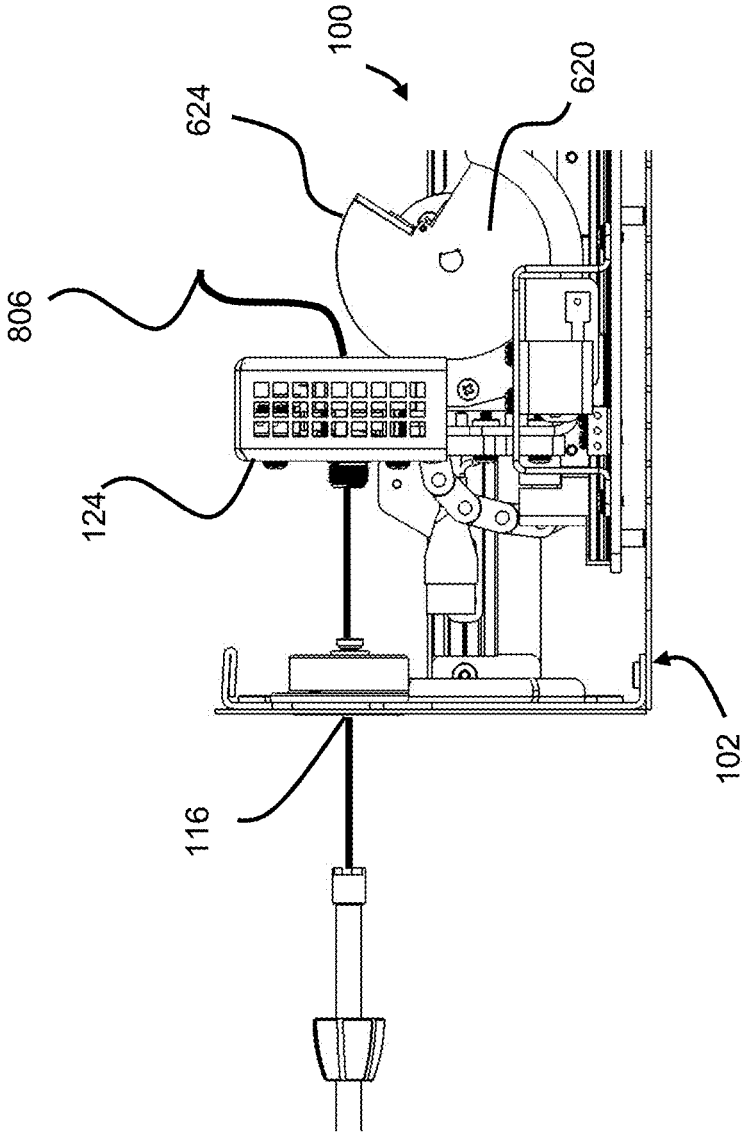


FIG. 8



**FIG. 9**

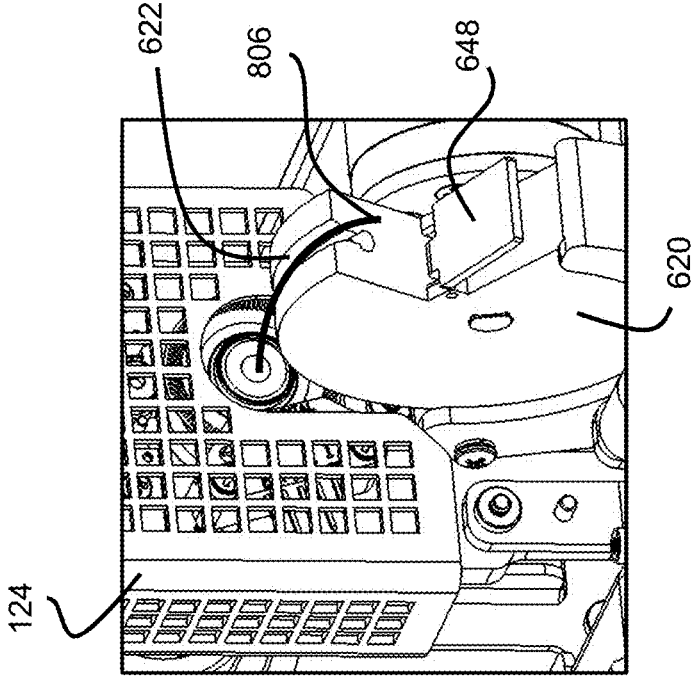


FIG. 10

