

A COUPLER FOR DISPENSING AND REELING IN WIRES TO CONTROL A STEERABLE ARM

5 FIELD OF INVENTION

The present invention relates to surgical instruments for deployment inside larger devices such as endoscopes. In particular, the invention relates to a coupler comprising mechanisms for moving a miniature robotic arm on the distal end of the surgical instrument.

BACKGROUND OF THE INVENTION

Figure 1 and Figure 2 are photographs of some early designs of robotic surgical instruments, still in use today to perform minimally invasive procedures. Typically, the instruments comprise a rigid rod 103 having an end-effector such as a clamp 101, which is a pair of claws, for manipulating tissue. The proximal end of the rigid rod 103 is provided with a coupler 105 for coupling the instrument to a motorbox.

Inside the coupler are spools for reeling in and releasing wires, which pull on the claws to move the clamp 101. The base 107 of each spool is accessible outside the coupler, and may be driven by a mating driver in the motorbox.

The rigid rod 103 limits the use of these instruments to laparoscopic surgery, which requires a small incision made into the patient for inserting the clamp 101.

In an improvement of these instruments, the rigid rod is replaced by a thinner, longer, and flexible transmission tube. This allows the surgical instrument to be inserted into the instrument channel of an endoscope that provides passage into the gastrointestinal tract through a natural orifice of the body. The transmission tube can be pushed through the extremely smooth instrument channel easily, even if the endoscope is bent in several places to navigate about folds of the tract.

The distal end of the transmission tube has a miniature robotic arm which can be bent and straightened by pulling or releasing wires connected to the robotic arm. The other ends of these wires are attached to spools in the coupler. This robotic arm will be called a "steerable arm" from this point forth to distinguish it from unrelated instruments in the same technical field that may also meet the description of a "robotic arm".

Although these surgical instruments are single-use consumables, the meaning of "single-use" includes multiple re-insertions into an endoscope during a procedure.

It is proposed that these surgical instruments are in great need of further improvements. For example, the steerable arms are often rather slow to respond to wire control, which undermines the skills and efficiency of the surgeon using the instrument. Also, the control wires in the instruments could slip off the spools too easily, which runs a risk of emergency surgical instrument replacement mid-surgery. Furthermore, the ordinary event of making multiple extractions and re-insertions of surgical instruments into an endoscope during surgery seems to cause positional

drifts of the endoscope all too easily, which affects the reach of the steerable arm. Also, it has been found that the instrument channel of an endoscope becomes increasingly difficult to disinfect just after having been used in merely several procedures.

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Accordingly, it is desirable to propose an improvement or improvements, which can overcome or mitigate one or more these problems.

SUMMARY OF THE INVENTION

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In a first aspect, the invention proposes a surgical instrument, comprising: a steerable arm having a bias to be in a first position; a wire; one end of the wire connected to the steerable arm and the other end of the wire connected to a spool; the spool being movable in a release direction to dispense wire, allowing the steerable arm to be moved by the bias into the first position; wherein when the spool is moved in the release direction into a maximum release point, the length of wire dispensed is insufficient to fully satisfy the bias.

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The residual bias provides a minimum degree of ever-present tension in the wire and the steerable arm, so that the steerable arm is ready to respond to a slight pull of the wire. These features may be embodied in devices in which the absolute length of wire from the spool and is short of allowing the bias to act fully.

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Preferably, however, a retaining device preventing the spool from moving past the maximum release point, such that the wire is prevented from being dispensed beyond a pre-determined length. The retainer can be a stop, a wedge or a set of mechanically incompatible parts that resists or prevents release of the wire beyond a certain extent.

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In some other embodiments, the retainer can be entirely software, such as a software that measures the extent of wire released (or held back by the spool) and prevents further release, or software that operates a detector for a positional tag on the wire and prevents release of wire after the tag (or held back by the spool).

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Preferably, however, the retainer comprises a set of gears that interoperate until a point of incompatibility in the gear teeth. For example, the surgical instrument further comprises a spool gear that rotates in unison with the spool for reeling in or releasing the wire, the spool gear having teeth engaged by a driving-gear for driving the spool gear to move the spool; wherein the retaining device is provided as absence of at least an indentation on the tip circumference of the spool gear.

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Typically, the position lacking a tooth is levelled with the gear tip circumference of the spool-gear, i.e. the circumference defined by the tips of the other gear teeth.

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Preferably, the spool gear is integral and axially aligned with the spool. Alternatively, the spool may be moved by the spool gear indirectly, through actions of a series of gears.

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Preferably, the surgical instrument further comprises: a one-way gear allowing the spool to move in the reel-in direction and preventing the spool to move in the release

direction, i.e. the direction against the bias in the steerable arm. Typically, this is provided in the form of a ratchet, although any other suitable mechanism for ensuring one-way movement.

- 5 In some embodiments, the spool gear as described above is a first spool gear; the spool is a first spool; the wire is a first wire; the surgical instrument further comprising: a second spool gear that rotates in unison with movement of a second spool for reeling in or releasing a second wire, the second spool gear having teeth engaged by the driving-gear; wherein the driving-gear is capable of driving the first spool gear
10 and the second spool gear to move the respective first spool and second spool to reel in or release the respective first wire and second wire; and a retaining device is provided as absence of at least an indentation on the second spool gear.

- 15 This allows a person to rotate a plurality of spool gears, and the connected spools, by operating just one driving-gear, relieving the person from having to operate the spool gears separately.

- 20 Preferably, the surgical instrument further comprises: a maximum reel-in point that limits the movability of the spool in the reel-in direction; wherein the maximum reel-in point is provided by a reel-in limiting device that prevents movement of the spool beyond a pre-determined reel-in limit. This feature prevents over-flexing of the steerable arm, and prevents weakening the bias.

- 25 Preferably, the surgical instrument further comprises: a spool gear that rotates in unison with movement of the spool for reeling in or releasing the wire, the spool gear having teeth engaged by a driving-gear for driving the spool gear to move the spool; wherein the reel-in limiting device is provided as absence of at least an indentation on the tip circumference of the spool gear.

- 30 Typically, the driving-gear is capable of disengaging the spool gear. In embodiments wherein there are two spool gears, the driving-gear is capable of disengaging the first spool gear and the second spool gear. This allows the bias in the steerable arm to become the dominant force on the respective spools and wires.

- 35 Preferably, the driving-gear is a ring gear having a larger circumference; the spool gear has a smaller circumference, and the spool gear is placed to engage the ring gear while inside the ring gear. This allows the driving-gear to be gripped steadily by all the fingers of a hand and turned.

- 40 Preferably, the row of gear teeth on the driving-gear, i.e. the ring gear, is endless along the inner circumference of the ring gear. This feature allows re-engagement of the driving-gear and the spool gear easily. In contrasting embodiments, the gear teeth on the ring gear occupy a limited section of the inner circumference of the ring. The two ends of the section are points of incompatibility with the teeth of the spool
45 gear, which limit the extent of engagement. Similarly, the teeth of the spool gear are continuous only within a limited section of the gear circumference. In this embodiment, the ring gear and spool gear may be rotated to re-engage at the respective ends of the sections of teeth for allowing sufficient degree of inter-operative rotation for straightening the steerable arm.

