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(73) Proprietor: **Intuitive Surgical Operations, Inc.**
Sunnyvale CA 94086 (US)

(72) Inventors:
- **OHLINE, Robert M.**
  Redwood City, CA 94061 (US)
- **TARTAGLIA, Joseph M.**
  Morgan Hill, CA 95037 (US)
- **BELSON, Amir**
  Cupertino, CA 95014 (US)
- **ROTH, Alex T.**
  Redwood City, CA 94061 (US)
- **KELLER, Wade, A.**
  Aliso Viejo
  CA 92656 (US)
- **ANDERSON, Scott, C.**
  Sunnyvale, CA 94087 (US)
- **JULIAN, Chris, A.**
  Los Gatos, CA 95033 (US)

(74) Representative: **Price, Nigel John King et al**
J A Kemp
14 South Square
Gray's Inn
London WC1R 5JJ (GB)

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Description

FIELD OF THE INVENTION

[0001] The present invention relates generally to endoscopes and endoscopic procedures. More particularly, it relates to an apparatus to facilitate insertion of a flexible endoscope along a tortuous path, such as for colonoscopic examination and treatment.

BACKGROUND OF THE INVENTION

[0002] An endoscope is a medical instrument for visualizing the interior of a patient's body. Endoscopes can be used for a variety of different diagnostic and interventional procedures, including colonoscopy, bronchoscopy, thoracoscopy, laparoscopy and video endoscopy.

[0003] Colonoscopy is a medical procedure in which a flexible endoscope, or colonoscope, is inserted into a patient's colon for diagnostic examination and/or surgical treatment of the colon. A standard colonoscope is typically 135-185 cm in length and 12-19 mm in diameter, and includes a fiberoptic imaging bundle or a miniature camera located at the instrument's tip, illumination fibers, one or two instrument channels that may also be used for insufflation or irrigation, air and water channels, and vacuum channels. The colonoscope is inserted via the patient's anus and is advanced through the colon, allowing direct visual examination of the colon, the ileocecal valve and portions of the terminal ileum.

[0004] Insertion of the colonoscope is complicated by the fact that the colon represents a tortuous and convoluted path. Considerable manipulation of the colonoscope is often necessary to advance the colonoscope through the colon, making the procedure more difficult and time consuming and adding to the potential for complications, such as intestinal perforation. Steerable colonoscopes have been devised to facilitate selection of the correct path though the curves of the colon. However, as the colonoscope is inserted farther into the colon, it becomes more difficult to advance the colonoscope along the selected path. At each turn, the wall of the colon must maintain the curve in the colonoscope. The colonoscope rubs against the mucosal surface of the colon along the outside of each turn. Friction and slack in the colonoscope build up at each turn, making it more and more difficult to advance and withdraw, and can result in looping of the colonoscope. In addition, the force against the wall of the colon increases with the buildup of friction. In cases of extreme tortuosity, it may become impossible to advance the colonoscope all of the way through the colon.

[0005] Steerable endoscopes, catheters and insertion devices for medical examination or treatment of internal body structures are described in the following U.S. patents: 4,054,128; 4,543,090; 4,753,223; 4,873,965; 5,174,277; 5,337,732; 5,383,852; 5,487,757; 5,624,380; and 5,662,587.

[0006] US 2002/0022765 A1 and US 2002/0062062 A1 both disclose a steerable endoscope has an elongated body with a selectively steerable distal portion and an automatically controlled proximal portion. The endoscope body is inserted into a patient and the selectively steerable distal portion is used to select a desired path within the patient's body. When the endoscope body is advanced, an electronic motion controller operates the automatically controlled proximal portion to assume the selected curve of the selectively steerable distal portion. Another desired path is selected with the selectively steerable distal portion and the endoscope body is advanced again. As the endoscope body is further advanced, the selected curves propagate proximally along the endoscope body, and when the endoscope body is withdrawn proximally, the selected curves propagate distally along the endoscope body. This creates a serpentine motion in the endoscope body that allows it to negotiate tortuous curves along a desired path through or around and between organs within the body.

[0007] US 5 203 319 A1 discloses a tubular, fluid-controlled bending neck for an elongated flexible probe, such as a video borescope. An elongated tubular elastomeric bladder is fitted to a proximal connector that fits onto a distal end of the probe insertion tube, and a distal fitting seals the distal end of the bladder. A tubular braid is disposed over the bladder to confine the same and is mechanically attached to the distal fitting and to the proximal connector. The connector provides communication of fluid pressure from a controlled fluid pressure source to the interior of the bladder. An elastically bendable, but axially substantially incompressible, spine is disposed at the interface between the bladder and the braid. This spine is preferably set or biased to be curved into one bending direction. As fluid pressure is applied to the bladder, the bladder inflates laterally. This shortens the braid on the side away from the spine, thereby bending the neck in the opposite direction. By applying a pressure intermediate between a zero pressure and the pressure required for full bending the bending neck will assume a straight orientation.

[0008] US 4 919 112 A1 discloses an endoscope having a separable, disposable shaft wherein a push-pull mechanism, housed in a liquid tight fashion in a control handle unit, is operable to actuate a shaft flexure means within the shaft effective to deflect the distal end of the shaft. In the push-pull mechanism, push rods are in abutting contact with opposite ends of a rocker arm. These opposite ends of the rocker arm are each connected to a respective control wire via a bead or wire head. The abutting contact between the push rods and the opposite ends of the rocker arm is such that the push rods can only push their respective ends of the rocker arm rather than pull them.

[0009] WO 93/15648 A1 discloses an endoscope comprising a handheld control module and a disposable insertion tube removably attached at a proximal end to the control module. Mechanically actuated cables are provided with attachment or coupling elements at their proximal ends for releasably attaching the cables to the control module for operation by a joystick. The endoscope control module of Fig. 5 is provided with a button-like cable coupling element for applying compressive forces directly to the proximal ends of specific respective cables.

SUMMARY OF THE INVENTION

[0010] According to the present invention there is provided the apparatus of claim 1.

[0011] There are described and illustrated herein steerable endoscopes for the examination of a patient's colon, other internal bodily cavities, or other internal body spaces with minimal impingement upon the walls of those organs. One variation of the steerable endoscope described herein has a segmented, elongated body with a manually or selectively steerable distal portion (at least one segment) and an automatically controlled proximal portion. The selectively steerable distal portion can be flexed in any direction by controlling the tension on tendons, e.g., cables, wires, etc., from their proximal ends; these tendons are routed selectively throughout the length of the endoscope. The controllable proximal portion of the endoscope contains at least one independently articulatable segment that can also be bent in any direction via the tendons, and can be made to assume the shape of the distal segment as the endoscope is advanced distally.

[0012] The selectively steerable distal portion can be selectively steered (or bent) up to, e.g., a full 180 degrees, in any direction. A fiberoptic imaging bundle and one or more illumination fibers may extend through the body from the proximal portion to the distal portion. The illumination fibers are preferably in communication with a light source, i.e., conventional light sources, which may be positioned at some external location, or other sources such as LEDs. Alternatively, the endoscope may be configured as a video endoscope with a miniature video camera, such as a CCD camera, positioned at the distal portion of the endoscope body. The video camera may be used in combination with the illumination fibers. Optionally, the body of the endoscope may also include one or two access lumens that may be used, for example, for: insufflation or irrigation, air and water channels, and vacuum channels, etc. Generally, the body of the endoscope is highly flexible so that it is able to bend around small diameter curves without buckling or kinking while maintaining the various channels intact. The endoscope can be made in a variety of sizes and configurations for other medical and industrial applications.

[0013] In operation, the steerable distal portion of the endoscope may be first advanced into the patient's rectum via the anus. The endoscope may be simply advanced, either manually or automatically by a motor, until the first curvature is reached. At this point, the user (e.g., a physician or surgeon) can actively control the steerable distal portion to attain an optimal curvature or shape for advancement of the endoscope. The optimal curvature or shape is the path that presents the least amount of contact or interference from the walls of the colon. In one variation, once the desired curvature has been determined, the endoscope may be advanced further into the colon such that the automatically controlled segments of the controllable portion follow the distal portion while transmitting the optimal curvature or shape proximally down the remaining segments of the controllable portion. Thus, as the instrument is advanced, it follows the path that the distal portion has defined. The operation of the controllable segments will be described in further detail below.

[0014] Tendons, also called tensioning members, may be used to articulate the controllable segments of the endoscope, including the distal steerable portion. Examples of appropriate tendons are push- pull cables that are flexible but minimally compressible or extensible. In one variation, this tendon is a Bowden cable where an internal cable is typically coaxially surrounded by a housing or sleeve through which the cable is free to move. Bowden cables can be used to apply either tensile or compressive forces in order to articulate the endoscope and can be actuated remotely to deliver forces as desired at locations on the endoscope.

[0015] In one variation using Bowden push-pull cables for the tendons, three tendons may be attached at sites equally spaced around the circumference of the controllable endoscope segment. Another variation may alternatively use two tendons, as described further below. The sleeves of the Bowden cables may be affixed at the proximal end of the segment, and the internal cables may be attached to the distal end of the same segment. Applying a tensile or compressive force to one of these internal cables causes the segment to bend in the direction of the cable being pushed or pulled. The bending is continuous and proportional to the displacement of the cable. Thus, a segment can be bent in virtually any direction using tendons by applying tension or compression on one or a combination of tendons attached to the distal end of the segment. Other variations of this invention using Bowden cables may use four or more Bowden cables spaced either equally or in specified positions around the circumference of the segment to be bent depending upon the desired articulation. A further variation may even use two Bowden cables in combination with biasing elements, e.g., springs, elastic elements, pistons, etc., to articulate the segments.

[0016] Another variation of the tendon uses a non-compressible, non-extensible push-pull cable in compression rather than in tension in order to bend a segment. Alternatively, a combination of tendons under both compression and tension could also be used.

[0017] The controllable proximal portion of the endoscope is comprised of at least one segment and preferably many segments that are each articulatable relative to one another via a controller and/or a computer located at a distance from the endoscope. In one variation, the majority of the insertable length of the endoscope comprises controllable segments. Segments are preferably non-compressible and non-expansible, and therefore maintain a constant length along their centerline when bending. An example describing such a variation may be found in U.S. Patent Application Publication No. 2002/0022765 A1 entitled "Steerable Endoscope and Improved Method of Insertion". Each of the segments may have tendons to allow for controlled motion of the segments in space. Thus, coordinating the articulation of individual tendons can bend each segment across a wide range of motion. Individual tendons can be actuated by, for example, an electromechanical motor operably connected to the proximal end of the tendon. Alternatively, pneumatic or hydraulic cylinders, pneumatic or hydraulic motors, solenoids, shape memory alloy wires, or electronic rotary actuators could be utilized to actuate the segments using the tendons.