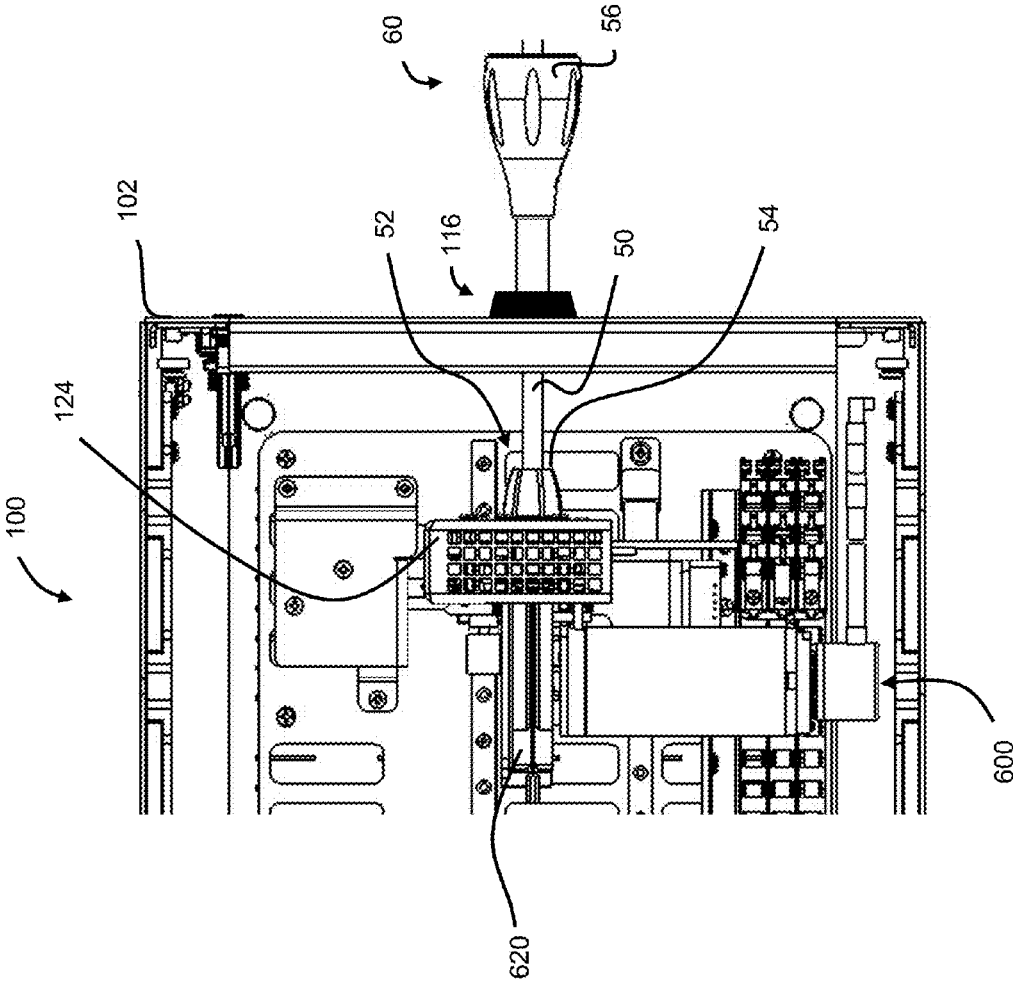


FIG. 11

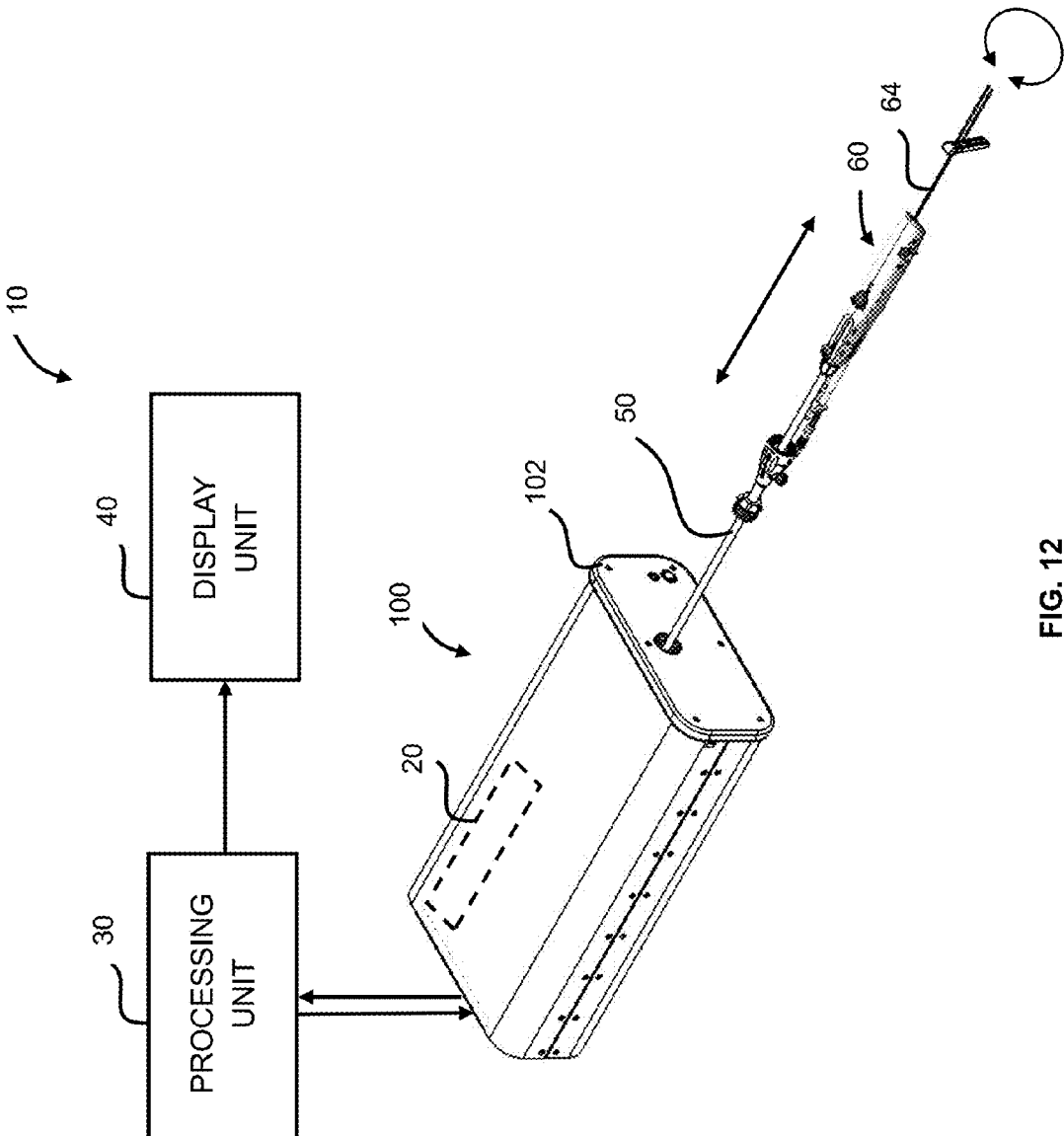
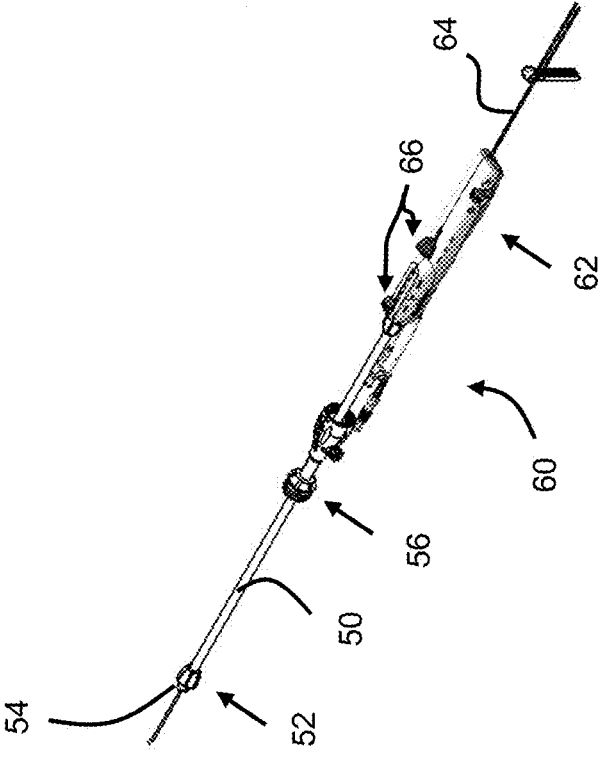