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Accordingly, the invention provides a possibility of a steerable arm straightened from any bent configuration before passing the steerable through an instrument channel. This reduces scratching of the instrument channel surface, which could become habitat for germs which are difficult to clean. Also, this creates less disruption to the
5 endoscope's position when passing surgical instruments through the endoscope, making the position of the endoscope more stable.

In a second aspect, the invention proposes a method of passing a surgical instrument through an instrument channel of an endoscope, the tip of the surgical
10 instrument comprising a bendable and straighten-able steerable arm, comprising the steps of: straightening the steerable arm before passing the surgical instrument through the instrument channel. Any bend in the steerable may spring into manifestation once the steerable arm is outside the instrument channel.

15 The passing can be part of the process of inserting the surgical instrument into the instrument channel.

Alternatively, the passing can be part of the process of pulling the surgical instrument out of the instrument channel.

20 In a third aspect, the invention proposes a coupler for dispensing and reeling in wires to control a steerable arm, comprising: a wire; one end of the wire connected to a steerable arm and the other end of the wire connected to a spool; the spool being movable in a release direction to dispense a length of the wire tied to the spool;
25 wherein when the spool is moved in the release direction into a maximum release point, the length of wire dispensed is insufficient to fully satisfy a bias in the steerable arm. That is, a minimum degree of bias is provided in the steerable arm urging the steerable to be in a certain position, configuration or shape. This feature relates to couplers that are supplied separately from the rest of the surgical instrument.

30 Preferably, a retaining device preventing the spool from moving past the maximum release point.

35 Preferably, the coupler further comprises a spool gear that rotates in unison with movement of the spool for reeling in or releasing the wire, the spool gear having teeth engaged by a driving-gear 2601 for driving the spool gear to move the spool; wherein the retaining device is provided as absence of at least an indentation on the tip circumference of the spool gear.

40 Preferably, the spool gear is a first spool gear; the spool is a first spool; the wire is a first wire; the surgical instrument further comprising a second spool gear that rotates in unison with movement of a second spool for reeling in or releasing a second wire, the second spool gear having teeth engaged by the driving-gear; wherein the driving-gear is capable of driving the first spool gear and the second spool gear to move the
45 respective first spool and second spool to reel in or release the respective first wire and second wire; wherein a retaining device is provided as absence of at least an indentation on the second spool gear.

Typically, the driving-gear is capable of disengaging the spool gear.
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Preferably, the coupler further comprises a one-way gear allowing the spool to move in the reel-in direction and preventing the spool to move in the release direction.

5 Preferably, the coupler further comprises a maximum reel-in point that limits the movability of the spool in the reel-in direction; wherein the maximum reel-in point is provided by a reel-in limiting device that prevents movement of the spool beyond a pre-determined reel-in limit.

10 Preferably, the driving-gear 2601 is a ring gear having a larger circumference; the spool gear has a smaller circumference, and the spool gear is placed to engage the ringer while inside the ring gear.

Typically, the gear teeth on the ring gear are endless, and extend inwardly of the ring gear.

15 In a further aspect, the invention proposes a steerable arm capable of being in a first position and a second position, the steerable arm biased to be in a first position but retained from fully satisfying the bias in order to be readily responsive when a force acts to urge the steerable towards the second position.

20 In a further aspect, the invention proposes a surgical instrument, comprising a steerable arm having a bias to be in a first position; a wire; one end of the wire connected to the steerable arm and the other end of the wire connected to a spool; the spool being movable in a release direction to dispense wire, allowing the
25 steerable arm to be moved by the bias into the first position; a retaining device preventing the spool from moving past a maximum release point; wherein when the spool is moved in the release direction into the maximum release point, the length of wire dispensed is insufficient to fully satisfy the bias.

30 Preferably, the spool is movable in a reel-in direction to reel in wire, pulling the steerable arm against the bias into a second position.

Preferably, the surgical instrument further comprises: a one-way gear allowing the spool to move in the reel-in direction and preventing the spool from moving in the
35 release direction.

Preferably, the surgical instrument further comprises: a driving-gear; a spool-gear that rotates in unison with the spool; the driving-gear arranged to drive the spool-gear; wherein the spool-gear has gear teeth; and the retaining device comprises a
40 discontinuity in the arrangement of gear teeth of the spool-gear that blocks the further movement of the drive-gear.

Preferably, the spool-gear is a first spool-gear; the spool is a first spool; and the wire is a first wire; the retaining device is a first retaining device; the surgical instrument
45 further comprising: a second spool-gear; a second spool; a second wire; a second retaining device; the steerable arm having a second bias to be in a third position; one end of the second wire connected to the steerable arm and the other end of the second wire connected to the second spool; the second spool being movable in a release direction to dispense the second wire, allowing the steerable arm to be
50 moved by the second bias into the third position; wherein when the second spool is

moved in the release direction into a maximum release point, the length of the second wire dispensed is insufficient to fully satisfy the second bias; the second spool is movable in a reel-in direction to reel in the second wire, pulling the steerable arm against the second bias into a fourth position; the second spool-gear capable of rotating in unison with the second spool; the driving-gear arranged to drive the second spool-gear; wherein the second spool-gear has gear teeth; and the second retaining device comprises a discontinuity in the arrangement of gear teeth of the second spool-gear that blocks the further movement of the drive-gear.

10 Preferably, the surgical instrument further comprises: a reel-in limiting device that prevents movement of the spool in the reel-in direction beyond a maximum reel-in point.

15 Preferably, the surgical instrument further comprises: a driving-gear; a spool-gear that rotates in unison with the spool; the driving-gear arranged to drive the spool-gear; wherein the driving-gear is capable of disengaging the spool-gear such that the steerable arm is unrestrained to move into the first position according to the bias.

20 Preferably, the driving-gear is a ring gear enclosing the spool-gear; the ring gear comprising: a ring having an external edge and an internal edge; gear teeth provided on the internal edge that engages the gear teeth of the spool gear, such that turning the ring drives the spool gear.

25 In a further aspect, the invention proposes a coupler for dispensing and reeling in wires to control a steerable arm, comprising: a spool for a wire; the spool being movable in a release direction to dispense wire; a retaining device preventing the spool from moving past a maximum release point; a driving-gear; a spool-gear that rotates in unison with the spool; the driving-gear arranged to drive the spool-gear; wherein the spool-gear has gear teeth; the retaining device comprises a discontinuity
30 in the arrangement of gear teeth of the spool-gear that blocks the further movement of the drive-gear.

Preferably, the driving-gear is capable of disengaging the spool-gear such that the spool is able to move unrestrained by the driving-gear.

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Preferably, the spool is movable in a reel-in direction to reel in wire; comprising a reel-in limiting device that prevents movement of the spool in the reel-in direction beyond a maximum reel-in point.