[0018] Another variation of the endoscope uses ring-shaped support pieces, or vertebrae, as control rings to achieve bendable segments. A segment is comprised of a plurality of adjacent or stacked vertebrae where the vertebrae are connected to each other by jointed sections, e.g., hinged joints, giving the segment flexibility in any direction. Thus, vertebra-type control rings can be hinged to adjacent vertebrae by flanges with through holes. In one variation, pairs of hinge joints project perpendicularly from the face of each vertebra and can connect to the hinge joints of adjacent vertebrae both proximally and distally. Each pair of hinge joints allows limited motion in one axis. The hinge joints projecting from the opposite face of the vertebra are preferably located 90 degrees in rotation from the pair on the other face of the vertebra. This creates a second axis of motion in a plane perpendicular to the first. Adding additional vertebrae in this way result in a segment that could be bent in any direction. For example, approximately ten vertebrae could be linked to create one such segment. Other variations can have more or fewer vertebrae per segment.

[0019] In addition to hinged joints, there are other features that could be included in the control ring. Thus, the inner surface of the vertebra could have channels forming a common lumen in the endoscope, such as for the working channels, the air and water channels, the optical fiber channels, tendons, and so forth. The vertebra could also include attachment sites for the tendons, including the sleeve and inner cable of the Bowden cable examples. Further, the outer edge of the control ring could include channels for holding tendons that control more distal segments. These channels could provide methods of arranging and organizing such tendons. For example, in another variation, the tendons controlling more distal segments are helically wound around the outer surface of more proximal segments as the tendons project proximally to the controller. Such helical winding could prevent unintended tension on tendons controlling more distal segments when proximal segments are bent. Alternatively, the tendons can include excess "slack." Such excess slack could also help prevent proximal segments from being constrained by bypassing tendons controlling more distal segments.

[0020] Another variation of the control ring omits hinged vertebrae, but instead relies on a flexible backbone throughout the endoscope, to which control rings (also called support rings) are attached at intervals. In one variation using a Bowden cable, the tendon inner cables are attached at the most distal control ring in a segment, and the tendon sleeve is attached at the most proximal control ring. The control rings may have spaces allowing components to pass through the segments, and most of the same features described for the vertebra-type control rings.

[0021] A proximal handle may be attached to the proximal end of the endoscope and may include imaging devices connected to the fiberoptic imaging bundle for direct viewing and/or for connection to a video camera or a recording device. The handle may be connected to other devices, e.g., illumination sources and one or several luer lock fittings for connection to various instrument channels. The handle may also be connected to a steering control mechanism for controlling the steerable distal portion. The handle may optionally have the steering controller integrated directly into the handle, e.g., in the form of a joystick, conventional disk controller using dials or wheels, etc.

[0022] As the endoscope is advanced or withdrawn axially, a depth referencing device, or axial transducer, may be used to measure the relative current depth (axial position) of the endoscope. This axial motion transducer can be made in many possible configurations, such as devices that work by contacting, signaling, or communicating to the endoscope. For example, as the body of the endoscope slides through the transducer, it produces a signal indicating the axial position of the endoscope body with respect to the fixed point of reference. This measure corresponds to the depth of the endoscope within the body cavity. The transducer may also use non-contact methods for measuring the axial position of the endoscope body, such as optical, capacitive, resistive, radio frequency or magnetic detection.

[0023] Another variation of the endoscope is fully articulatable over its entire length. Thus, for example, if the endoscope is a standard length of 180 cm, a total of 18 segments (including the steerable distal end), each 10 cm long, could be combined to create a fully articulating, controllable endoscope. In an alternative variation, a passive region proximal to the automatically controlled proximal region could be made of a flexible tubing member that can conform to an infinite variety of shapes.

[0024] In this variation, the entire assembly, i.e. segments, tendons, etc., may be encased in a sheath or covering of a biocompatible material, e.g. a polymer, that is also preferably lubricious to allow for minimal friction resistance during endoscope insertion and advancement into a patient. Because the endoscope is used medically, it may be desirable that this covering being removable, replaceable and/or sterilizable.

[0025] Similarly, it is desirable that the endoscope be easily disconnected from the controller. The tendons projecting proximally from the segments of the endoscope are collectable in a umbilicus that has an interface which couples with a controller unit containing the actuators, e.g., motors, that apply force to the tendons. This interface is a quick- disconnect mechanism between the tendons and the controller. One variation of the quick- disconnect mechanism is a "nail head" positionable in a slot design in which the terminus of each tendon cable is configured into, e.g., a flattened protrusion. An array of such tendons at the end of the umbilicus mates with an interface on the controller. The flattened tendon ends may be fitted into corresponding slots defined in the controller housing. The corresponding fit enables the tendon ends to be removably secured within their respective slots and thereby allows the actuators to apply force to specific tendons. Further, the controller can determine the shape of a segment based on the tension being applied by its controlling tendons. The controller can also be adapted to determine segment configuration based upon the position of the cable relative to the cable housing. Moreover, the controller may be further adapted to sense the amount of rotation or linear movement of the controlling tendons and can determine segment configuration based upon this data.

[0026] Many alternatives of the quick-disconnect mechanism are contemplated by this invention. Another variation has a mating connector with pins that couple to dimpled receptors; motions of the pins against the receptor are translated into motion of the tendons, e.g. using levers, gears or gear racks, or threaded couplings.

[0027] A typical endoscope has a diameter less than 20 mm, although various industrial applications may utilize endoscopes having a diameter greater than 20 mm. Likewise, one variation of this invention also has a radial dimension of less than 20 mm. In another variation of the invention, the radius of more distal segments decreases in a telescope-like fashion. This allows the steerable distal portion to have a much smaller radius, e.g., 12.5 mm, than the more proximal segments. In this variation, the larger radius of more proximal segments provides increased space for tendons from distal segments.

[0028] Another alternative variation of this invention uses fewer segments by having segments of different lengths. Thus, more distally located segments can be made shorter, e.g., the most distal segment can have a length of 6 cm, and more proximally located segments increasingly longer, e.g., up to 20 cm length for the most proximal segment. This variation modifies the way selected curves are propagated by the advancement of the endoscope, resulting in an "averaging" or smoothing of the curve as it propagates down the scope. In this variation, a special algorithm can be used to coordinate the automation of the differently sized segments.

[0029] One method of propagating the selected turns of the steerable tip along the body of the endoscope involves having the endoscope follow the pathway selected by the user as it is advanced or withdrawn from the body. This method begins by inserting the distal end of the endoscope into a patient, either through a natural orifice or through an incision, and steering the selectively steerable distal portion to select a desired path. When the endoscope body is advanced or inserted further into the patient's body, the electronic controller registers the motion and controls the proximal portion of the endoscope to assume the curve selected by the user when the steerable distal tip was in approximately the same position within the body. Similarly, when the endoscope is withdrawn proximally, the selected curves are propagated distally along the endoscope body, either automatically or passively.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] Fig. 1 shows a representation of a conventional endoscope in use.

[0031] Fig. 2 shows a variation of the tendon driven endoscope of the present invention

[0032] Fig. 3A shows the range of motion of a controllable segment of the present invention actuated by three tendons.

[0033] Figs. 3B to 3F show the use of three tendons to actuate a controllable segment used in the endoscope of the present invention.

[0034] Fig. 4A and 4B show the use of two tendons to actuate a controllable segment in the endoscope of the present invention.

[0035] Fig. 4C and 4D show the use of four tendons to actuate a controllable segment in the endoscope of the present invention.

[0036] Fig. 5 shows a partial schematic representation of a single tendon bending a segment.

[0037] Figs. 6A and 6B show an end view and a side view, respectively, of a vertebra-type control ring which may be used to form the controllable segments of the endoscope of the present invention.

[0038] Fig. 6C shows a side view of interconnected vertebra-type control rings used to form the controllable segments of the endoscope of the present invention.

[0039] Fig. 6D and 6E show a side view and a perspective view, respectively, of another example of a vertebra-type control ring.

[0040] Fig. 7A shows a perspective view of an endoscope device variation with the outer layers removed to reveal the control rings and backbone.

[0041] Fig. 7B shows an end view of a variation of the control ring for an endoscope of the present invention.

[0042] Figs. 8A to 8C illustrate advancing the tendon driven endoscope of the present invention through a tortuous path.

[0043] Fig. 9 shows a variation of the tendon driven endoscope of the present invention that has segments of differing diameters.

[0044] Fig. 10 shows a variation of the tendon-driven endoscope of the present invention that has segments of different length.

[0045] Fig. 11A shows a variation of a quick-release mechanism for attaching and detaching the tendon driven endoscope from the actuators that relies on pins to actuate the tendons.

[0046] Fig. 11B shows a second variation of a quick-release mechanism for attaching and detaching the tendon driven endoscope from the actuators that relies on a nail-head configuration to actuate the tendons.

[0047] Figs. 12A to 12E illustrate a representative example of advancing an endoscope through a patient's colon using a tendon driven endoscope of the present invention.

[0048] Fig. 12F illustrates a variation on withdrawing the tendon driven endoscope of the present invention.

[0049] Fig. 13 shows a flow diagram for initializing or re-initializing an endoscopic device during a procedure.

DETAILED DESCRIPTION OF THE INVENTION

[0050] Fig. 1 shows a prior art colonoscope **10** being employed for a colonoscopic examination of a patient's colon **C.** The colonoscope **10** has a proximal handle **16** and an elongate body **12** with a steerable distal portion **14.** The body **12** of the colonoscope **10** has been lubricated and inserted into the colon **C** via the patient's anus **A.** Utilizing the steerable distal portion **14** for guidance, the body **12** of the colonoscope **10** has been maneuvered through several turns in the patient's colon C to the ascending colon **G.** Typically, this involves a considerable amount of manipulation by pushing, pulling and rotating the colonoscope **10** from the proximal end to advance it through the turns of the colon **C.** After the steerable distal portion **14** has passed, the walls of the colon **C** maintains the curve in the flexible body **12** of the colonoscope **10** as it is advanced. Friction develops along the body **12** of the colonoscope **10** as it is inserted, particularly at each turn in the colon **C**. Because of the friction, when the user attempts to advance the colonoscope **10,** the body **12**' tends to move outward at each curve, pushing against the wall of the colon **C**, which exacerbates the problem by increasing the friction and making it more difficult to advance the colonoscope **10.** On the other hand, when the colonoscope **10** is withdrawn, the body **12"** tends to move inward at each curve taking up the slack that developed when the colonoscope **10** was advanced. When the patient's colon **C** is extremely tortuous, the distal end of the body **12** becomes unresponsive to the user's manipulations, and eventually it may become impossible to advance the colonoscope **10** any farther. In addition to the difficulty that it presents to the user, tortuosity of the patient's colon also increases the risk of complications, such as intestinal perforation.