FIG. 12



**FIG. 13**

**APPARATUS FOR SIMULATING INSERTION  
OF AN ELONGATED INSTRUMENT INTO A  
STRUCTURE INCLUDING A PULLEY AND A  
PULLEY POSITION SENSING  
ARRANGEMENT**

TECHNICAL FIELD

**[0001]** The present invention generally relates to apparatuses for simulating insertion of an elongated instrument into a structure and medical insertion simulators for healthcare training.

BACKGROUND

**[0002]** Minimally invasive surgical procedures through the use of endoscopic instruments are more and more used for replacing conventional surgery. Indeed, technological progresses have provided miniaturized tools and implements that can be inserted through an endoscopic instrument in the body of a human for performing various tasks. These tools are generally combined with a video system to view from the inside the procedure being performed.

**[0003]** Virtual simulation systems have been developed for training medical professionals to perform these types of procedures. These simulation systems aim to produce realistic real-time simulated operating conditions for providing interactive training through the combination of real-time visual representation and interactive tactile force feedback returned to the medical professional under training.

**[0004]** The systems of the prior art are however complex, cumbersome and expensive. The haptic sensation returned to the trained medical professional is oftentimes not realistic enough. Moreover, such simulation systems often have to be used at a training center, as they are not designed to be easily transportable.

**[0005]** It would therefore be desirable to provide an improved simulation apparatus that would reduce at least one of the above-mentioned drawbacks of known simulation system.

SUMMARY

**[0006]** It is an object of the present invention to obviate or mitigate at least one disadvantage of previous simulation apparatus for simulating insertion of an elongated instrument into a structure.

**[0007]** It is another object to provide a portable simulation apparatus for simulating insertion of an elongated instrument into a structure that is transported in a conventional carry-on luggage.

**[0008]** It is another object of the invention to provide a simulation apparatus particularly adapted for simulation of transcatheter pacemaker implantation procedure.

**[0009]** Accordingly, there is provided an apparatus for simulating insertion of an inner elongated instrument attached to a tether into a structure through an outer elongated instrument. The apparatus comprises a casing having an aperture for receiving a distal end of the outer elongated instrument therethrough and a longitudinal guide fixedly mounted in the casing. The apparatus is provided with a carriage comprising a mounting plate for mounting the distal end of the outer elongated instrument, the carriage being slidably mounted onto the longitudinal guide for translation thereon according to a translation of the outer elongated instrument through the aperture of the casing. The apparatus

also has a carriage position sensing element for sensing a longitudinal position of the carriage along the longitudinal guide. The apparatus further comprises a pulley having an outer tether receiving groove on a peripheral portion thereof and an anchoring element therein for anchoring a distal end of a tether extending through the outer elongated instrument, the pulley being rotatably mounted on the carriage for rotating according to a longitudinal translation of the tether into the outer elongated instrument. The apparatus is also provided with a pulley position sensing arrangement for sensing an angular position of the pulley representative of a relative longitudinal position of the inner elongated instrument attached to the tether. The apparatus also has a feedback force actuator mounted on the carriage and operatively connected to the casing for applying an adjustable resistive force to a translation of the carriage on the longitudinal guide according to the sensed longitudinal position of the carriage and resistance characteristics of the structure, the feedback force actuator being further connected to an axle of the pulley for applying an adjustable resistive force to a rotation of the pulley according to the sensed angular position of the pulley and the resistance characteristics of the structure.