40 Preferably, the driving-gear is a ring gear enclosing the spool-gear; the ring gear comprising: a ring having an external edge and an internal edge; gear teeth provided on the internal edge that engages the gear teeth of the spool gear, such that turning the ring drives the spool gear.

45 BRIEF DESCRIPTION OF THE FIGURES

It will be convenient to further describe the present invention with respect to the accompanying drawings that illustrate possible arrangements of the invention, in which like integers refer to like parts. Other arrangements of the invention are possible, and consequently the particularity of the accompanying drawings is not to
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be understood as superseding the generality of the preceding description of the invention.

- 5 Figure 1 (prior art) is a picture of instruments having a coupler for being connected to a mechanical driver from the da Vinci system of the company Intuitive Surgical, Inc.;
- Figure 2 (prior art) is a further picture of the instruments in Figure 1;
- Figure 3 is a perspective view of a coupler as an embodiment of the invention;
- 10 Figure 4 is schematic illustration of a surgical instrument comprising the coupler of Figure 3;
- Figure 5 is a photograph of the surgical instrument illustrated in Figure 4;
- Figure 6 illustrates two of the surgical instrument shown in Figure 4 inserted into an endoscope;
- Figure 7 is an enlargement of a drawing insert in Figure 6, showing the tip of the endoscope of Figure 6;
- 15 Figure 8 shows a setup for an endoscopic surgery that uses the surgical instrument of Figure 4;
- Figure 9 illustrates a motorbox to which the coupler of the surgical instrument of Figure 4 may be attached;
- 20 Figure 10 is an enlarged view of a coupler-receptacle on the motorbox of Figure 9;
- Figure 11 shows the coupler-receptacle of Figure 10 and an unattached coupler;
- Figure 12 illustrates the body of a steerable arm, such as the one provided at the distal end of the surgical instrument of Figure 4;
- Figure 13 shows a steerable arm, which may be provided at the distal end of the surgical instrument of Figure 4, having a bend in the steerable arm body;
- 25 Figure 14 shows the steerable arm of Figure 13 flexed or articulated into becoming straightened;
- Figure 15 illustrates how the bent body of the steerable arm of Figure 13 can be straightened by the pull of a controlling wire;
- 30 Figure 16 is the bottom view of the coupler illustrated in Figure 3;
- Figure 17a is an exploded view of the coupler illustrated in Figure 3;
- Figure 17b is an exploded view of the parts of a spool, shown with the base of the coupler of Figure 3;
- Figure 18 is another exploded view of the parts of a spool but without the rest of the coupler;
- 35 Figure 19 illustrates a spool assembled from the parts shown in Figure 18.
- Figure 20 shows the spool in Figure 19 attached with wires for controlling the steerable arm of the surgical instrument shown in Figure 4;
- Figure 21 shows the coupler of Figure 3 without the coupler housing revealing the coupler base and a nozzle extending from the coupler base;
- 40 Figure 22 is illustrates the base part of the nozzle shown in Figure 21;
- Figure 23 is the plan view of the base part of the nozzle shown in Figure 22;
- Figure 24 is a cross-sectional view of the base part of the nozzle shown in Figure 22;
- Figure 25 illustrates how a spool of in the coupler of Figure 3 is prevented from releasing all of the wire, by the use of a stop;
- 45 Figure 26 illustrates how the spool gear shown in Figure 27 can be driven by a driving-gear 2601 through a pinion gear;
- Figure 27 shows a stop, which is provided in the form of a toothless portion along the arrangement of gear teeth on the spool gear;

Figure 28 illustrates how the driving-gear 2601 shown in Figure 27 can be disengaged from the pinion gear;

Figure 29 illustrates how the pinion gear shown in Figure 26 can drive two different spools at once, each spool causing different bends in the steerable arm to be straightened;

Figure 30 shows the stages of inserting the coupler in Figure 26 into a coupler-receptacle of a motorbox;

Figure 31 shows the base of another coupler, as another embodiment, having a ring gear, as an alternative to the embodiment shown in Figure 26;

Figure 32 shows how the ring gear in Figure 31 drives spool gears;

Figure 33 shows how the ring gear of Figure 31 may be disengaged from the spool gears;

Figure 34a shows how the ring gear in Figure 31 may drive spool gears;

Figure 34b shows how the ring gear in Figure 31 is received inside the coupler-receptacle of a motorbox;

Figure 35 shows the base of yet another coupler, as a further embodiment, having a different ring gear to that shown in Figure 31.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

Figure 3 is a perspective view of a coupler 301 of a surgical instrument 401. The coupler 301 has a dome-shaped housing 303 placed over a coupler base 305. The housing 303 is made of two lateral parts 303a, 303b. The bottom 307 of the coupler base 305 is relatively flat, and provides access to control the spools inside the housing 303. The orientation shown in Figure 3 is used as the positional reference in the rest of this description.

Figure 4 is an illustration of a surgical instrument 401, having a transmission tube 405 as the main body. The transmission tube 405 has a length of 0.5 m to 1.8 m typically. The coupler is on the proximal end of the surgical instrument 401, and a steerable arm 403 is on the distal end.

The steerable arm 403 is a hollow, tubular device about 3 cm when extended fully, and is able to bend and straighten, swing left and right, or shorten and lengthen when pulled on by a wire attached to the internal surface of the steerable arm 403. The wire is threaded through the transmission tube 405 and connected to a spool inside the coupler 301.

Figure 5 is photograph of a prototype of the surgical instrument 401, provided so that the reader may appreciate the relative size of the steerable arm 403 with the rest of the surgical instrument 401.

Figure 6 illustrates an endoscope 601, having a surgical instrument 401 in each of two instrument channels 609 in the endoscope 601, which is inserted through respective openings near the proximal end of the endoscope 601 where a controller 607 for operating the body of the endoscope is provided.

Figure 7 is an enlarged view of the endoscope tip 603 shown as an insert in Figure 6. The endoscope tip 603 has a light source 701 and a camera 703. The distal openings of the two instrument channels 609 can be seen, extending from each

instrument channel 609 is a steerable arm 403 of a surgical instrument 401. The distal end of each steerable arm 403 is provided with an end-effector 605.

5 Figure 8 illustrates a possible setup for an endoscopic operation, wherein an endoscope 601 is held up by a telescopic arm 803 extending from a trolley 801. The white arrows point to a motorbox 805 on the trolley 801. The motorbox has coupler-receptacles into which the couplers 301 may be inserted. However, the coupler-receptacles are hidden from view by a motorbox cover 802 in Figure 8.

10 Figure 9 is a close up view of the motorbox 805 with the motorbox cover 802 removed, revealing two coupler-receptacles 901. The coupler-receptacle 901 on the right side of the drawing as shown is inserted with the coupler 301 of a surgical instrument 401. The transmission tube 405 can be seen extending from the tip of the coupler 301.

15 Figure 10 is a close up view of a coupler-receptacle 901. Figure 11 gives a similar view, but also showing the bottom 307 of a coupler 301.