[0051] Fig. 2 shows a variation of the tendon driven endoscope **20** of the present invention. The endoscope **20** has an elongate body **21** with a manually or selectively steerable distal portion **24**, an automatically controlled portion **28**, and a flexible and passively manipulated proximal portion **22**, which may be optionally omitted from the device. The steerable distal portion **24** can be articulated by hand or with mechanical assistance from actuators. The automatically controlled portion **28** is segmented, and each segment is capable of bending through a full range of steerable motion. The distal portion **24** is also a controllable segment.

[0052] The selectively steerable distal portion **24** can be selectively steered or bent up to, e.g., a full 180° bend in any direction **26**, as shown. A fiberoptic imaging bundle **40** and one or more illumination fibers **42** may extend through the body **21** from the proximal portion **22** to the distal portion **24**. Alternatively, the endoscope **20** may be configured as a video endoscope with a miniaturized video camera, such as a CCD or CMOS camera, positioned at the distal portion **24** of the endoscope body **21**. The images from the video camera can be transmitted to a video monitor by a transmission cable or by wireless transmission where images may be viewed in real-time and/or recorded by a recording device onto analog recording medium, e.g., magnetic tape, or digital recording medium, e.g., compact disc, digital tape, etc. LEDs or other light sources could also be used for illumination at the distal tip of the endoscope.

[0053] The body **21** of the endoscope **20** may also include one or more access lumens **38** that may optionally be used for illumination fibers for providing a light source, insufflation or irrigation, air and water channels, and vacuum channels. Generally, the body **21** of the endoscope **20** is highly flexible so that it is able to bend around small diameter curves without buckling or kinking while maintaining the various channels intact. When configured for use as a colonoscope, the body **21** of the endoscope **20** may range typically from 135 to 185 cm in length and about 13-19 mm in diameter. The endoscope **20** can be made in a variety of other sizes and configurations for other medical and industrial applications.

[0054] The controllable portion **28** is composed of at least one segment **30**, and preferably several segments **30**, which are controllable via a computer and/or electronic controller (controller) **45** located at a distance from the endoscope **20.** Each of the segments **30** has tendons mechanically connected to actuators to allow for the controlled motion of the segments **30** in space. The actuators driving the tendons may include a variety of different types of mechanisms capable of applying a force to a tendon, e.g., electromechanical motors, pneumatic and hydraulic cylinders, pneumatic and hydraulic motors, solenoids, shape memory alloy wires, electronic rotary actuators or other devices or methods as known in the art. If shape memory alloy wires are used, they are preferably configured into several wire bundles attached at a proximal end of each of the tendons within the controller. Segment articulation may be accomplished by applying energy, e.g., electrical current, heat, etc., to each of the bundles to actuate a linear motion in the wire bundles which in turn actuate the tendon movement. The linear translation of the actuators within the controller may be configured to move over a relatively short distance, e.g., within a few inches or less such as ± 1 inch, to accomplish effective articulation depending upon the desired degree of segment movement and articulation.

[0055] It is preferable that the length of the insertable portion of the endoscope comprises controllable segments **30**, although a passive proximal portion **22** can also be used. This proximal portion **22** is preferably a flexible tubing member that may conform to an infinite variety of shapes, and may be made from a variety of materials such as thermoset and thermoplastic polymers which are used for fabricating the tubing of conventional endoscopes.

[0056] Each segment **30** preferably defines at least one lumen running throughout to provide an access channel through which wires, optical fibers, air and/or water channels, various endoscopic tools, or any variety of devices and wires may be routed. A polymeric covering, or sheath, **39** may also extend over the body of the endoscope **21** including the controllable portion **28** and steerable distal portion **24.** This sheath **39** can preferably provide a smooth transition between the controllable segments **30,** the steerable distal portion **24**, and the flexible tubing of proximal portion **22.**

[0057] A handle **32** may be attached to the proximal end of the endoscope. The handle **32** may include an ocular connected to the fiberoptic imaging bundle **42** for direct viewing. The handle **32** may otherwise have a connector **54** for connection to a video monitor, camera, e.g., a CCD or CMOS camera, or a recording device **52.** The handle **32** may be connected to an illumination source **43** by an illumination cable **44** that is connected to or continuous with the illumination fibers **42**. Alternatively, some or all of these connections could be made at the controller **45**. Luer lock fittings **34** may be located on the handle **32** and connected to the various instrument channels.

[0058] The handle **32** may be connected to a motion controller **45** by way of a controller cable **46.** A steering controller **47** may be connected to the motion controller **45** by way of a second cable **48** or it may optionally be connected directly to the handle **32.** Alternatively, the handle may have the steering control mechanism integrated directly into the handle, e.g., in the form of a joystick, conventional disk controllers such as dials, pulleys or wheels, etc. The steering controller **47** allows the user to selectively steer or bend the selectively steerable distal portion **24** of the body **21** in the desired direction **26**. The steering controller **47** may be a joystick controller as shown, or other steering control mechanism, e.g., dual dials or rotary knobs as in conventional endoscopes, track balls, touchpads, mouse, or sensory gloves. The motion controller **45** controls the movement of the segmented automatically controlled proximal portion **28** of the body **21**. This controller **45** may be implemented using a motion control program running on a microcomputer or using an application-specific motion controller. Alternatively, the controller **45** may be implemented using, e.g., a neural network controller.

[0059] The actuators applying force to the tendons may be included in the motion controller unit **45,** as shown, or may be located separately and connected by a control cable. The tendons controlling the steerable distal portion **24** and the controllable segments **30** extend down the length of the endoscope body **21** and connect to the actuators. Fig. 2 shows a variation in which the tendons pass through the handle **32** and connect directly to the motion controller **45** via a quick-release connector **60**. In this variation, the tendons are part of the control cable **46**, although they could independently connect to the actuators, so long as the actuators are in communication with the controller **45.**

[0060] An axial motion transducer (also called a depth referencing device or datum) **49** may be provided for measuring the axial motion, i.e., the depth change, of the endoscope body **21** as it is advanced and withdrawn. The depth referencing device **49** can be made in many possible configurations. For example, the axial motion transducer **49** in Fig. 2 is configured as a ring **49** that may surround the body **21** of the endoscope **20.** The axial motion transducer **49** is preferably attached to a fixed point of reference, such as the surgical table or the insertion point for the endoscope **20** on the patient's body. As the body **21** of the endoscope **20** slides through the axial motion transducer **49**, it indicates the axial position of the endoscope body **21** with respect to the fixed point of reference and sends a signal to the electronic controller **45** by telemetry or by a cable. The axial motion transducer **49** may use optical, electronic, magnetic, radio frequency or mechanical methods to measure the axial position of the endoscope body **21**.

[0061] When the endoscope body **21** is advanced or withdrawn, the axial motion transducer **49** detects the change in position and signals the motion controller **45.** The controller can use this information to propagate the selected curves proximally or distally along the controllable portion **28** of the endoscope body **21** to keep the endoscope actively following the pathway selected by the user steering the distal portion **24**. The axial motion transducer **49** also allows for the incrementing of a current depth within the colon **C** by the measured change in depth. This allows the endoscope body **21** to be guided through tortuous curves without putting unnecessary force on the wall of the colon **C**.

[0062] A more detailed description on the construction and operation of a variation of the segments may be found in U.S. Pat. Publication No. 6,610,007 entitled "Steerable Segmented Endoscope and Method of Insertion" filed October 2, 2001.

[0063] Fig. 3A shows an example of the resulting segment articulation which may be possible through the use of two or three tendons to articulate the controllable segments, including the steerable distal section. Fig. 3A shows one example of a possible range of motion of a controllable segment of the present invention actuated, in this example, by three tendons. A segment in the relaxed, upright position **301** can be bent in virtually any direction relative to the x-y plane. The figure, as an illustrative example, shows a segment **302** that has been bent down and at an angle relative to its original position **301.** The angles α and β describe the bend assumed by the segment. Angle β gives the angle in the x-y plane, while α is the angle describing the motion in the x-z plane. In one variation, the controllable segments of the endoscope can bend through all 360 degrees in the β angle and up to 90 degrees in the α angle. An angle α greater than 90 degrees would result in looping of the endoscope. In Fig. 3A, the segment is shown bent approximately 45 degrees along angle α. The freedom of movement of a segment is, in part, determined by the articulation method, the size of the segment, the materials from which it is constructed, and the manner in which it is constructed, among others. Some of these factors are discussed herein.

[0064] The steerable distal portion, as well as the endoscope and the controllable segments are bendable but preferably not compressible or expansible. Thus, in Fig. 3A, the centerline **304** of the relaxed segment **301** is approximately the same length as the centerline **306** of the segment after bending **302**.

[0065] Figs. 3B to 3F show the use of three tendons to actuate a controllable segment used in an endoscope of the present invention. The tendons shown in this example are all Bowden type cables **310** that have an internal cable **312** coaxially surrounded by a housing or sleeve **314** in which the cable is free to move. Bowden cables can be used to apply either tensile or compressive forces, i.e., they may be pushed or pulled, to articulate the endoscope and can be actuated remotely to deliver forces as desired at locations along the endoscope. Force from a tendon is exerted across or through the segment by attaching the tendon cable at the distal end of the segment **320** and the tendon housing **314** at the proximal end of the segment **322**. Fig. 3B shows a view of the top of the segment with three attachment sites for the tendon cables indicated **320**.

[0066] In one variation, three tendons are used to actuate each segment, including the steerable distal portion, although four or more tendons could be used. Three tendons can reliably articulate a segment in any direction without having to rotate the segment or endoscope about its longitudinal axis. The three cable tendons **312** are preferably attached at the distal end of the segment **320** close to the segment's edge, spaced equally apart. In Fig. 3B, tendons are attached at the two o'clock, six o'clock and 10 o'clock positions. It is desirable to use fewer tendons, because of space concerns, since the tendons controlling each segment project proximally to the actuators. Thus, two tendons could be used to control a segment. It may also be desirable to include one or more biasing element, e.g., a spring, to assist in articulating a segment in three dimensions. In another variation, two tendons may be used to articulate a segment in three dimensional space by controlling motion in two directions while rotating the segment about its longitudinal axis.

[0067] Fig. 3C shows a relaxed segment with three tendons attached. The tendon sleeves **314** are shown attached to the proximal end of the segment **322** directly below the corresponding cable attachment sites. Figs. 3D to 3F show this segment bent by each of the controlling tendons **310** separately.

[0068] As shown in Fig. 3D, applying tension by pulling on the first tendon **330** results in a bending in the direction of the first tendon **330**. That is, looking down on the top of the unbent segment (as in Fig. 3B), if the first tendon is attached at the six o'clock position, then pulling on just this tendon results in bending the segment towards the six o'clock position. Likewise, in Fig. 3E, putting tension only on a second tendon **332** attached at the two o'clock position results in bending the segment towards the two o'clock direction. Finally, pulling on the tendon in the ten o'clock position **334** bends the segment towards the ten o'clock direction. In all cases, the bending is continuous; the greater the tension applied, the further the bending (the α angle, in the x-z plane of Fig. 3A). A segment can be bent in any direction by pulling on individual tendons or a combination of two tendons. Thus, to bend the segment in the twelve o'clock direction, both the second **332** and the third **334** tendon could be pulled with equal force. Alternatively, first tendon **330** in the six o'clock position may be pushed either alone or in combination with second **332** and third tendons **334** being pulled to result in the same configuration.