**[0010]** According to another aspect, there is also provided a medical insertion simulator comprising an apparatus for simulating insertion of an inner elongated instrument attached to a tether into a structure through an outer elongated instrument. The medical insertion simulator is provided with an outer elongated instrument for attachment in the apparatus and a control unit for controlling the feedback force actuator. The medical insertion simulator further has a processing unit for receiving the sensed longitudinal position of the carriage, the sensed angular position of the pulley and a model of a patient's internal structure and associated resistance characteristics of the structure. The processing unit further determines the adjustable resistive force to apply to the translation of the carriage and the adjustable resistive force to apply to the rotation of the pulley according to previously received information for operating the control unit. The processing unit then further produces a visual display image of the patient's internal structure and movement of the inner and outer elongated instruments therein. The medical insertion simulator is further provided with a display unit for displaying the produced visual display image.

BRIEF DESCRIPTION OF THE DRAWINGS

**[0011]** Embodiments of the disclosure will be described by way of example only with reference to the accompanying drawings, in which:

**[0012]** FIG. 1 is a partially exploded perspective view of an example of an apparatus for simulating insertion of an elongated instrument;

**[0013]** FIG. 2 is a further partially exploded perspective view of a portion of the apparatus of FIG. 1;

**[0014]** FIG. 3 is a further partially exploded perspective view of another portion of the apparatus of FIG. 1;

**[0015]** FIG. 4 is an exploded perspective view of a mounting plate and a mounting shaft arrangement;

**[0016]** FIG. 5 is a partially exploded perspective view of the mounting plate of FIG. 4 with a sensing element;

**[0017]** FIG. 6 is an exploded view of a pulley and a feedback force actuator of the apparatus of FIG. 1;

[0018] FIG. 7 is a top view of another example of an apparatus for simulating insertion of an elongated instrument;

[0019] FIG. 8 is an exploded partial side view of the apparatus shown in FIG. 7;

[0020] FIG. 9 is an enlarged view of the right portion of FIG. 8;

[0021] FIG. 10 is a perspective partial view showing the mounting of a tether with a pulley;

[0022] FIG. 11 is a top view of a portion of the apparatus of FIG. 7, with an elongated instrument mounted therein;

[0023] FIG. 12 is a schematic view of an example of a medical insertion simulator; and

[0024] FIG. 13 is a perspective view of an example of an elongated instrument.

#### DETAILED DESCRIPTION

[0025] The foregoing and other features will become more apparent upon reading of the following non-restrictive description of illustrative embodiments thereof, given by way of example only with reference to the accompanying drawings. Like numerals represent like features on the various drawings.

[0026] Various aspects of the present disclosure generally address one or more of the problems of simulating medical interventions relying on insertion of a medical instrument into an anatomical structure of a patient such as veins, arteries and other tubular anatomical structures. In the present description, these aspects will be described in the specific application of simulating the implantation of a micro-pacemaker small enough to be delivered with minimally invasive techniques through a catheter, and implanted directly into the heart. In one example, the micro-pacemaker is provided with flexible tines attachable to the interior of the right ventricle. The tines can be engaged and disengaged during the implantation process without causing trauma to the cardiac tissue, thereby allowing the device to be repositioned during implantation or retrieved if needed.

[0027] The various aspects of the present disclosure described therein are particularly well suited for training medical professionals to perform such transcatheter pacemaker implantation process although the skilled person in the art will appreciate that various other applications not limited to the medical field may also be envisaged.

[0028] Transcatheter pacemaker implantations are generally performed through an opening realized in the femoral artery in the groin region although other entry points may be used.

[0029] Training of such a procedure may be done as a sequence of procedures, for example an initial catheter insertion up to the heart, fine manipulation of the implant inside the heart before final attachment, or as complete procedure encompassing all the manipulations required for a complete implantation process.

[0030] The present apparatus thus allows training medical professionals on a sequence of procedures of the complete procedure with improved realistic feedback feeling.

[0031] The apparatus may be used with a conventional portable PC and is compact enough to provide a complete portable simulator fitting in a conventional carry-on luggage, as detailed below.

[0032] Referring to FIG. 1, there is shown a partially exploded view of an example of an apparatus 100 for

simulating insertion of an elongated instrument (not shown), a medical catheter for example, into a structure such as an artery.

[0033] In the illustrated embodiment, the apparatus 100 has a casing 102 provided with bottom, top, front and back panels 104, 106, 108, 110 mounted together. The top panel 106 can be slidably mounted to the bottom panel 104 through slides 112, 114 mounted on the longitudinal sides of the panels 106, 104 for easing access to the interior of the casing 102 and enabling a quick installation of the elongated instrument in the apparatus 100.

[0034] The front panel 108 is provided with an aperture 116 for receiving a distal end of the elongated instrument therethrough, as it will become more apparent below with reference to FIGS. 8 to 12. Various additional apertures are provided, for example in the front and back panels, for power and electronics communication.