20 The coupler-receptacle 901 comprises a short cylindrical shell having a diameter and height suitable for holding the coupler 301 by the coupler base 305. To let the motorbox control the spools and wires in the surgical instrument 401 programmatically, the coupler 301 is inserted into the coupler-receptacle 901 and held by two snap grips 1003. In the depth of the shell are four spool-drivers, each being a female, lever-receiver 1001 for mating with a corresponding, male, spool-lever 1101 on the base of each spool.

25 Figure 3 shows two buttons 309 provided on opposite sides of the coupler housing 303. Pressing on the buttons 309 releases the snap grips 1003. This allows the coupler 301 to be pulled out of the coupler-receptacle 901.

30 The spool-levers 1101 may be twisted to rotate the spools to reel in wires and straighten the steerable arm 403, or to release wires to bend the steerable arm 403. That is, a surgeon may twist the spool-levers 1101 manually, with one hand while holding the coupler 301 with the other hand. Alternatively and preferably, the coupler 35 301 is inserted into a coupler-receptacle 901 so that the motorbox 805 may control each of the spools programmatically.

40 At the start of a surgical operation, the endoscope 601 is inserted by the tip 603 into the mouth or rectum of an anesthetised or sedated patient. The endoscope 601 is moved to the surgical target on the gastrointestinal tract by bending about the folds of the tract. Brakes (not illustrated) on the wheels 807 of the trolley 801 can be applied to prevent the trolley 801 from being moved. After the endoscope has reached the target site and placed stably, the surgical instruments 401 can be inserted into the endoscope.

45 The coupler 301 of the first of surgical instruments 401 is then inserted into a coupler-receptacle 901. Subsequently, software running the motorbox causes the appropriate female, lever-receivers 1001 to turn the spool-levers 1101 and straighten the steerable arm 403.

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The straightened steerable arm is inserted into one of the instrument channels 609, and pushed on by the transmission tube 405 until the steerable arm 403 emerges from the endoscope tip 603.

- 5 Straightening the steerable arm 403 before insertion into the instrument channel 609 reduces friction from and the drag of passing the steerable arm 403 through the instrument channel 609. It is now easier to insert a surgical instrument 401 through an endoscope, compared to doing same using an un-straightened steerable arm 403. The benefit is even more pronounced if one considers how a sharp diathermy knife
10 at the end of the straightened steerable arm 403 may be prevented from cutting the surface of the instrument channel 609.

- It follows that, with less scratching and cutting on the instrument channel 609, there are fewer crevices for hiding and breeding germs, increasing the efficiency of
15 endoscope disinfection. Accordingly, even if surgical instruments 401 are inserted into and removed from the instrument channel without reduction in daily use intensity, wear and tear of the instrument channel is possibly slower, giving the endoscope a possibility of a longer and more robust use-life.

- 20 Furthermore, reduced dragging and scratching on the instrument channel 609 also reduces the likelihood of tugging on the endoscope 601. This helps to keep the endoscope tip 603 as stable as possible even if the surgeon changes surgical instruments frequently during a procedure.

- 25 A short distance away from the setup in Figure 8, the surgeon holds remote controllers to make virtual surgical movements, based on live images transmitted by the camera 703 to a display (not shown). The virtual surgical movements are detected as movement coordinates by a wireless detector in the trolley, and a processor in the motorbox 805 programmatically translates the coordinates into
30 movements of the steerable arm 403 and the end-effector 605.

- The end-effector 605 determines the function of the surgical instrument 401, and may be pair of forceps, a diathermy knife, an injection needle, a suturing tool, and so on. Surgical instruments 401 with different end-effectors 605 may be removed from
35 the endoscope 601 and re-inserted many times during a surgical operation, the purpose being to use the end-effectors 605 just like a painter would pick and use the same paintbrushes repeatedly.

- Figure 12 shows the body 1201 of a steerable arm 403, without end-effector 605, wires and transmission tube 405. The body is made of a straight, hollow tube of a
40 highly resilient metal alloy such as Nitinol. The length of the body is about 3 cm to 3.5 cm, and has a diameter between 2.5 mm to 3.5 mm in order to fit into the instrument channels 609 of most endoscopes.

- 45 The tube is laser-cut to provide on one side of the tube 1201 a series of separated ribs 1203. The other side of the tube becomes a spine 1205 to which the ribs 1203 are attached. The ribs 1203 open up when the tube 1201 is bent towards the side of the spine 1205. The bent tube 1201 is then held still, heat-treated and cooled, so that the bend becomes the tube's permanent shape when at rest. This provides a
50 concave spine side and a convex rib side.

Being made of a single, hollow tube of highly resilient metal alloy and having such a small size provides the steerable arm 403 with the structural strength and shape resilience of a continuum structure.

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Figure 13 show a steerable arm 403 made from the bent tube 1201, affixed with an end-effector 605. The proximal end of the steerable arm 403, called the shoulder 1301, is attached to the transmission tube in such a way that the hollow core in the steerable arm 403 is aligned to the core of the transmission tube 405. This allows one end of a wire attached to the internal surface of the steerable arm 403 to be threaded through the transmission tube, and attached to a spool in the coupler 301. Figure 14 shows the steerable arm 403 articulated and straightened, which happens when the wire is reeled in by the spool.

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Typically, the end-effector 605 is controlled by another wire attached to another spool in the coupler 301, and the shoulder 1301 controlled by yet another wire attached to yet another spool in the coupler 301 to turn the steerable arm 403 left and right on the transmission tube. However, the rest of this description is focused on features of the coupler 301 that allow straightening of a steerable arm 403 before being passing through an instrument channel, which possibly reduces the displacement of the endoscope tip, reduces scratches of the instrument channel and maintains efficiency of disinfection.

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Figure 15 is a series of schematic illustrations of the articulation of the resiliently bent steerable arm 403. The end of a wire inside the core of the steerable arm 403 is connected to a rib 1203 near the distal end of the steerable arm 403. The wire 1501 extends out of the steerable arm 403, passing through the transmission tube 405, and is tied to a controlling spool in the coupler 301. The left-most drawing in Figure 15 shows the steerable arm 403 in the rest state wherein the spine 1205 side is concave (Figure 15a). The ribs 1203 are on the convex side and spread apart to accommodate the bend. When the wire 1501 is reeled in by the spool, some of the ribs 1203 are brought closer to each other, and the spine 1205 is flexed and straightened (Figure 15b). Reeling more of the wire 1501 in pulls the ribs 1203 even closer to each other, and even reverses the curvature of the steerable arm 403 to bend in the opposite side (Figure 15c). Letting go of the control spool control allows the bias in the steerable arm 403 to be the dominant force on the spool, springing the steerable arm 403 back to the bent shape. This bias makes the use of any counter wire unnecessary; a single wire 1501 is adequate for flexing the steerable arm 403.

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Figure 16 shows the bottom 307 of the coupler 301, where the shaft-base 1601 of the spool can be accessed to control the spool.