[0069] Fig. 4A and 4B show a variation in which a segment is articulated by two tendons and one biasing element. Fig. 4A shows a planar top view of the segment. The attachment sites for the biasing element **340** and the two tendons **320** are spaced around the perimeter of the distal end of the segment as shown. The tendons **320** may be attached at the two o'clock and ten o'clock positions, looking down on the top of the section, and the biasing element **340** is attached at the six o'clock position. Fig. 4B shows a perspective view of the segment in the unbent configuration. In this variation, the biasing element is configured to apply tension to the side of the segment such that it will bend towards the six o'clock position. The biasing element can be any element that can apply compressive or tensile forces across the segment, e.g. a spring, elastic element, a piston, etc. The segment is held in the neutral or unbent position shown in Fig. 4B by applying tension from both tendons **312**. Controlling the amount of tension applied by the tendons results in bending of the segment in three dimensional space. More than one biasing element could also be used with two or more tendons. For example, a biasing element could be located opposite each tendon.

[0070] Alternatively, if the tendon is a push- pull cable, and each tendon can apply compression as well as tension, then two tendons can control the motion of segment without any biasing element at all.

[0071] More than three tendons can also be used to control the bending of a segment. Fig. 4C shows a top planar view of a segment that is controlled by four tendons attached in the eleven o'clock, two o'clock, five o'clock and eight o'clock positions. As with the three-tendon example, tension applied on one or a combination of the tendons results in shortening the side of the segment. Thus, if tension is applied only on the tendon attached distally at the eleven o'clock position 355, the corresponding side of the tendon will shorten, and the segment will bend in the eleven o'clock direction.

[0072] In all these variations, the circumferential locations of the tendons and/or biasing elements are illustrative and are not intended to be limited to the examples described herein. Rather, they may be varied according to the desired effects as understood by one of skill in the art.

[0073] Fig. 5 shows a partial schematic representation of a single tendon bending a segment. For clarity, the other parts of a complete endoscope, including other tendons and segments, have been omitted from Fig. 5. Tension applied to a tendon cable is transferred across the entire segment, resulting in bending. By using a Bowden cable **310** whose sleeve **314** is attached to the base **322** of the segment and also fixed at the proximal actuator end **403**, only the intended segment **401** is bent by applying tension to the tendon **312**, and more proximal segments are unaffected. The tendon is placed in tension by the actuator **410**, which is shown, in this variation, as a motor pulling on the tendon cable **312**.

[0074] Linked control rings may provide the flexible structure needed to construct the steerable distal portion and the controllable segments. Two examples of the types of control rings that may be utilized are shown. The first is shown in Fig. 6A which shows a vertebra-type control ring that forms the controllable segments of the present invention. Fig. 6A shows an end view of a single vertebra. Each ring-shaped vertebra **501** can define a central channel or aperture **504** or apertures that can collectively form the internal lumen of the device as previously described. The vertebrae may have two pairs of hinges; the first pair **506** projecting perpendicularly from a first face of the vertebra and a second pair **508**, located 90 degrees around the circumference from the first pair, projecting perpendicularly away from the face of the vertebra on a second face of the vertebra opposite to the first face. The hinges shown in Figs. 6A and 6B are tab-shaped, however other shapes may also be used.

[0075] The vertebra control ring in Fig. 6A is shown with three holes **510** through the edge of the vertebra that may act, e.g., as attachment sites for the tendon cable **312** if the vertebra is the most distal vertebra in a segment, or as a throughway for a tendon cable that can actuate the segment in which the vertebra is used. These holes **510** can also be used to attach the sleeve of the Bowden-type tendon cable **314** when the vertebra is the most proximal control disk in a segment. Alternatively, rather than a hole **510**, the attachment sites could be a recess or other specialized shape. Although Fig. 6A shows three holes **510**, the number of holes may depend upon the number of tendons used to control the segment to which the vertebra belongs. Since the holes **510** may be used as attachment sites for the tendons, there are as many holes as there are tendons controlling the segment.

[0076] The outer edge of the vertebra in Fig. 6A may be scalloped to provide spaces **512** for tendon housings of tendons that control more distal segments and bypass the vertebra. These tendon bypass spaces preferably conform to the outer diameter of the tendons used. The number of tendon bypass spaces **512** may vary depending on the number of tendons. Also, the orientation of the tendon bypass spaces may be varied if it is desirable to vary the way in which the bypassing tendons are wound around the endoscope. For example, the spaces **512'** in Fig. 6C are oriented at an angle relative to the longitudinal axis of the vertebra, allowing the tendons to wind around the body of the endoscope as they project proximally. Furthermore, the tendon bypass spaces could be lubricated or composed of a lubricious material in order to facilitate free movement of the bypassing tendons across the segment, and prevent interference between the bending of the segment and the bypassing tendons.

[0077] Fig. 6B and 6C show side views of the same vertebra as Fig. 6A. The two pairs of hinge joints **508, 506** are shown. Hinge joints **508, 506** are preferably located 90 degrees apart and extend axially so that the hinge joints can pivotally mate with hinge joints from adjacent vertebrae. This mating **520** with adjacent vertebrae is more clearly seen in Fig. 6C. These hinges can be joined, pinned, or connected through the holes **525** as shown **522**. Alternatively, hinges may also be made from materials utilizing, e.g., thermoplastics, shape memory alloys, etc. Once hinged, each vertebra can rotate relative to an adjoining vertebra in one axis. However, because vertebrae are hinged to each other in directions alternating by 90 degrees, an assembly of multiple vertebrae is able to move in virtually any direction. The greater the number of vertebrae joined in this manner, the greater the range of motion. In one example, two to ten vertebrae are used to comprise one segment, achieving a length of around 4 cm to 10 cm per segment. The dimensions of both the vertebrae and the hinge joints can be varied, e.g., longer hinge joints will have a greater bending radius when joined to another vertebra. Furthermore, the number of vertebrae per segment can vary, e.g. more than ten vertebrae could be used.

[0078] Fig. 6D and 6E show another variation of a vertebra in sectional and perspective views, respectively. In Fig. 6D and 6E, the tendons that bypass the segment may be contained within the body of the vertebra in a tendon bypassing space **550** rather than along the outer edge of the vertebra as shown in Fig. 6A. The vertebra of Fig. 6D and 6E show four tendon bypassing spaces **550**, and each space can hold approximately fifteen bypassing tendon sleeves. The number, shape and sizes of the tendon bypassing spaces can be varied. For example, a vertebra could have two tendon bypassing spaces that could hold more than thirty-five tendon sleeves. Moreover, the tendon bypassing space could also be located on the inside of the central aperture or lumen of the vertebra **504**.

[0079] Although Fig. 6D shows tendon sleeves holding only a single tendon cable **560**, more than one tendon cable could be contained in a tendon housing or sleeve. For example, if three tendons articulate a segment, all three tendons could be contained in a single tendon housing. Such a combined tendon housing could further utilize lubrication to accommodate independent movement by individual tendon cables and/or could be divided into compartments that isolate the tendons within the housing.

[0080] Fig. 6E also shows a perspective view of the hinge joints **506, 508** that can pivotally mate with pairs of hinge joints from adjacent vertebrae. Although Figs. 6A and 6B shows two pairs of hinge joints projecting axially, a single hinge joint on each face of the vertebra could also be used. Moreover, as long as the hinge joints can pivotally mate with adjacent vertebrae, the hinge joints can be located at different radial locations from the center of the vertebra. For example, the pairs of hinge joints shown in Figs. 6A to 6C are located closer to the center of the vertebra than the hinge joints in Fig. 6D and 6E.

[0081] Fig. 7 shows a second variation of control ring. The variation shown in the figure utilizes a flexible backbone **601** preferably made of a material that is relatively non-compressible and non-extensible, to which control rings **602** are attached at intervals. This structure allows bending in a continuous curve in any desired direction. Fig. 7A shows a side view of one controllable segment of this variation with the outer layers removed to show the control rings and backbone. Multiple control rings **602** may be attached to the flexible backbone at regular intervals. Fewer or more control rings could be used to comprise a single segment depending upon the desired degree of articulation. The tendon cable **312** attaches to the most distal control ring of the segment **604.** As with the vertebra-type variation, this central backbone embodiment is shown actuated by three tendons **310** attached at sites equally spaced around the edge of the most distal control ring of the segment **604**. The tendon cables controlling the segment **312** pass through spaces or holes **610** defined in the control rings **602** through which they are free to move. These holes **610** could be lubricated, lined with a lubricious material or the control rings **602** may be composed of some lubricious material to facilitate cable motion through the holes **610**. The tendon sleeve preferably attaches at a location **614** to the most proximal control ring in the segment **612**. When a tendon **312** is placed under tension, this force is distributed along the entire segment. Because the inner tendon cable **312** is freely slidable within the tendon sleeve **314**, and the tendon sleeve is fixed at both ends of the tendon **614**, pulling on the tendon cable causes bending only in the selected segment.

[0082] Fig. 7A also shows the first control ring of a more proximal segment **604'**. The tendons controlling the more distal segment may pass over the outside of the more proximal segments as they project proximally to the actuators. The outer edge of the control rings for the flexible backbone embodiment are shown with channels or tendon bypassing spaces **616** for bypassing tendons, as seen in Fig. 7B. As with the vertebra-type control rings, these tendon bypassing spaces could also be located within the control ring, for example, in an enclosed tendon bypassing space.

[0083] Fig. 7B shows an end view of control ring **602** which may be used with the flexible backbone embodiment of the endoscope. The center of the control ring contains a channel through which the flexible backbone **601** can be attached. A number of additional channels through the control ring **618** are also shown. These channels can be aligned with channels in neighboring control rings to form an internal lumen or channel for a fiber optic imaging bundle, illumination fibers, etc. as discussed above. Moreover, adjacent control rings may be spaced adjacently to one another at uniform or various distances depending upon the desired degree of bending or control. Fig. 7B shows three equally spaced holes **610** through which the tendon cable can pass; these holes **610** could also be used as attachment sites for the tendon cable, e.g., when the control ring is the most distal control ring in the segment **604**, or for the tendon cable sleeve, e.g. when the control ring is the most proximal control ring in the segment **612**. These holes **610** could be shaped specifically to receive either the tendon end or the tendon sleeve. Control rings of other designs could be used for different regions of the segment, or for different segments.