[0035] Still referring to FIG. 1 and also to FIG. 2 and FIG. 3 which are further exploded view of portions of the apparatus 100, the apparatus 100 is also provided with a longitudinal guide 118 fixedly mounted in the casing 102, for example through a guide rail 120 secured to a bottom mounting plate 122 secured to the bottom panel 104. The longitudinal guide 118 could consist of a rail, a pair of rails, a channel, a tunnel, or any other type of structure, which can act as a longitudinal guide. The apparatus 100 also has a carriage 124 slidably mounted onto the longitudinal guide 118 for translation therealong. In the illustrated embodiment, the carriage 124 has a base plate 126 freely sliding onto the guide 118 between two abutting positions defined with abutting elements 128, 130 mounted on each end on the guide 118 to restrain the travel of the carriage 124 onto a longitudinal operating range. Limits switches (not shown) can be provided for control purposes. The carriage 124 further has a mounting bracket 132 secured to the base plate 126 and a mounting plate 400 secured to the carriage 124 through the mounting bracket 132.

[0036] The mounting plate 400, which is better shown in exploded views thereof in FIG. 4 and FIG. 5, is used for mounting the distal end of the elongated instrument to the carriage 124. With this arrangement, a translation of the elongated instrument operated by a user through the aperture 116 of the casing 102 for simulating insertion and/or removal of the elongated instrument will generate a corresponding translation of the carriage 124 along the longitudinal guide 118 inside the casing 102.

[0037] The mounting plate 400 has a receiving portion 402 for receiving a corresponding attaching portion (not shown) mounted at the distal end of the instrument. In the illustrated example, a shaft 404 is rotatably mounted through the mounting plate 400 and secured in place with snap ring 406 to thereby provide a axial rotating connection of the elongated instrument to the carriage 124. The tip 408 of the shaft 404 projecting outward the casing 102 has a threaded portion 410 for receiving a corresponding threaded portion of the distal end of the instrument to firmly secure the two elements together. An optional rotation stopper 412 may be installed with the shaft 404 to limit the axial rotational course of the shaft 404 to thereby limit the axial rotational course of the elongated instrument through the aperture 116 of the casing 102.

[0038] To provide a more realistic feedback to a user of the apparatus 100, a feedback system sensitive to the axial rotation of the instrument is provided. As illustrated, an



angular position sensing element **500** can be used for sensing a relative axial rotation of the shaft **404** and thereby of the elongated instrument. The angular position sensing element **500** can be for example an optical encoder **502** having a circular disk **504** fixedly mounting around the shaft **404** and an associated optical reader **506** secured to the mounting plate **400**. An angular feedback force actuator (not shown) mounted with the mounting plate **400** may be used for applying an adjustable resistive force to a rotation of the shaft **404** according to the sensed relative axial rotation, as further detailed below.

[0039] Referring again to FIG. 2, the apparatus **100** is provided with a feedback force actuator **600** mounted on the carriage **124** and operatively connected to the casing **102** for applying an adjustable resistive force to a translation of the carriage **124** on the longitudinal guide **118**. In the illustrated embodiment, the feedback force actuator **600** has an electric motor **602** (for example a stepper motor) whose frame **604** is secured to the carriage **124** through a supporting plate **606** secured to the mounting plate **400**. The feedback force actuator **600** may optionally further comprise a transmission element **200** mounted between the motor **602** and the guide **118** for applying a resistive force to the carriage **124**. The transmission element **200** could consist of a belt cooperating with the rotating shaft **608** of the motor **602** although various other arrangements for applying a resistive force to the carriage **124** may alternatively be envisaged.

[0040] A carriage position sensing element **300**, a linear encoder strip **302** mounted along the guide **118** and a corresponding optical reader **304** as shown in FIG. 3 for example, is used for sensing a longitudinal position of the carriage **124** along the longitudinal guide **118**.

[0041] The apparatus **100** is provided with an embedded control unit **220** mounted on the bottom plate **122** for controlling the feedback force actuator **600** according to the sensed position of the carriage **124** and eventually the sensed relative axial rotation of the elongated instrument, and further according to resistance characteristics of the structure. The resistance characteristics of the structure are representative of a patient's internal structure into which a medical catheter is to be inserted. These resistance characteristics may be provided by a specific 3D model of a structure of a specific patient and may embed natural movements of a human body like heart beating and breathing.

[0042] With reference to FIG. 12, a medical insertion simulator **10** will now be described. The medical insertion simulator **10** is provided with an apparatus **100** for simulating insertion of an elongated instrument into a structure as described above and shown in FIG. 1 and a corresponding elongated instrument **50** for attachment in the apparatus **100**. The medical insertion simulator **10** also has a control unit **20** embedded in the casing **102** of the apparatus **100** for controlling the feedback force actuator **600**.

[0043] The medical insertion simulator **10** is further provided with a processing unit **30** connected to the apparatus **100** for receiving the sensed longitudinal position of the carriage **124** and eventually the sensed relative axial rotation of the elongated instrument **50**. At least one model of a patient's internal structure and associated resistance characteristics of the structure is provided to the processing unit **30** for further determination of the adjustable resistive force to apply to the translation of the carriage **124** and eventually the adjustable resistive force to apply to the relative axial rotation of the elongated instrument **50** according to previ-

ously received position information. The processing unit **30** further operates the control unit **20** to simulate a realistic insertion in the specific structure in providing forces (i.e. haptic feedback) to the movements of the user operating the elongated instrument **50**. The processing unit **30** further produces a visual display image of the patient's internal structure and movement of the elongated instrument **50** therein and displays the produced visual display image in real time on a display unit **40**. The processing unit **30** can be for example a portable computer provided with suitable control cards and software.