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Figure 17a is an exploded view of the coupler 301, showing the two lateral parts 303a, 303b of the housing 303 separated from each other and the coupler base 305. Four spools 1701 can be seen, each of which is set into a corresponding shaft-hole in the coupler base 305. A nozzle 1703 extends upwardly between the spools 1701, from the centre of the coupler base 305. The nozzle 1703 has a top part 1705 and a bottom part 1707. The top part of the nozzle 1703 is called the transmission-tube-clamp 1705, which holds the transmission tube tightly, while allowing the wires inside

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the transmission tube to slide. In the assembled coupler 301, the transmission-tube-clamp 1705 protrudes slightly from an opening on the top of the housing 303 (also visible in Figure 3).

- 5 Figure 17b is an exploded view of a spool 1701, with the parts shown aligned to a shaft-hole 1717 in the coupler base 305. Typically, the spool 1701 comprises a spool-shaft 1715 and various reel parts 1709. A bearing 1711 is provided for insertion into the shaft-hole 1717 from the bottom 307, and a constriction (not visible) mid-way along the shaft-hole 1717 prevents the bearing 1711 from having full
10 passage. Another bearing 1711 is provided for insertion into the shaft-hole 1717 but from the top, and also does not have full passage because of the constriction.

- To assemble the spool 1701, the spool-shaft 1715 is inserted from the bottom 307, through the shaft-hole 1717 and both bearings 1711, passing through the
15 constriction. The spool-shaft 1715 has a shaft-base 1601 which is bigger than and, therefore, covers over the shaft-hole 1717. The spool-lever 1101 extends from the shaft-base 1601 and is, therefore, accessible outside the coupler 301.

- Figure 18 shows the reel parts 1709 that are assembled onto the spool-shaft 1715, i.e. the part of the spool-shaft 1715 that has extended through the coupler base 305.
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- Figure 19 show that the assembled spool 1701, which has two reels 2501. Each of the two reels 2501 comprises wide, gentle slopes, which prevent the attached wire 1501 from escaping the reel 2501 in the event of low wire tension. Optionally, each
25 reel 2501 can be attached with the end of a different wire 1501, in which case turning the spool 1701 can reel in or dispense the two wires 1501 at the same time. Alternatively, having two reels is also useful if counter wires are required for some reason. Figure 20 shows, for example, a certain length of a wire has rolled about the top reel, while the bottom reel is merely connected to the end of another wire.
30 Rotating the spool 1701 to release wire from the top reel will reel in wire around the bottom reel concurrently. Reversing the rotation directions reels in wire around the top reel and releases wire from the bottom reel.

- The reel parts 1709 shown in Figure 18 comprise a left lower reel part 1709a and a
35 right lower reel part 1709b. The right lower reel part 1709b has a collar for placing over the spool-shaft 1715. Beneath the collar is a gap into which the left lower reel part 1709a fits radially. When screwed together, these parts hold the bottom part of the spool-shaft 1715 tightly. Furthermore, there are a left upper reel part 1709c and a right upper reel part 1709d that have the same but vertically inverted configuration,
40 such that a collar on the left upper reel part 1709c is placed over the spool-shaft 1715, and a gap in the left upper reel part 1709c is closed by the right upper reel part 1709d and a screw to hold the upper part of the spool-shaft 1715 tightly.

- Figure 21 comprises a left drawing and a right drawing, both showing the coupler base 305 and the nozzle 1703, without any spool 1701. The left drawing also shows
45 some of the bearings 1711 placed into the respective shaft-holes 1717. The right drawing is an exploded view of the nozzle 1703, and showing bearings 1711 separated from the shaft-holes 1717.

- 50 The bottom part of the nozzle 1703 is called a nozzle-base 2101 and a top part, as

already mentioned in a preceding paragraph, is called a transmission-tube-clamp 1705.

5 The lower end of the transmission-tube-clamp 1705 has a square skirt that extends outward horizontally, the corners of which have spin-holes 2103 that may be aligned to respective shaft-holes 1717, into which a rotation-tip 1713 on the top of each spool-shaft 1715 may be inserted and loosely or rotate-ably held (refer to Figure 17a).

10 The transmission-tube-clamp 1705 itself comprises two lateral parts 1705a, 1705b as seen in the right drawing in Figure 21. Each part provides a lateral half of a funnel 2105. The funnel 2105 is aligned to the centre of the coupler base 305, providing a narrowing passage that urges wires 1501 towards the centre of the nozzle-base 2101, that is, if there is more than one wire 1501.

15 Figure 22 is a perspective view of the nozzle-base 2101, Figure 23 is the corresponding plan view, and Figure 24 is the side view in the plane AA. The lower end of the nozzle 1703 has four toes 2201 which extend in different directions. A screw hole in each toe 2201 allows a screw to secure the toe 2201 to the coupler base 305.

20 The top of the nozzle-base 2101 has four ledges 2203 extending in different directions. Each ledge 2203 is provided with a screw hole that may be aligned to a corresponding hole 2107 in the skirt of the transmission-tube-clamp 1705, for the transmission-tube-clamp 1705 to be screwed to the nozzle-base 2101.

25 Wires 1501 extending from the transmission tube 405 are threaded through the funnel 2105. Deeper into the nozzle, each wire is threaded into a different slit 2301 inside the nozzle-base 2101, to ensure wire separation before turning each wire 1501 about a respective roller 2205 to be directed to the reel 2501 of a spool 1701. The slit is just a narrow passage in which a wire is threaded. Two crossing slits can be seen in Figure 23.

30 Although four spools 1701 are illustrated in Figure 17a, there may be more or fewer spools 1701 in other embodiments, depending on the number of controllable parts in the steerable arm 403 requiring wire control. A corresponding number of lever-receivers 1001 on the spools 1701 may have to be provided in the coupler-receptacle 901.

40 Pre-tensioning stop or retainer 1

45 When the steerable arm moves from being straight into being bent, a certain length of wire has to be released by the spool to allow the bending. The dimensions of the spool (and the reel) are pre-selected such that the required length is released without requiring the spool to make a complete rotation. As the length of the steerable arm 403 is only about 3 cm, this required length of wire tends to be much shorter.

50 Figure 16 shows the bottom of the coupler 301, where four shaft-bases 1601 can be

accessed to rotate the respective spools inside the coupler. There is a protrusion 1603 extending radially from the edge of each shaft-base 1601. Furthermore, there is a stop 1605 next to each shaft-base 1601, also provided on the coupler bottom 307.

5 Each stop is in the path of the respective protrusion 1603 when the corresponding spool 1701 rotates to release wire. Therefore, the stop limits the extent of spool rotation. The position of the stop is selected such that a certain length of wire is prevented from being released. Rather, the position of the stop is selected such that
10 the maximum length of wire release-able by the spool 1701 is slightly insufficient to allow the steerable arm to bend fully as urged by the bias. The unsatisfied bias pulls on the wire unceasingly, which provides a minimum degree of pre-tension in both the wire 1501 and the bent steerable arm 403. This allows the steerable arm to be responsive immediately whenever the spool rotates the other way to reel in wire.