[0084] Figs. 8A to 8C illustrate a variation of the tendon driven endoscope navigating a tortuous path. The path **701** is shown in Fig. 8A. This pathway may represent a portion of colon, for example. In Fig. 8A, the distal tip of the device **704** approaches the designated bend. Fig. 8B shows the distal tip being steered **705** to assume the appropriate curve. This steering could be performed manually by the user, e.g. a doctor, or automatically using an automatic detection method that could determine the proximity of the walls of the pathway. As described, the bending of the steerable tip is performed by placing tension on the tendon, or combination of tendons that results in the appropriate bending.

[0085] The device is then advanced again in Fig. 8C; as it is advanced, the selected curve is propagated down the proximal length of the endoscope, so that the bend of the endoscope remains in relatively the same position with respect to the pathway **701**. This prevents excessive contact with the walls, and allows the endoscope to move more easily along the tortuous pathway **701**. The endoscope is in continuous communication with the motion controller, and the motion controller can monitor the location of the endoscope within the pathway, e.g., depth of insertion, as well as the selected bends or curves that define the pathway of the endoscope. Depth can be determined by, e.g., the axial motion transducer **49** previously described, or by more direct measurement techniques. Likewise, the shape of each segment could be determined by the tension applied to the tendons, or by direct measurement, such as direct measurement of displacement of the tendon cables. The motion controller can propagate the selected shape of a segment at a specified location, or depth, within the body, e.g., by setting the lengths of the sides of more proximal segments equal to the corresponding lengths of the sides of more distal segments as the device is moved distally. The controller can also use this information to automatically steer the body of the endoscope, or for other purposes, e.g. creating a virtual map of the endoscope pathway for analytic use.

[0086] In addition to measuring tendon displacement, the motion controller can also adjust for tendon stretch or compression. For example, the motion controller can control the "slack" in the tendons, particularly in tendons that are not actively under tension or compression. Allowing slack in inactive tendons reduces the amount of force that is required to articulate more proximal segments. In one variation, the umbilicus at the distal end of the endoscope may contain space to allow slack in individual tendons.

[0087] The bending and advancing process can be done in a stepwise or continuous manner. If stepwise, e.g., as the tendon is advanced by a segment length, the next proximal segment **706** is bent to the same shape as the previous segment or distal steerable portion. A more continuous process could also result by bending the segment incrementally as the tendon is advanced. This could be accomplished by the computer control, for example when the segments are smaller than the navigated curve.

[0088] Controllable segments, including the steerable distal portion, can be selected to have different dimensions, e.g., different diameters or lengths, even within the same endoscope. Segments of different dimensions may be desirable because of considerations of space, flexibility and method of bending. For example, the more segments in an endoscope, the further it can be steered within a body cavity; however, more segments require more tendons to control the segments. Figs. 9 and 10 illustrate two variations on tendon driven endoscopes.

[0089] Fig. 9 shows a tendon driven endoscope variation that has segments 800 of differing diameters. More distal segments may have a smaller diameter **803** than more proximal segments, e.g., **802**, **801.** The diameter of a typical endoscope could decrease from, e.g., 20 mm, down to, e.g., 12.5 mm. The endoscope shown in Fig. 9 appears telescoped, as the diameter decreases distally in a stepwise manner. This design would be responsive, e.g., to internal body structures that become increasingly narrow. This design would also help accommodate bypassing tendons from more distal segments as they proceed towards the proximal actuators because of the larger diameter of the more proximal segments. Fig. 9 shows four differently sized segments; however, virtually any number of differently sized segments could be used. Moreover, although the segments appear stepped in this variation, the outer surface may be gently tapered to present a smooth outer surface decreasing in diameter towards the distal end.

[0090] Fig. 10 shows another variation of the tendon driven endoscope that has segments of different lengths. Using segments of different lengths may require fewer overall segments **900** to construct an equivalent length of articulatable endoscope. As shown in Fig. 10, more proximal segments **901** are increasingly longer than more distal, e.g., **902**, **903**, segments. For example, segment length could be decreased from 20 cm at a proximal segment down to 6 cm at a distal most segment. The lengths may be decreased incrementally segment to segment by a constant factor; alternatively, lengths may be decreased geometrically, exponentially, or arbitrarily depending upon the desired articulation. In practice this results in an "averaging" of curves by more distal segments as bends and turns are propagated proximally. In order to accomplish this, the motion controller may be configured to accommodate the differently sized segments accordingly. Alternatively, endoscopes could be comprised of a combination of segments of different length and thickness, depending upon the application.

[0091] The tendons that articulate the segments are in mechanical communication with the actuators. However, it is desirable to have the insertable distal portion of the endoscope be removable from the actuators and controller, e.g., for cleaning or disinfecting. A quick-release mechanism between the proximal end of the endoscope and the actuators is an efficient way to achieve an endoscope that is easily removable, replaceable or interchangeable. The proximal ends of the tendons are organized to allow predictable attachment to corresponding actuators. The tendons may be organized into a bundle, array, or rack. This organization could also provide other advantages to the endoscope, such as allowing active or passive control of the tendon slack. Furthermore, the proximal ends of each tendon can be modified to allow attachment and manipulation, e.g., the ends of the tendons may be held in a specially configured sheath or casing.

[0092] Figs. 11A and 11B show two quick-release mechanisms for attaching and detaching the tendon driven endoscope from the actuators. Fig. 11A shows a quick-release mechanism that is not in accordance with the claimed invention. The proximal end of the tendons is bundled in an umbilicus 950, and the individual tendons terminate in dimpled connectors 962 that are held in an organized array in a connector interface 952. The connector interface 952 mates to a complementary receiving interface 956 on the structure that houses the actuators 970, e.g. as part of the controller box. The actuators may project "pins" 960 which can mate with the dimpled connectors and convey force from the actuators to the tendons. Thus, for example, an actuator may cause a pin 960 to apply pressure to a corresponding dimpled receiver 962. The dimpled receiver translates the pushing of the pin into a tensile or compressive force applied to the affiliated tendon. This could be achieved using levers to reverse the direction of the force, for example. Since every pin preferably mates to a corresponding receiver, it is desirable to maintain the register of the connectors from the endoscope and the actuators. An orientation notch 954 on the connector that fits into a receiving orientation mate 958 on the actuator could be used to align both interfaces. Alternatively, the arrangement of the pins and receptacles could be orientation specific.

[0093] This feature is not limited to pins and receptacles, since virtually any convenient mechanism for transferring force from the actuator to the tendons would work. Fig. 11B shows a quick-release mechanism for attaching and detaching the tendon driven endoscope from the actuators that relies on a nail-head configuration to actuate the tendons, which mechanism is in accordance with the claimed invention. The tendons preferably terminate in a flattened out protrusion resembling a nail-head 972. The array of nail-heads project from the connector interface 952 at the end of the umbilicus holding the endoscope tendons 950, and can mate with slotted holes 974 on the interface 956 of the actuator mechanism 970. Thus the slotted holes 974 of the actuators can be individually retracted by the actuators to apply tension to individual tendons. The quick-release mechanism could also be designed allow users to use different tendon driven endoscopes, even of different configurations, from the same actuator and/or controller unit.

[0094] Figs. 12A to 12F show the endoscope **100** of the present invention being employed for a colonoscopic examination of a patient's colon. In Fig. 12A, the endoscope body **102** has been lubricated and inserted into the patient's colon **C** through the anus **A.** The distal end **108** of the endoscope body **102** is advanced through the rectum **R** until the first turn in the colon **C** is reached, as observed through the ocular or on a video monitor. To negotiate the turn, the selectively steerable distal portion **104** of the endoscope body **102** is manually steered toward the sigmoid colon **S** by the user through the steering control. The control signals from the steering control to the selectively steerable distal portion **104** are monitored by the electronic motion controller **49**. When the correct curve of the selectively steerable distal portion **104** for advancing the distal end **108** of the endoscope body **102** into the sigmoid colon **S** has been selected, the curve is logged into the memory of the controller **45** as a reference. This step can be performed in a manual mode, in which the user gives a command to the controller **45** to record the selected curve, using keyboard commands or voice commands. Alternatively, this step can be performed in an automatic mode, in which the user signals to the controller that the desired curve has been selected by advancing the endoscope body **102** distally. In this way, a three dimensional map of the colon or path may be generated and maintained for future applications.

[0095] In one variation, the curve is entered into the controller's memory by recording the change in lengths of the sides of the steerable distal portion after the distal portion has been articulated into the selected shape. In variations where the tendons are Bowden-type cables, the change in the length of the distal portion may be determined from the distance traveled by the tendon cable after steering the distal portion from the neutral, unbent, position. This distance traveled by the tendon cable may be determined relative to the cable housing or to another point located within the controller. Likewise, the change in lengths of the sides of any controllable segment can be determined in the same way.

[0096] As the endoscope is advanced distally, a curve is propagated proximally down the endoscope by setting the lengths of the sides of the more proximal segment equal to the lengths of the same sides of the steerable distal tip when the distal tip was in approximately the same axial position. In one variation the lengths of the sides are equal to the lengths of the non-extensible, noncompressible tendons. The tendons in the more proximal segment are tensioned or compressed so that the sides of the proximal segment are approximately equal in length to the recorded lengths of the sides of the distal region when it was in the same position. Alternatively, if the controllable segments are of different lengths from each other and/or the steerable distal tip, ratios of the lengths of the sides of the steerable distal tip can be used to propagate the selected curve down the endoscope rather than absolute lengths. In variations where the endoscope is withdrawn, or moved proximally, the lengths of tendons controlling more proximal segments can be used to set the lengths of the tendons controlling more distal segments.

[0097] Whether operated in manual mode or automatic mode, once the desired curve has been selected with the selectively steerable distal portion **104**, the endoscope body **102** is advanced distally. The axial motion is detected by the axial motion transducer, or datum, and the selected curve is propagated proximally along the automatically controlled proximal portion **106** of the endoscope body **102** by the controller **45**, as described above. The curve remains fixed in space while the endoscope body **102** is advanced distally through the sigmoid colon **S**. In a particularly tortuous colon, the selectively steerable distal portion **104** may have to be steered through multiple curves to traverse the sigmoid colon **S**.

[0098] As illustrated in Fig. 12B, the user may stop the endoscope **100** at any point for examination or treatment of the mucosal surface or any other features within the colon **C**. The selectively steerable distal portion **104** may be steered in any direction to examine the inside of the colon **C**. When the user has completed the examination of the sigmoid colon **S**, the selectively steerable distal portion **104** is steered in a superior direction toward the descending colon **D**. Once the desired curve has been selected with the selectively steerable distal portion **104**, the endoscope body **102** is advanced distally into the descending colon **D**, and the second curve as well as the first curve are propagated proximally along the automatically controlled proximal portion **106** of the endoscope body **102**, as shown in Fig. 12C.