[0044] Reference is now made to FIG. 13 showing an example of a training handle **60** usable with the apparatus **100** and to FIG. 11. The training handle **60** has a gripping portion **62** connected to a rigid elongated instrument **50** connectable to the mounting plate **400**. The distal end **52** of the rigid elongated instrument **50** is provided with a threaded tip **54** for mounting with the threaded portion **410** of the tip **408** of the shaft **404**. Optionally, an introducer **56** may be coaxially secured with the rigid elongated instrument **50** in the aperture **116** of the casing **102** to provide a sliding longitudinal relationship of the training handle **60** in and out of the casing **102**.

[0045] In the illustrated example, the training handle **60** is further provided with a tether **64** extending through the rigid elongated instrument **50** and the gripping portion **62** and therealong. The distal end of the tether **64** (which corresponds to the distal end **52** of the rigid elongated instrument **50**) is used to simulate the position of a medical implantable device to which the tether **64** is attached. The tether **64** is driven inside and out of the rigid elongated instrument **50** through controls **66** provided on the gripping portion **62**. The controls **66** further allow controlling the distal end **52** of the rigid elongated instrument **50**. Additional controls for simulating further spatial movements of the medical implantable device attached to the tether **64** may also be provided for further realistic simulation of a complete implantation procedure, as it will become apparent below.

[0046] Referring again to FIG. 1 and FIG. 2 and also to FIG. 6 which is an exploded view of a portion of the apparatus shown in FIG. 1, the apparatus **100** may also be used for simulating insertion of an elongated instrument, for example a medical implantable device, attached to a tether into a structure, for example a patient's internal structure into which the medical implantable device is to be implanted. In other words, this arrangement may enable to simulate installation of the medical implantable device into the structure once this implantable device has already been brought proximate the structure into which the implantation has to be performed.

[0047] The aperture **116** of the casing **102** receives a distal end of the tether therethrough for attachment therein, as better described below with reference to FIG. 10. The apparatus **100** is provided with a pulley **620** having an outer tether receiving groove **622** on a peripheral portion **624** thereof and an anchoring element **626** therein for anchoring the distal end of the tether extending through the aperture **116** of the casing **102**. The pulley **620** is rotatably mounted in the casing **102** for rotating according to a longitudinal translation of the tether relatively to the casing **102**.

[0048] The apparatus **100** also has a feedback force actuator **600** connected to an axle **628** of the pulley **620** for applying an adjustable resistive force to a rotation of the pulley **620**. As better shown in FIG. 6, the feedback force

actuator **600** is for example an electric motor **602**, such as for example a stepper motor, operatively connected to the axle **628** of the pulley **620**. In the illustrated example, the stepper motor **602** is operatively connected to the casing **102** through a mounting plate **630** attached to the frame **604** of the motor **602**. The shaft **640** of the motor **602** is mounted on the axle **628** of the pulley **620** and is secured in place through a set screw **642** extending radially to the axle **628** through the pulley **620**. In the illustrated example, the pulley **620** has the shape of a partial disk or a disk in which a radial portion has been removed to provide opposed radial surfaces **644**, **646**. The set screw **642** is mounted with the axle through one of the radial surfaces. A retaining plate **648** associated with a torsion spring **650** and a pin spring **652** is arranged between the two radial surfaces **644**, **646** to retain the retaining plate **648** against a corresponding radial surface. This arrangement defines an anchoring point **654** for anchoring the distal end of the tether to the pulley **620** while a portion of the tether extends in the outer tether receiving groove **622** on the peripheral portion **624** of the pulley **620**. With this arrangement, the tether can be easily installed and removed from the apparatus **100**.

[0049] Still referring to FIG. 6, the pulley **620** may be provided with an abutting pin **656** extending radially on the side **658** of the pulley **620** and cooperating with an associated abutting device attached to the casing **102** for restraining a pivotal movement of the pulley **620**. As illustrated, the mounting plate **630** used for mounting the motor **602** may be shaped to provide an abutting shaped surface limiting the rotational course of the pulley **620**. As an example, the mounting plate **630** has a circular portion around which the abutting pin **656** may freely move and two abutting elements **660**, **662** projecting radially for defining two abutting positions. Various alternative arrangements may be envisaged for restraining movement of the pulley **620**.

[0050] The apparatus **100** is also provided with a sensing arrangement **664** for sensing an angular position of the pulley **620**. The sensing arrangement **664** has a sensor mounted to the mounting plate **630** for sensing a relative position of the abutting pin **656**. Alternatively, as it should become apparent below, the relative position of the tether tip could be determined through the controls provided on a training handle.

[0051] In addition to FIG. 6, reference is now made to FIG. 8 to FIG. 10 which are partial views of the apparatus **100** showing the anchoring of the distal end of the tether to the pulley **620**. In the illustrated example, a training handle **800** similar to the one illustrated in FIG. 13 and provided with a tether **802** is used. The distal end **804** of the tether **802**, which can be provided with a tip **806** having a larger diameter than the outer tether receiving groove **622** of the pulley **620**, is first inserted through the aperture **116** of the casing **102**. To attach the distal end **804** of the tether **802** to the pulley **620**, one has first to rotate the retaining plate **648** (see FIG. 10), insert the tip **806** of the distal end **804** in the outer tether receiving groove **622** on the peripheral portion **624** and trap this end **804** with the pulley **620** in releasing the spring biased retaining plate **648**.

[0052] As it should become apparent, upon longitudinal translation of the tether **802** inside the casing **102**, the pulley **620** rotates accordingly while the tether **802** freely winds in the receiving groove portion **622**. The sensed angular posi-

tion of the pulley **620** is representative of a relative longitudinal position of the tip **806** of the tether **802** in the casing **102**.