15

Figure 25 is a schematic illustration of how the stop works. The top drawing in Figure 25 shows a spool 1701 without any stop inserted into neighbouring stub-holes 2503. For convenience of illustration, a fin 2501 is drawn extending radially from the body
20 of the spool 1701, instead of a protrusion 1603 from a shaft-base 1601 on the other side of the coupler base 305. When the spool 1701 rotates, the fin 2501 is turned about the spool 1701.

The bottom drawing in Figure 25 shows a stop inserted into one of the stub-holes 2503. The position of the stop 1605 prevents the spool 1701 from dispensing the length of wire 1501 required to satisfy the bias fully. Preferably, the maximum length
25 of wire 1501 release-able allows the steerable arm 403 to manifest the bend almost fully, except for an extent so small that it is not noticeable to the human eye.

30 Although embodiments described so far has a steerable arm 403 that is bent in the rest state, other embodiments (not illustrated) are also possible in which the steerable arm 403 is biased to be straight in the rest state. This straight steerable may be bent to one side by the pull of a wire 1501 inside the steerable arm 403, on the distal rib 1203. The pull closes the gaps between the ribs and bends the
35 steerable arm towards the rib side. Even in such an embodiment, the steerable arm 403 can be pre-tensioned by being pulled to bend to the rib side, but so slightly that the human eye cannot see the bend.

Referring again to an embodiment of a steerable arm 403 biased to bend, depending
40 on steerable arm dimensions and material, some steerable arms can be over-flexed, which weakens the strength of the bias. In order to provide an upper limit to the flexing of the steerable arm 403, i.e. reeling in the wire, a small retainer block 2505 may be used in place of the stop 1605. A not-to-scale retainer block 2505 is shown as a drawing insert in Figure 25, accompanied by a white arrow.

45

The retainer block 2505 is preferably arcuate to match the curvature of the path of the fin 2501. The base of the retainer block 2505 may be provided with two stubs for fitting into respective stub-holes 2503.

50 The retainer block 2505 has two ends, and a distance between the two ends. The

end of the retainer block 2505 that abuts the fin rotating in the wire-releasing direction prevents full release of the wire 1501. The other end of the retainer block 2505 abuts the fin in the reverse rotation prevents over-flexing of the steerable arm 403.

5

Preferably, all the parts of the coupler base 305 are made of a hard plastic material.

Pre-tensioning stop or retainer 2

10 Other embodiments that comprise limitation to spool rotation are possible. Figure 26 to Figure 30 shows one such other embodiment.

Figure 26 shows the bottom of a coupler 301, whereupon a driving-gear 2601 is provided in the centre of the round coupler base 305. A spool 1701 is shown on the top side of the coupler base 305. On the bottom side of the coupler base 305, the shaft-base 1601 of the spool 1701 is provided with a spool-gear 2701. The spool-gear 2701 engages with the driving-gear 2601 through an intermediary pinion gear 2603.

15

20 Figure 27 shows the spool-gear 2701 separately. A spool-lever 1101 is provided on the surface of the spool-gear 2701 for mating with a corresponding lever-receiver 1001 when the coupler 301 is inserted a motorbox 805.

Generally, any gear is made of circumferentially arranged teeth, which are made by cutting or making indentations into the circumference of the gear, in order to define the gear teeth. The root of the teeth is aligned to a root circumference defined by a root diameter while the tip of the teeth are aligned to the tip circumference or outer circumference defined by a tip diameter. If the gear is a ring gear which is a ring, wherein the inner circumference is provided with inward pointing gear teeth, the root circumference would be larger than the tip circumference.

25

30

A portion of the spool-gear 2701 is not provided with indentations, i.e. there is a toothless region 2703 which is missing at least one gear tooth. The toothless region is levelled with the outer diameter or tip circumference of the spool-gear 2701 due to a lack of indentation. The two ends of this toothless region 2703 cannot engage the teeth of the pinion gear 2603. One of these ends limit spool rotation in the wire-release direction to prevent full release of the wire 1501, in order to provide pre-tension in the wire 1501 and the steerable arm 403. The other end of this toothless region limits the steerable arm 403 from being over flexed.

35

40

A side view of the driving-gear 2601 is shown in Figure 28. The driving-gear 2601 also has a lever extending therefrom, which may be used by the surgeon to twist the driving-gear 2601 manually. This lever is called a driver-lever 2801 for distinction. Typically, the driving-gear 2601 is only used by the surgeon, and not by the motorbox.

45

The driving-gear 2601 has a set of upper gear teeth 2803 and a set of lower gear teeth 2805. The upper gear teeth 2803 engages with a ratchet 2807 on the coupler bottom 307 to prevent the bias in steerable arm pulling the driving-gear 2601 in the release direction. This allows the surgeon to lift and re-position his hand to continue

50

twisting the driving-gear 2601, or to free his hand for inserting a surgical instrument into an endoscope 601. The lower gear teeth 2805 engages the pinion gear 2603 to turn the spool-gear 2701.

- 5 The surgeon can twist the driver-lever 2801 to straighten the steerable arm 403 before passing the steerable arm through an instrument channel 609 of an endoscope 601.

- 10 The driving-gear 2601 can be toggled between two positions. The drawing on the right in Figure 28 shows the driving-gear 2601 elevated from the coupler bottom 307, in which the lower gear teeth 2805 engages the pinion gear 2603 and the upper gear teeth 2803 engages the ratchet 2807.

- 15 Pressing the driving-gear 2601 down towards the coupler bottom 307 disengages the driving-gear 2601 from both the pinion gear 2603 and the ratchet 2807, and therefore also from the spool 1701. This allows the bias in the steerable arm 403 to become the dominant force on the spool 1701. As the disengaged spool 1701 is free to rotate in response to the bias, the length of wire 1501 required to accommodate manifestation of the bend is pulled off the spool 1701, except for a very short length
20 which is prevented from being released. This release limit is provided by the abutment between the pertinent end of the toothless region 2703 on the spool-gear 2701 and the pinion gear 2603. Therefore, this end of the toothless region is like the fin 2501 on the spool 1701 in Figure 25, while the pinion gear 2603 is like the stop 1605.

- 25 Typically, a spring (not shown) is provided to bias the driving-gear 2601 back to the elevated position when the force pressing on the driving-gear 2601 is lifted.

- 30 The pinion gear 2603 remains engaged with the spool-gear 2701 when the driving-gear 2601 is depressed. Therefore, the toothless region 2703 abuts the pinion gear 2603 in the same positions after re-engagement driving-gear 2601.

- 35 The drawing on the left of Figure 29 shows a steerable arm 403 that has two bends marked by white arrows, each bending in a different direction. Two spools 1701 are used (one hidden from view), each to control a wire 1501 for flexing one of the bends. To straighten the steerable arm 403 manually, the surgeon twists the centrally-placed driver-lever 2801 on the coupler bottom 307, turning both spools 1701 at once to reel in the wires 1501. The drawing on the right shows the two bends
40 straightened. The turning of the driving-gear 2601 and the spool-gears 2701 is illustrated by the change in orientation of the levers from the left drawing to the right drawing.