[0099] If, at any time, the user decides that the path taken by the endoscope body **102** needs to be revised or corrected, the endoscope **100** may be withdrawn proximally and the controller **45** commanded to erase the previously selected curve. This can be done manually using keyboard commands or voice commands or automatically by programming the controller **45** to go into a revise mode when the endoscope body **102** is withdrawn a certain distance. The revised or corrected curve is selected using the selectively steerable distal portion **104**, and the endoscope body **102** is advanced as described before. Alternatively, the user can select a "relaxed" or "reset" mode from the motion controller, allowing the automatically controllable proximal portion of the endoscope, possibly including the steerable distal tip, to be passively advanced or withdrawn.

[0100] The endoscope body **102** is advanced through the descending colon **D** until it reaches the left (splenic) flexure $\mathbf{F}_l$ of the colon. Here, in many cases, the endoscope body **102** must negotiate an almost 180 degree hairpin turn. As before, the desired curve is selected using the selectively steerable distal portion **104**, and the endoscope body **102** is advanced distally through the transverse colon **T**, as shown in Fig. 12D. Each of the previously selected curves is propagated proximally along the automatically controlled proximal portion 106 of the endoscope body **102**. The same procedure is followed at the right (hepatic) flexure $\mathbf{F}_r$ of the colon and the distal end **108** of the endoscope body **102** is advanced through the ascending colon **G** to the cecum **E,** as shown in Fig. 12E. The cecum **E**, the ileocecal valve **V** and the terminal portion of the ileum **I** can be examined from this point using the selectively steerable distal portion **104** of the endoscope body **102**.

[0101] Fig. 12F shows the endoscope **100** being withdrawn through the colon **C**. As the endoscope **100** is withdrawn, the endoscope body **102** follows the previously selected curves by propagating the curves distally along the automatically controlled proximal portion **106**, as described above. At any point, the user may stop the endoscope **100** for examination or treatment of the mucosal surface or any other features within the colon C using the selectively steerable distal portion **104** of the endoscope body **102**. At any given time, the endoscope **100** may be withdrawn or back-driven by a desired distance.

[0102] Thus, when the endoscope **100** is withdrawn proximally, each time it is moved proximally, the automatically controlled proximal portion **106** is signaled to assume the shape that previously occupied the space that it is now in. The curve propagates distally along the length of the automatically controlled proximal portion **106** of the endoscope body **102**, and the shaped curve appears to be fixed in space as the endoscope body **102** withdraws proximally. Alternatively, the segments of controlled portion **28** could be made to become flaccid and the withdrawal would then be passive.

[0103] To initialize or calibrate the endoscope **100**, the entire system may be calibrated prior to use and even during use. During endoscope procedures, such as those described above, various errors may accumulate in the controller and/or computer. These errors may arise from a variety of factors, e.g., errors in detecting cable motion, software errors in the controller and/or computer, positioning inaccuracies, etc.

[0104] To account for such possible errors, the position of endoscope **100** at any arbitrary position and/or depth of insertion relative to a fixed reference point, as described above, may be utilized as an additional reference for executing the advancement and withdrawal by re-initializing the endoscope **100** and the system while endoscope **100** is in use within the body of the patient. This newly-created additional reference point may be used for advancing the endoscope **100** further past this new reference. In this case, selectably steerable distal portion **104** may be used to define new, advancing conditions, as described above.

[0105] In the case of withdrawing endoscope **100** relative to the re-initialized reference point, the distal portion **104** can remain under the surgeon's control. Proximal portion **106** are placed under the control of the computer and are made to conform to the positions of the more-proximal segments at each depth of insertion as endoscope **100** is withdrawn similarly to the method described above.

[0106] Initialization or re-initialization may be performed manually if so desired. To accomplish this, once the surgeon or technician detects excessive error accumulation in the operation of endoscope **100**, or if the computer detects an error level beyond a predetermined level, the controller may be programmed to re-initialize periodically, e.g., every several seconds, several minutes, or three minutes, etc., based upon the degree of error accumulation. Alternatively, this re-initializing process may be performed at least once during an exploratory or treatment procedure or it may be performed an arbitrary number of times, again depending upon the error accumulation.

[0107] The controller may be configured to continuously compare the optimal position of each or several segments against achievable segment position and actuation effort. When detected discrepancies are larger than a predetermined value, a reinitialization may be performed.

[0108] Fig. 13 shows a flow diagram **1000** of one variation for initializing or re-initializing an endoscope device **100** during use in, e.g., a patient. Once it has been determined to initialize, e.g., prior to use, or re-initialize the device and system, an initialization or re-initialization command may be issued, as in step **1002**. The endoscopic device may then be allowed to relax, i.e., no force is applied to the tendons to actuate movement of the segments, and assume a shape of the lumen or passageway in which the device is positioned, as in step **1004**.

[0109] After the device has assumed the new positions, the new position information of the segments (and/or axes of the segments) may be logged into the computer to replace and/or supplement prior logged information with this newly logged information, as shown in step **1006.** The depth of insertion may also be newly logged, as in step **1008.**

[0110] Following logging the new positional information, it may be determined in step **1010** whether the endoscope **100** is advancing or withdrawing by sensing the motion, as described above. If the endoscope **100** is advanced, normal operations may continue as in step **1014** utilizing the newly logged information. If endoscope **100** is withdrawn, as in step **1012**, the newly logged information may be used to control segments proximally located from the re-initialization reference point and normal operations may be continued, as in step **1014.**

[0111] Although the endoscope of the present invention has been described for use as a colonoscope, the endoscope can be configured for a number of other medical and industrial applications. In addition, the present invention can also be configured as a catheter, cannula, surgical instrument or introducer sheath that uses the principles of the invention for navigating through tortuous body channels. The present invention may also be used for industrial applications such as inspection and exploratory applications within tortuous regions, e.g., machinery, pipes, etc.

[0112] In a variation of the method that is particularly applicable to laparoscopy or thoracoscopy procedures, the steerable endoscope can be selectively maneuvered along a desired path around and between organs in a patient's body cavity. The distal end of the endoscope may be inserted into the patient's body cavity through a natural opening, through a surgical incision or through a surgical cannula, introducer, or trocar. The selectively steerable distal portion can be used to explore and examine the patient's body cavity and to select a path around and between the patient's organs. The motion controller can be used to control the automatically controlled proximal portion to follow the selected path and, if necessary, to return to a desired location using the three-dimensional model in the electronic memory of the motion controller. Modification of the above-described assemblies and methods for carrying out the invention, and variations of aspects of the invention that are obvious to those of skill in the art are intended to be within the scope of the claims.

Claims

1. An apparatus for insertion into a body cavity, comprising:

an elongated body (21) comprising a plurality of articulatable segments (30), a proximal end, and a steerable distal portion (24);
a plurality of tendons (312) attached to at least a majority of the segments and extending from the segments to the proximal end of the elongated body; and
an external control unit (45) including a plurality of actuators;
wherein each of the segments is configurable to assume a selected shape along an arbitrary path by actuation of the tendons attached thereto, each of the segments is articulatable by at least one of the tendons, and said segments adjacent to one another are adapted to assume a selected shape of the adjacent segment by actuation of the tendons when the elongated body is advanced distally or proximally;
characterised in that the apparatus further comprises:

a first connector interface (952) holding proximal ends of the tendons in an organized array;
a second connector interface (956) provided on the external control unit; and
a quick-release connector (60) for respectively mechanically coupling the plurality of actuators to the plurality of tendons, the quick-release connector comprising the first and second connector interfaces, said connector interfaces being arranged to mate with one another thereby to allow retraction of each actuator to apply tensile force directly to the proximal end of a specific respective tendon.

2. An apparatus as claimed in claim 1, wherein the proximal ends of the tendons terminate in flattened out protrusions (972) and the second connector interface is provided with a plurality of slotted holes (974) to mate with said protrusions, which slotted holes can be individually retracted by the actuators to apply tension to individual tendons.

3. The apparatus of claim 1, further comprising a handle (32) located proximal to the articulatable segments (30).

4. The apparatus of claim 3, wherein the steerable distal portion (24) is configurable via controls located on the handle (32).

5. The apparatus of claim 1, wherein the steerable distal portion is configurable via the external control unit (45).

6. The apparatus of claim 1, wherein the control unit

(45) further comprises a computer.

7. The apparatus of claim 1, wherein the control unit (45) is adapted to adjust the tendons for compressive and tensile forces applied to the tendons.

8. The apparatus of claim 1, wherein the actuators are selected from the group consisting of electromechanical motors, pneumatic cylinders, hydraulic cylinders, pneumatic motors, hydraulic motors, solenoids, shape memory alloy wires, and electronic rotary actuators.

9. The apparatus of claim 1, wherein each of the segments is arranged to be actuated by at least two of the tendons.

10. The apparatus of claim 9, further comprising at least one biasing element adapted to provide a biasing force in opposition to the tendons.

11. The apparatus of claim 1, wherein a segment proximal to another segment is adapted to assume the selected shape of the segment more distally located by actuation of the tendons when the apparatus is advanced distally.

12. The apparatus of claim 1, wherein a segment distal to another segment is adapted to assume the selected shape of the segment more proximally located by actuation of the tendons when the apparatus is retracted proximally.

13. The apparatus of claim 1, wherein the proximal segments are longer relative to a length of the distal segments.

14. The apparatus of claim 1, wherein the proximal segments have a wider diameter relative to a diameter of the distal segments.

15. The apparatus of claim 1, further comprising a flexible, passive tubular member extending proximally from the elongated and segmented body.

16. The apparatus of claim 1, wherein each of the segments comprises a plurality of control rings, and the control rings have passages defined therethrough forming a lumen.

17. The apparatus of claim 16, wherein the control rings further comprise hinges for attaching to adjacent control rings.

18. The apparatus of claim 16, wherein the elongated body further comprises a flexible backbone axially located within the elongated body to which the control rings are attachable.

19. The apparatus of claim 16, wherein each of the tendons comprises a tendon cable and a tendon housing radially encompassing the tendon cable such that the tendon cable is free to move axially within the tendon housing.

20. The apparatus of claim 19, wherein the most distal control ring of each of the segments further comprises attachment sites for at least two of the tendon cables;
wherein the control rings proximal to the most distal control ring of each of the segments further comprise passageways for at least two of the tendon cables; and
wherein the most proximal control ring of each of the segments further comprises attachment sites for the tendon housings.

21. The apparatus of claim 1, wherein the elongated body defines one or more lumens therethrough.

22. The apparatus of claim 1, wherein at least two tendons are attached to each of at least a majority of the segments for actuating said segments; wherein when the distal end assumes a selected curve that selected curve is propagatable along the elongate body by the tendons selectively actuating the segments; and wherein the control unit is in communication with each of the segments for selectively controlling each tendon to alter the relative position of the segments when the selected curve is propagated along the elongated body.