[0053] The apparatus **100** is provided with an embedded control unit **220** mounted on the bottom plate **122** for controlling the feedback force actuator **600** according to the sensed angular position of the pulley **620**, and further according to resistance characteristics of the structure. The resistance characteristics of the structure are representative of a patient's internal structure into which an elongated instrument like a medical implantable device is to be inserted. These resistance characteristics may be generated using a 3D model of a structure of a specific patient, embedding natural movements of a human body like heart beating and breathing. The resistance characteristics may comprise a combination of predetermined resistance characteristics (i.e. static) and modeled resistance characteristics (i.e. dynamic).

[0054] The assembly of the pulley **620** and the actuator **600** may be fixedly mounted in the casing **102**. Alternatively and as illustrated in FIG. 1 to FIG. 3, the pulley **620** may be mounted on the carriage **124** slidable along the longitudinal guide **118**. This latter arrangement may provide a more realistic simulation of an installation of a medical implantable device into a structure embedding natural movements of a human body.

[0055] Referring again to FIG. 12, another example of a medical insertion simulator **10** for simulating an installation of a medical implantable device into a structure will now be described. The medical insertion simulator **10** is provided with an apparatus **100** for simulating insertion of an elongated instrument, such as a medical implantable device, attached to a tether, into a structure, the apparatus **100** having a pulley and feedback force actuator assembly **620**, **600** just previously described and shown in FIG. 6. The medical insertion simulator **10** is also provided with a tether **64** embedded in a training handle **60**. The tether **64** has a distal end for anchoring to the anchoring element of the pulley **620**. The medical insertion simulator **10** also has a control unit **20** embedded in the casing of the apparatus **100** for controlling the feedback force actuator **600** of the pulley **620**.

[0056] The insertion simulator **10** is further provided with a processing unit **30** connected to the apparatus **100** for receiving the sensed angular position of the pulley **620**. At least one model of a patient's internal structure and associated resistance characteristics of the structure is provided to the processing unit **30** for further determination of the adjustable resistive force to apply to the rotation of the pulley **620** according to previously received position information. The processing unit **30** further operates the control unit **20** to simulate a realistic implantation in the specific structure in providing forces to the movements of the user operating the tether **64**. The processing unit **30** further produces a visual display image of the patient's internal structure and movement of the implantable device therein and displays the produced visual display image in real time on a display unit **40**.

[0057] As it should be apparent, the apparatus for simulating insertion and associated simulators previously described enable a realistic medical training of the initial catheter insertion up to the heart only, or the fine manipulation only of the implantable device inside the heart structure before final attachment thereto.

[0058] Referring again to FIG. 1 and FIG. 2 and also to FIG. 12, another example of an apparatus 100 and associated simulator 10 enabling to simulate the whole implantation procedure including initial catheter insertion up to the heart and subsequent fine manipulation of the implantable device outside the catheter for final attachment will now be described. This apparatus 10 controls whole or partial simulation. In the following description and for ease of understanding, in which the catheter used to bring the implantable device up to the structure is alternatively called the outer elongated instrument while the implantable device initially extending inside the catheter and attached to a tether is called the inner elongated instrument.

[0059] The apparatus 10 has a casing 102 having an aperture 116 for receiving a distal end of the outer elongated instrument therethrough and a longitudinal guide 118 fixedly mounted in the casing 102. The apparatus 100 also has a carriage 124 provided with a mounting plate 400 for mounting the distal end of the outer elongated instrument. The carriage 124 is slidably mounted onto the longitudinal guide 118 for translation thereon according to a translation of the outer elongated instrument through the aperture 116 of the casing 102, as previously detailed. A carriage position sensing element 300 is provided for sensing a longitudinal position of the carriage 124 along the longitudinal guide 118. The apparatus 100 is also provided with a pulley 620 having an outer tether receiving groove 622 on a peripheral portion 624 thereof and an anchoring element 626 therein for anchoring a distal end of a tether extending through the outer elongated instrument. The pulley 620 is rotatably mounted on the carriage 124 for rotating according to a longitudinal translation of the tether into the outer elongated instrument, as previously detailed. A pulley position sensing arrangement 664 is also provided for sensing an angular position of the pulley 620 representative of a relative longitudinal position of the inner elongated instrument attached to the tether. The apparatus 100 is also provided with a feedback force actuator 600 mounted on the carriage 124 and operatively connected to the casing 102 for applying an adjustable resistive force to a translation of the carriage 124 on the longitudinal guide 118 according to the sensed longitudinal position of the carriage 124 and resistance characteristics of the structure as previously detailed. The feedback force actuator 600 is further connected to an axle 628 of the pulley 620 for applying an adjustable resistive force to a rotation of the pulley according to the sensed angular position of the pulley 620 and the resistance characteristics of the structure. To provide a more realistic simulation, an axial rotation of the outer elongated instrument through the aperture 116 of the casing 102 may be sensed with an angular position sensing element 500 mounted on the mounting plate 400 of the carriage 124, while an angular feedback force actuator (not shown) is provided for applying an adjustable resistive force to such sensed axial rotation, according to the resistance characteristics of the structure. The apparatus 100 is provided with an embedded control unit 220 for controlling the feedback force actuators according to the various sensed positions.

[0060] The apparatus 100 previously described may be used in a medical insertion simulator as illustrated in FIG. 12.