- 45 For avoidance of doubt, in a coupler 301 that has four spools 1701, there are four pinion gears 2603. Each pinion gear 2603 engages with a different side of the same driving-gear 2601. Therefore, the driver-lever 2801 rotates all four spools 1701. Typically, the wires, spools and gears are pre-configured such that when the driving-gear 2601 disengages the spool-gears 2701, the bias in the steerable arm 403 pulls the spools 1701 into such an orientation that the spool-levers 1101 are aligned to
50 mate with lever-receivers 1001 in the motorbox 805 smoothly.

Figure 30 shows the stages of a coupler-receptacle 901 engaging the motorbox 805 engages the coupler 301. Stage 1 is shown in the top drawing, wherein the surgical instrument 401 has a straightened steerable arm 403. This could be done by the surgeon twisting the driver-lever 2801. The straightened steerable arm 401 is prevented from springing back into the bent state by the ratchet. The coupler 301 is pushed by the coupler bottom 307 into the coupler-receptacle 901.

A poker 3001 extends from the depth of the coupler-receptacle 901, reaching beyond the lever-receivers 1001. Stage 2 is shown in the middle drawing, in which the poker 3001 presses on the driving-gear 2601, disengaging the spool-gears 2701 and letting the steerable arm 403 spring into the bent shape. Stage 3 is shown in the bottom drawing, during which the spool-levers 1101 mate with the lever-receivers 1001, allowing the motorbox 805 to drive each spool 1701 independently. The two snap grips 1003 hold the coupler 301 in the coupler-receptacle 901 firmly until release by pressing on the buttons 309.

When so inserted into the motorbox 805, the steerable arm 403 can be straightened by operation of the motorbox 805 on each of the spools 1701. Nevertheless, the possibility of manually twisting the driver-lever 2801 is useful when the motorbox 805 cannot be operated due to loss of power.

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Figure 31, Figure 32, Figure 33 and Figure 34 are illustrations of a further embodiment in which the central driving-gear 2601 in the embodiment of Figure 26 is replaced by a ring gear 3101.

The ring gear 3101 comprises a ring, which is a round, endless loop, typically made of the same material as the rest of the coupler 301. The circumference of the ring has a width, such that the outer edge has a slightly larger diameter than the coupler base to provide a better grip. The inner edge has a smaller circumference. On opposite sides of the inner edge are provided two rows of inwardly extending driving teeth 3103, each of the rows being able to engage and drive a neighbouring spool-gear 2701.

A row of finer teeth 3105 is provided on the inner edge immediately adjacent each row of driving teeth 3103 on the clockwise side, to engage a ratchet on the coupler bottom 307 for the same reasons of preventing automatic release of wire after the surgeon has reeled in wire manually. Only one ratchet gear is required. Therefore, a ratchet on the coupler bottom 307 engages only either one of the two rows of finer teeth illustrated. In some embodiments, there is only one row of such finer teeth on the ring gear 3101.

In Figure 31 to Figure 34, each spool-gear 2701 has a toothless region flanked by two ends. The toothless region is levelled with the outer diameter or tip circumference of the spool-gear 2701 due to a lack of indentation.

When the spool-gear 2701 is rotated into a position where one of these ends abuts the driving teeth 3103, further rotation of the spool 1701 in the same direction is

prevented; the spool-gear 2701 has no teeth in this toothless region to intersect and move with the corresponding teeth on the ring gear 3101.

5 The ring gear 3101 can be toggled between an elevated position, to engage the spool-gears 2701 and the ratchet, and a depressed position, to disengage the spool-gears 2701 and the ratchet 2807.

10 Figure 32 shows the ring gear 3101 in the elevated position (top drawing) and turned anti-clockwise to drive two spool gears into rotating anti-clockwise (from bottom left drawing to bottom right drawing). This reels in the respective wire around the connected spool 1701, and straightens the steerable arm 403 (not illustrated). However, the anticlockwise end of the toothless region on each spool-gear 2701 abuts the respective driving teeth 3103, preventing further rotation and over-flexing of the steerable arm 403. Rotation of the spools 1701 in Figure 32 can be noted from
15 the change in orientation of the spool-levers 1101 as drawn. As there are two wires each controlled by a different spool 1701, the reader can tell that the steerable arm 403 has two bends.

20 Figure 33 illustrates the ring gear 3101 depressed towards the coupler base 307 (top drawing), which disengages the spool-gears 2701 and ratchet 2807. The steerable arm 403 straightened in Figure 32 is now free to spring back into a permanent shape, i.e. one that has two bends, by the force of the bias in each bend. The required length of each wire 1501 is pulled off the respective spool 1701 to accommodate the bends (not illustrated), rotating the spools 1701 in the release direction. However,
25 each spool is only able to release a pre-determined length of wire because a sidewise protrusion extending from the toothless region 2703 on the spool-gear 2701 abuts a neighbouring stop 3107 to prevent full discharge of the bias of the respective bend. When the depression force is lifted, a spring (not illustrated) pushes the ring gear 3101 back into engagement with the spool-gear 2701 and ratchet 2807.

30

Two spools 1701 are shown in Figure 31 to Figure 33, each having a spool-lever 1101 but which not provided with a spool-gear 2701 for engaging the ring gear 3101. These spools 1701 are used, for example, to control other parts of the steerable arm
35 403 such as the end-effector.

Figure 34b shows how the coupler 301 is engaged by a coupler-receptacle 901 in the motorbox 805. The first stage of the process is shown in the top drawing, and the second stage in the bottom drawing. The coupler-receptacle has a ledge 3401 lining
40 the inner circumference of the cylindrical shell. The ledge 3401 pushes on the ring gear 3101 to release the engagement between the ring gear 3101 and the spool gears 2601 before the spool-lever 1101 comes into contact with the lever-receiver 1001.

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Figure 35 shows a further embodiment similar to the embodiment shown in Figure 31 to Figure 34b, which also comprises a ring gear 3101 (i.e. the driving-gear 2601) to turn spool-gears 2701 from the circumference. A ratchet 2807 is provided to prevent
50 unintentional reversal of the rotation of the spools 1701. The drawing shows two

spools 1701 each provided with a spool gear. The drawing also shows two other spools 1701 but these are not provided with any spool-gear 2701.

5 In contrast to the embodiment of Figure 32, however, there is only one set of driving teeth for engaging spool gears and the ratchet. The driving teeth are provided as an endless row of teeth of the same size 3501, lining the entire inner circumference of the ring.

10 The operation of this embodiment is largely the same as the embodiment of Figure 34 for turning the spool-gears 2701, e.g. turning the ring gear 3101 rotates the spools 1701. Also, the ring gear 3101 can be depressed towards the coupler bottom 307 to disengage both the spool-gears 2701 and ratchet 2807.

15 The ring gear 3101 shown in Figure 40 can also be depressed by a ledge 3401 in the coupler-receptacle 901 to disengage the spool-gears 2701. While the coupler 301 is in the coupler-receptacle 901, the ring gear 3101 remains depressed.