23. The system of claim 1, further comprising an axial transducer having a sensor for measuring the distance the elongated body is advanced into or withdrawn from a body cavity.

24. The system of claim 22, further comprising a steering controller in communication with the steerable distal end for choosing the selected curve.

25. The system of claim 24, wherein the steering controller comprises a controller selected from the group consisting of joysticks, touch pads, track balls, mouse controllers, sensory gloves, and control wheels.

26. The system of claim 1, further comprising an imaging system for transmitting an image from the distal end to the proximal end of the elongated body.

27. The system of claim 26, wherein the imaging system comprises a fiberoptic imaging bundle extending from the distal end to the proximal end of the elongate body.

28. The system of claim 26 or claim 27, wherein the imaging system comprises a CCD camera.

29. The system of claim 26 or claim 27, wherein the imaging system comprises a CMOS camera.

30. The system of claim 1, further comprising at least one illumination source on the elongated body for providing a source of light.

31. The system of claim 30, wherein the illumination source comprises at least one illumination fiber extending from the distal end to the proximal end of the elongated body.

32. The system of claim 1, further comprising a recording device in communication with the elongated body for recording images from the distal end of the elongated body.

33. The system of claim 1, wherein the elongated body is configured as an endoscope for insertion into a patient's body.

34. The system of claim 1, wherein the elongated body is configured as a colonoscope for insertion into a patient's colon.

35. The system of claim 1, wherein the elongated body is configured as a laparoscope for insertion into a patient's body cavity.

36. The system of claim 1, wherein the elongated body defines one or more lumens therethrough.

Patentansprüche

1. Gerät zur Einführung in eine Körperhöhle, das enthält:

einen länglichen Körper (21), der eine Vielzahl von abwinkelbaren Segmenten (30), ein proximales Ende und einen lenkbaren distalen Teil (24) enthält;
eine Vielzahl von Spanngliedern (312), die an mindestens einer Mehrheit der Segmente befestigt sind und sich von den Segmenten zum proximalen Ende des länglichen Körpers erstrekken; und
eine externe Steuereinheit (45), die eine Vielzahl von Stellantrieben enthält;
wobei jedes der Segmente konfigurierbar ist, um durch Betätigung der daran befestigten Spannglieder entlang eines willkürlichen Pfads eine ausgewählte Form anzunehmen, wobei jedes der Segmente durch mindestens eines der Spannglieder abwinkelbar ist, und die einander benachbarten Segmente geeignet sind, um durch Betätigung der Spannglieder eine gewählte Form des benachbarten Segments anzunehmen, wenn der längliche Körper distal oder proximal vorwärts bewegt wird;

dadurch gekennzeichnet, dass das Gerät weiter enthält:

eine erste Verbinderschnittstelle (952), die proximale Enden der Spannglieder in einer geordneten Anordnung hält;
eine auf der externen Steuereinheit vorgesehene zweite Verbinderschnittstelle (956); und
einen Schnellverbinder (60) zur jeweiligen mechanischen Verbindung der Vielzahl von Stellantrieben mit der Vielzahl von Spanngliedern, wobei der Schnellverbinder die ersten und zweiten Verbinderschnittstellen enthält, wobei die Verbinderschnittstellen eingerichtet sind, um ineinander zu greifen, um dadurch das Zurückziehen jedes Stellantriebs zu erlauben, um direkt auf das proximale Ende eines spezifischen Spannglieds eine Spannkraft anzuwenden.

2. Gerät nach Anspruch 1, wobei die proximalen Enden der Spannglieder in abgeflachten Vorsprüngen (972) enden, und die zweite Verbinderschnittstelle mit einer Vielzahl von Langlöchern (974) zum Ineinandergreifen mit den Vorsprüngen versehen ist, wobei die Langlöcher einzeln von den Stellantrieben zurückgezogen werden können, um Spannung an die einzelnen Spannglieder anzuwenden.

3. Gerät nach Anspruch 1, das weiter einen Griff (32) enthält, der proximal zu den abwinkelbaren Segmenten (30) angeordnet ist.

4. Gerät nach Anspruch 3, wobei der lenkbare distale Teil (24) über auf dem Griff (32) angeordnete Steuerungen konfigurierbar ist.

5. Gerät nach Anspruch 1, wobei der lenkbare distale Teil über die externe Steuereinheit (45) konfigurierbar ist.

6. Gerät nach Anspruch 1, wobei die Steuereinheit (45) weiter einen Computer enthält.

7. Gerät nach Anspruch 1, wobei die Steuereinheit (45) geeignet ist, um die Spannglieder für an die Spannglieder angewendete Druck- und Zugkräfte anzupassen.

8. Gerät nach Anspruch 1, wobei die Stellantriebe aus der Gruppe ausgewählt werden, die aus elektromechanischen Motoren, Pneumatikzylindern, Hydraulikzylindern, Pneumatikmotoren, Hydraulikmotoren, Solenoiden, Drähten aus Formgedächtnislegierung und elektronischen Drehstellantrieben besteht.

9. Gerät nach Anspruch 1, wobei jedes der Segmente angeordnet ist, um von mindestens zwei der Spannglieder betätigt zu werden.

10. Gerät nach Anspruch 9, das weiter mindestens ein Vorspannelement enthält, das geeignet ist, um eine Vorspannkraft in Gegenwirkung zu den Spanngliedern zu liefern.

11. Gerät nach Anspruch 1, wobei ein zu einem anderen Segment proximales Segment geeignet ist, um die gewählte Form des distaler angeordneten Segments durch Betätigung der Spannglieder anzunehmen, wenn das Gerät distal vorwärts bewegt wird.

12. Gerät nach Anspruch 1, wobei ein zu einem anderen Segment distales Segment geeignet ist, um die gewählte Form des proximaler angeordneten Segments durch Betätigung der Spannglieder anzunehmen, wenn das Gerät proximal zurückgezogen wird.

13. Gerät nach Anspruch 1, wobei die proximalen Segmente bezüglich einer Länge der distalen Segmente länger sind.

14. Gerät nach Anspruch 1, wobei die proximalen Segmente einen größeren Durchmesser bezüglich eines Durchmessers der distalen Segmente haben.

15. Gerät nach Anspruch 1, das weiter ein flexibles, passives rohrförmiges Element enthält, das sich proximal vom länglichen und segmentierten Körper erstreckt.

16. Gerät nach Anspruch 1, wobei jedes der Segmente eine Vielzahl von Steuerringen enthält, und die Steuerringe durch sie hindurch definierte Durchgänge haben, die ein Lumen formen.

17. Gerät nach Anspruch 16, wobei die Steuerringe weiter Scharniere aufweisen, um sie an benachbarten Steuerringen zu befestigen.

18. Gerät nach Anspruch 16, wobei der längliche Körper weiter einen axial innerhalb des länglichen Körpers angeordneten flexiblen Hauptstrang enthält, an dem die Steuerringe befestigt werden können.

19. Gerät nach Anspruch 16, wobei jedes der Spannglieder ein Spanngliedkabel und ein Spanngliedgehäuse enthält, das radial das Spanngliedkabel umfasst, so dass das Spanngliedkabel sich axial frei innerhalb des Spanngliedgehäuses bewegen kann.

20. Gerät nach Anspruch 19, wobei der distalere Steuerring jedes der Segmente weiter Befestigungsstellen für mindestens zwei der Spanngliedkabel enthält;
wobei die Steuerringe proximal zum distalsten Steuerring jedes der Segmente weiter Durchgänge für mindestens zwei der Spanngliedkabel aufweisen; und
wobei der proximalste Steuerring jedes der Segmente weiter Befestigungsstellen für die Spanngliedgehäuse enthält.

21. Gerät nach Anspruch 1, wobei der längliche Körper ein oder mehrere Lumen durch ihn hindurch definiert.

22. Gerät nach Anspruch 1, wobei mindestens zwei Spannglieder an jedem mindestens einer Mehrzahl der Segmente befestigt sind, um die Segmente zu betätigen; wobei, wenn das distale Ende eine ausgewählte Kurve annimmt, diese ausgewählte Kurve sich entlang des länglichen Körpers dadurch fortpflanzen kann, dass die Spannglieder die Segmente selektiv betätigen; und wobei die Steuereinheit mit jedem der Segmente in Verbindung steht, um selektiv jedes Spannglied zu steuern, um die relative Stellung der Segmente zu verändern, wenn die ausgewählte Kurve entlang des länglichen Körpers fortgepflanzt wird.

23. System nach Anspruch 1, das weiter einen axialen Messwandler enthält, der einen Sensor zum Messen der Strecke aufweist, um die der längliche Körper in eine Körperhöhle vorwärts bewegt oder daraus herausgezogen wird.

24. System nach Anspruch 22, das weiter ein Lenksteuergerät in Verbindung mit dem lenkbaren distalen Ende zur Wahl der ausgewählten Kurve enthält.

25. System nach Anspruch 24, wobei das Lenksteuergerät ein Steuergerät enthält, das aus der Gruppe ausgewählt wird, die aus Joysticks, Touchpads, Rollkugeln, Maus-Steuergeräten, Sensorhandschuhen und Steuerrädern besteht.

26. System nach Anspruch 1, das weiter ein Bilderzeugungssystem zur Übertragung eines Bilds vom distalen Ende zum proximalen Ende des länglichen Körpers enthält.

27. System nach Anspruch 26, wobei das Bilderzeugungssystem ein faseroptisches bilderzeugendes Bündel enthält, das sich vom distalen Ende zum proximalen Ende des länglichem Körpers erstreckt.

28. System nach Anspruch 26 oder Anspruch 27, wobei das Bilderzeugungssystem eine CCD-Kamera enthält.

29. System nach Anspruch 26 oder Anspruch 27, wobei das Bilderzeugungssystem eine CMOS-Kamera enthält.

30. System nach Anspruch 1, das weiter mindestens eine Beleuchtungsquelle auf dem länglichen Körper zur Bereitstellung einer Lichtquelle enthält.

31. System nach Anspruch 30, wobei die Beleuchtungsquelle mindestens eine Beleuchtungsfaser enthält, die sich vom distalen Ende zum proximalen Ende des länglichen Körpers erstreckt.

32. System nach Anspruch 1, das weiter eine Aufzeichnungsvorrichtung in Verbindung mit dem länglichen Körper enthält, um Bilder vom distalen Ende des länglichen Körpers aufzuzeichnen.

33. System nach Anspruch 1, wobei der längliche Körper als ein Endoskop zur Einführung in den Körper eines Patienten konfiguriert ist.

34. System nach Anspruch 1, wobei der längliche Körper als ein Kolonoskop zur Einführung in das Kolon eines Patienten konfiguriert ist.

35. System nach Anspruch 1, wobei der längliche Körper als ein Laparoskop zur Einführung in die Körperhöhle eines Patienten konfiguriert ist.