[0061] In the illustrated examples, a single stepper motor 602 is controlled according to various modes of simulation for providing corresponding resistive forces to the pulley

620 and the carriage 124. This arrangement is of great advantage to provide a compact apparatus. Others arrangements for actuating the carriage 124 and the pulley 620 may also be envisaged, for example two distinct actuators suitably mounted and controlled.

[0062] FIG. 7 shows another embodiment of an apparatus 700 for simulation insertion wherein the arrangement used for applying the resistive force to the carriage 124 is slightly different. The carriage 124 is also mounted on two parallel longitudinal guides 118, 118'. A controlled latch mechanism 710 mounted to the casing 102 and having a movable member 712 cooperating with the carriage 124 is provided for latching the carriage 124 in resting position, for transport purposes and/or according to a specific simulation application for example.

[0063] With its embedded control unit and its compact design, the apparatus may be operated through a portable computer and associated control cards and software to provide a portable realistic simulator easy to mount and use. The apparatus may have a casing of a total weight of 10 lb with total dimensions small enough to fit with a portable computer and associated accessories in a carry-on whose dimensions are less than 25"×20"×14.5", which is of great advantage for transport purposes. In fact, the apparatus is designed small enough to fit in a carry-on while still providing an operating range long enough to enable a realistic simulation of an implantation of a medical implantable device in the heart through the femoral artery.

[0064] Although the present disclosure has been described hereinabove by way of non-restrictive, illustrative embodiments thereof, these embodiments may be modified at will within the scope of the appended claims without departing from the present claims.

1. An apparatus for simulating insertion of an inner elongated instrument attached to a tether into a structure through an outer elongated instrument, the apparatus comprising:

- a casing having an aperture for receiving the outer elongated instrument therethrough;
- a longitudinal guide fixedly mounted in the casing;
- a carriage comprising a mounting plate and a shaft rotationally mounted through the mounting plate, the shaft receiving a distal end of the outer elongated instrument, the carriage being slidably mounted onto the longitudinal guide for translation thereon according to a translation of the outer elongated instrument through the aperture of the casing;
- a carriage position sensing element for sensing a longitudinal position of the carriage along the longitudinal guide;
- a pulley having an outer tether receiving groove on a peripheral portion thereof and an anchoring element therein for anchoring a distal end of a tether extending through the outer elongated instrument, the pulley being rotatably mounted on the carriage for rotating in response to a pulling movement of the tether by a user of the outer elongated instrument in the outer elongated instrument;
- a pulley position sensing arrangement for sensing an angular position of the pulley representative of a relative longitudinal position of the inner elongated instrument attached to the tether; and
- a feedback force actuator mounted on the carriage for applying resistive force to a translation of the carriage

on the longitudinal guide according to the sensed longitudinal position of the carriage, the feedback force actuator being further connected to an axle of the pulley for applying resistive force to a rotation of the pulley according to the sensed angular position of the pulley.

2. (canceled)

3. The apparatus of claim 1, further comprising an angular position sensing element mounted on the mounting plate of the carriage for sensing a relative axial rotation of the outer elongated instrument through the aperture of the casing.

4. The apparatus of claim 3, further comprising an angular feedback force actuator for applying resistive force to a rotation of the outer elongated instrument through the aperture of the casing according to the sensed relative axial rotation.

5. The apparatus of claim 1, further comprising a control unit for controlling the feedback force actuator and applying the corresponding resistive forces to the translation of the carriage and the rotation of the pulley.

6. The apparatus of claim 1, wherein the feedback force actuator comprises a stepper motor mounted on the carriage and connected to the axle of the pulley, the feedback force actuator further comprising a transmission element mounted between the motor and the guide for applying the resistive force to the carriage.

7. (canceled)

8. (canceled)

9. The apparatus of claim 1, wherein the outer elongated instrument comprises a medical catheter and the inner elongated instrument attached to the tether is a medical implantable device, and further wherein the resistance characteristics of the structure are representative of a patient's internal structure into which the outer elongated instrument is to be inserted before the medical implantable device is to be implanted.

10. A medical insertion simulator comprising:

an apparatus for simulating insertion of an inner elongated instrument attached to a tether into a structure through an outer elongated instrument of claim 1;

an outer elongated instrument for attachment in the apparatus;

a control unit for controlling the feedback force actuator; a processing unit for receiving the sensed longitudinal position of the carriage, the sensed angular position of the pulley and a model of a patient's internal structure and associated resistance characteristics, the processing unit further determining the resistive force to apply to the translation of the carriage and the resistive force to apply to the rotation of the pulley according to previously received information for operating the control unit, the processing unit further producing a visual display image of the patient's internal structure and movement of the inner and outer elongated instruments therein; and

a display unit for displaying the produced visual display image.

11. A medical insertion simulator comprising:

an apparatus for simulating insertion of an inner elongated instrument attached to a tether into a structure through an outer elongated instrument of claim 4;

an outer elongated instrument for attachment in the apparatus;

a control unit for controlling the feedback force actuator; a processing unit for receiving the sensed longitudinal position of the carriage, the sensed angular position of the pulley, the sensed relative axial rotation and a model of a patient's internal structure and associated resistance characteristics, the processing unit further determining the resistive force to apply to the translation of the carriage, the resistive force to apply to the rotation of the pulley and the force to apply to the relative axial rotation according to previously received information for operating the control unit, the processing unit further producing a visual display image of the patient's internal structure and movement of the inner and outer elongated instruments therein; and

a display unit for displaying the produced visual display image.

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