20 However, when the depressing force on the ring gear 3101 is lifted, any part of the endless row of gear teeth 3501 may re-engage the spool-gears 2701 and the ratchet. In contrast, the ring gear 3101 in Figure 31 to Figure 35 has to be aligned so that the ratchet 2807 re-engages with the first tooth in the row of finer teeth 3105 to provide full flexing range for the steerable arm 403.

Other embodiments

25 In the foregoing embodiments, the stop functions provided by the various stop configurations retain a length of wire from being released by the spool, or permit release of a specific length of wire. These allow the convenience of providing a spool with excess length of wire first, and limiting the maximum release-able length later.

30 In a more rudimentary embodiment, however, the exact length of wire for letting the steerable arm bend only to the required degree is provided between the spool and the distal rib in the steerable arm. There is no need of the protrusion and stop mechanism to limit the length of release-able wire. However, this embodiment introduces other problems. Providing an exact length of wire is tedious and is subject to assembly intolerances, undermining the required precision.

40 Accordingly, all the embodiments embody a steerable arm capable of being in a first position and a second position, the steerable arm biased to be in a first position but retained from fully satisfying the bias in order to be readily responsive when a force acts to urge the steerable towards the second position. The first position and a second position determined by the length of a wire dispensed from a spool. The retention from fully satisfying the bias is provided by a limit to the length of the wire dispensable from the spool.

45

While there has been described in the foregoing description preferred embodiments of the present invention, it will be understood by those skilled in the technology concerned that many variations or modifications in details of design, construction or

operation may be made without departing from the scope of the present invention as claimed.

5 For example, all male and female configurations described in different parts of the embodiments can be reversed; instead of a male, spool-lever 1101 on the each shaft-base 1601 to mate with corresponding a female, lever-receiver 1001 in the coupler-receptacle 901, a female, lever-receiver 1001 can be provide on each shaft-base 1601 with enough depth to mate with a corresponding male, protruding lever in the depth of the coupler-receptacle 901.

10 It is not necessary that the coupler has a housing, or that the spools must be in the form of a vertical, elongate, rotatable device as illustrated, but may be any form of wire dispensing and wire in-reeling device.

15 In all the embodiments, a prominent feature is a steerable arm capable of being in a first position and a second position, the steerable arm biased to be in a first position but restrained from fully satisfying the bias in order to be readily responsive when a force acts to urge the steerable towards the second position.

20

CLAIMS

1. A surgical instrument, comprising
a steerable arm having a bias to be in a first position;
a wire;
one end of the wire connected to the steerable arm and the other end
of the wire connected to a spool;
the spool being movable in a release direction to dispense wire,
allowing the steerable arm to be moved by the bias into the first position;
a retaining device preventing the spool from moving past a maximum
release point; wherein
when the spool is moved in the release direction into the maximum
release point, the length of wire dispensed is insufficient to fully satisfy
the bias.
2. A surgical instrument as claimed in claim 1, wherein
the spool is movable in a reel-in direction to reel in wire, pulling the
steerable arm against the bias into a second position.
3. A surgical instrument as claimed in claim 2, further comprising:
a one-way gear allowing the spool to move in the reel-in direction and
preventing the spool from moving in the release direction.
4. A surgical instrument as claimed in claim 2 or claim 3, further comprising
a driving-gear; a spool-gear that rotates in unison with the spool; the
driving-gear arranged to drive the spool-gear; wherein
the spool-gear has gear teeth; and
the retaining device comprises a discontinuity in the arrangement of
gear teeth of the spool-gear that blocks the further movement of the drive-
gear.
5. A surgical instrument as claimed in claim 4, wherein
the spool-gear is a first spool-gear;
the spool is a first spool; and
the wire is a first wire;
the retaining device is a first retaining device;
the surgical instrument further comprising:
a second spool-gear;
a second spool;
a second wire;
a second retaining device;
the steerable arm having a second bias to be in a third position;
one end of the second wire connected to the steerable arm and the
other end of the second wire connected to the second spool;
the second spool being movable in a release direction to dispense the
second wire, allowing the steerable arm to be moved by the second bias
into the third position; wherein
when the second spool is moved in the release direction into a
maximum release point, the length of the second wire dispensed is
insufficient to fully satisfy the second bias;

- the second spool is movable in a reel-in direction to reel in the second wire, pulling the steerable arm against the second bias into a fourth position;
- the second spool-gear capable of rotating in unison with the second spool;
- the driving-gear arranged to drive the second spool-gear; wherein the second spool-gear has gear teeth; and
- the second retaining device comprises a discontinuity in the arrangement of gear teeth of the second spool-gear that blocks the further movement of the drive-gear.
6. A surgical instrument as claimed in claim 2, further comprising a reel-in limiting device that prevents movement of the spool in the reel-in direction beyond a maximum reel-in point.
7. A surgical instrument as claimed in claim 6 further comprising a driving-gear; a spool-gear that rotates in unison with the spool; the driving-gear arranged to drive the spool-gear; wherein the driving-gear is capable of disengaging the spool-gear such that the steerable arm is unrestrained to move into the first position according to the bias.
8. A surgical instrument as claimed in claim 4, wherein the driving-gear is a ring gear enclosing the spool-gear; the ring gear comprising: a ring having an external edge and an internal edge; gear teeth provided on the internal edge that engages the gear teeth of the spool gear, such that turning the ring drives the spool gear.
9. A coupler for dispensing and reeling in wires to control a steerable arm, comprising: a spool for a wire; the spool being movable in a release direction to dispense wire; a retaining device preventing the spool from moving past a maximum release point; a driving-gear; a spool-gear that rotates in unison with the spool; the driving-gear arranged to drive the spool-gear; wherein the spool-gear has gear teeth; the retaining device comprises a discontinuity in the arrangement of gear teeth of the spool-gear that blocks the further movement of the drive-gear.
10. A coupler for dispensing and reeling in wires to control a steerable arm as claimed in claim 9, wherein the driving-gear is capable of disengaging the spool-gear such that the spool is able to move unrestrained by the driving-gear.
11. A coupler for dispensing and reeling in wires to control a steerable arm as claimed in claim 9 or claim 10, wherein

the spool is movable in a reel-in direction to reel in wire; comprising a reel-in limiting device that prevents movement of the spool in the reel-in direction beyond a maximum reel-in point.

12. A coupler for dispensing and reeling in wires to control a steerable arm as claimed in any one of claim 9, claim 10 and claim 11, wherein the driving-gear is a ring gear enclosing the spool-gear; the ring gear comprising:
 - a ring having an external edge and an internal edge;
 - gear teeth provided on the internal edge that engages the gear teeth of the spool gear, such that turning the ring drives the spool gear.
13. A method of passing a surgical instrument through an instrument channel of an endoscope, the tip of the surgical instrument comprising a bendable and straighten-able steerable arm, comprising the steps of:
 - straightening the steerable arm before passing the surgical instrument through the instrument channel.