36. System nach Anspruch 1, wobei der längliche Körper ein oder mehrere Lumen durch ihn hindurch definiert.

Revendications

1. Appareil destiné à être inséré dans une cavité corporelle, comprenant :

un corps allongé (21) comprenant une pluralité de segments articulables (30), une extrémité proximale et une partie distale orientable (24) ;
une pluralité de cordons (312) attachés à au moins une majorité des segments et s'étendant des segments à l'extrémité proximale du corps allongé ; et
une unité de commande externe (45) comprenant une pluralité d'actionneurs ;
dans lequel chacun des segments est configurable pour prendre une forme choisie le long d'un chemin arbitraire par actionnement des cordons attachés à celui-ci, chacun des segments est articulable par au moins l'un des cordons, et lesdits segments adjacents les uns aux autres sont adaptés pour prendre une forme choisie du segment adjacent par actionnement des cordons quand on fait avancer le corps allongé de façon distale ou proximale ;
caractérisé en ce que l'appareil comprend en outre :

une première interface de connecteur (952) qui maintient les extrémités proximales des cordons en un ensemble organisé ;
une deuxième interface de connecteur (956) placée sur l'unité de commande externe ; et
un connecteur rapide (60) pour accoupler mécaniquement respectivement la pluralité d'actionneurs à la pluralité de cordons, le connecteur rapide comprenant les première et deuxième interfaces de connecteur, lesdites interfaces de connecteur étant agencées pour s'accoupler l'une à l'autre pour permettre de ce fait la rétraction de chaque actionneur pour appliquer une force de traction directement à l'extrémité proximale d'un cordon respectif spécifique.

2. Appareil selon la revendication 1, dans lequel les extrémités proximales des cordons se terminent en protubérances aplaties (972) et la deuxième interface de connecteur est pourvue d'une pluralité de trous à encoche (974) destinés à s'accoupler avec lesdites protubérances, lesquels trous à encoche peuvent être rétractés individuellement par les actionneurs pour appliquer une tension aux cordons individuels.

3. Appareil selon la revendication 1, comprenant en outre une poignée (32) en position proximale par rapport aux segments articulables (30).

4. Appareil selon la revendication 3, dans lequel la partie distale orientable (24) est configurable via des commandes situées sur la poignée (32).

5. Appareil selon la revendication 1, dans lequel la partie distale orientable est configurable via l'unité de commande externe (45).

6. Appareil selon la revendication 1, dans lequel l'unité de commande (45) comprend en outre un ordinateur.

7. Appareil selon la revendication 1, dans lequel l'unité de commande (45) est adaptée pour ajuster les cordons pour les forces de compression et de traction appliquées aux cordons.

8. Appareil selon la revendication 1, dans lequel les actionneurs sont choisis dans le groupe comprenant les moteurs électromécaniques, les vérins pneumatiques, les vérins hydrauliques, les moteurs pneumatiques, les moteurs hydrauliques, les solénoïdes, les fils métalliques en alliage à mémoire de forme et les actionneurs électroniques rotatifs.

9. Appareil selon la revendication 1, dans lequel chacun des segments est agencé pour être actionné par au moins deux des cordons.

10. Appareil selon la revendication 9, comprenant en outre au moins un élément de sollicitation adapté pour fournir une force de sollicitation en opposition aux cordons.

11. Appareil selon la revendication 1, dans lequel un segment proximal par rapport à un autre segment est adapté pour prendre la forme choisie du segment situé de façon plus distale par actionnement des cordons quand on fait avancer l'appareil de façon distale.

12. Appareil selon la revendication 1, dans lequel un segment distal par rapport à un autre segment est adapté pour prendre la forme choisie du segment situé de façon plus proximale par actionnement des cordons quand on rétracte l'appareil de façon proximale.

13. Appareil selon la revendication 1, dans lequel les segments proximaux ont une longueur supérieure à celle des segments distaux.

14. Appareil selon la revendication 1, dans lequel les segments proximaux ont un diamètre plus grand que celui des segments distaux.

15. Appareil selon la revendication 1, comprenant en outre un élément tubulaire flexible passif s'étendant de façon proximale depuis le corps allongé et segmenté.

16. Appareil selon la revendication 1, dans lequel chacun des segments comprend une pluralité d'anneaux de commande, et les anneaux de commande comportent des passages définis à travers ceux-ci qui forment une lumière.

17. Appareil selon la revendication 16, dans lequel les anneaux de commande comprennent en outre des charnières destinées à être fixées aux anneaux de commande adjacents.

18. Appareil selon la revendication 16, dans lequel le corps allongé comprend en outre une ossature centrale flexible située axialement dans le corps allongé sur laquelle les anneaux de commande peuvent être fixés.

19. Appareil selon la revendication 16, dans lequel chacun des cordons comprend un câble de cordon et un boîtier de cordon qui entoure radialement le câble de cordon de telle manière que le câble de cordon est libre de se déplacer axialement à l'intérieur du boîtier de cordon.

20. Appareil selon la revendication 19, dans lequel l'anneau de commande le plus distal de chacun des segments comprend en outre des sites de fixation pour au moins deux des câbles de cordon ;
dans lequel les anneaux de commande en position proximale par rapport à l'anneau de commande le plus distal de chacun des segments comprennent en outre des passages pour au moins deux des câbles de cordon ; et
dans lequel l'anneau de commande le plus proximal de chacun des segments comprend en outre des sites de fixation pour les boîtiers de cordon.

21. Appareil selon la revendication 1, dans lequel le corps allongé définit une ou plusieurs lumières le traversant.

22. Appareil selon la revendication 1, dans lequel au moins deux cordons sont attachés à chacun d'au moins une majorité des segments pour actionner lesdits segments ; dans lequel quand l'extrémité distale se courbe de façon sélectionnée, cette courbe sélectionnée peut se propager le long du corps allongé par l'actionnement sélectif des segments par les cordons ; et dans lequel l'unité de commande est en communication avec chacun des segments pour commander de façon sélective chaque cordon pour modifier la position relative des segments quand la courbe sélectionnée est propagée le long du corps allongé.

23. Système selon la revendication 1, comprenant en outre un transducteur axial ayant un capteur pour mesurer la distance sur laquelle le corps allongé avance dans ou est retiré d'une cavité corporelle.

24. Système selon la revendication 22, comprenant en outre un dispositif de commande de direction en communication avec l'extrémité distale orientable pour choisir la courbe sélectionnée.

25. Système selon la revendication 24, dans lequel le dispositif de commande de direction comprend un dispositif de commande sélectionné dans le groupe comprenant les manches à balai, les pavés tactiles, les boules de commande, les dispositifs de commande à souris, les gants sensoriels et les volants de commande.

26. Système selon la revendication 1, comprenant en outre un système d'imagerie pour transmettre une image de l'extrémité distale à l'extrémité proximale du corps allongé.

27. Système selon la revendication 26, dans lequel le système d'imagerie comprend un faisceau d'imagerie à fibre optique s'étendant de l'extrémité distale à l'extrémité proximale du corps allongé.

28. Système selon la revendication 26 ou 27, dans lequel le système d'imagerie comprend une caméra CCD.

29. Système selon la revendication 26 ou 27, dans lequel le système d'imagerie comprend une caméra CMOS.

30. Système selon la revendication 1, comprenant en outre au moins une source d'éclairage sur le corps allongé pour fournir une source de lumière.

31. Système selon la revendication 30, dans lequel la source d'éclairage comprend au moins une fibre d'éclairage s'étendant de l'extrémité distale à l'extrémité proximale du corps allongé.

32. Système selon la revendication 1, comprenant en outre un dispositif d'enregistrement en communication avec le corps allongé pour enregistrer des images provenant de l'extrémité distale du corps allongé.

33. Système selon la revendication 1, dans lequel le corps allongé est configuré en tant qu'endoscope destiné à être inséré dans le corps d'un patient.

34. Système selon la revendication 1, dans lequel le corps allongé est configuré en tant que coloscope destiné à être inséré dans le côlon d'un patient.

35. Système selon la revendication 1, dans lequel le corps allongé est configuré en tant que laparoscope destiné à être inséré dans une cavité corporelle d'un patient.

36. Système selon la revendication 1, dans lequel le corps allongé définit une ou plusieurs lumières le traversant.

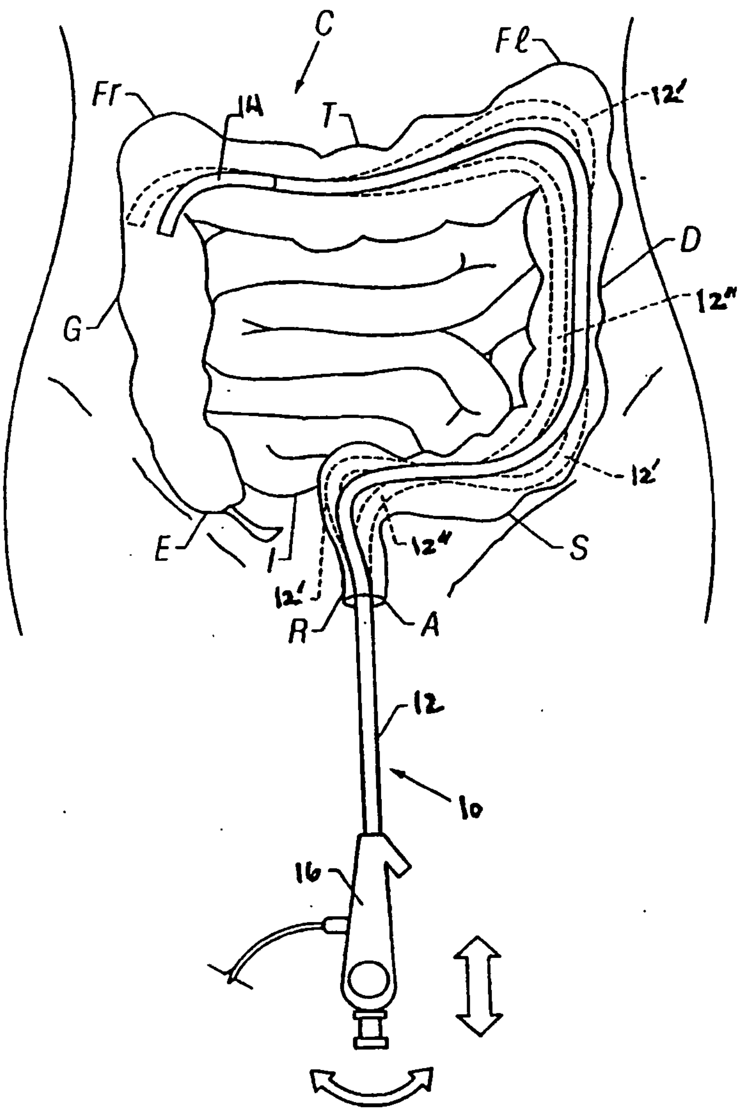
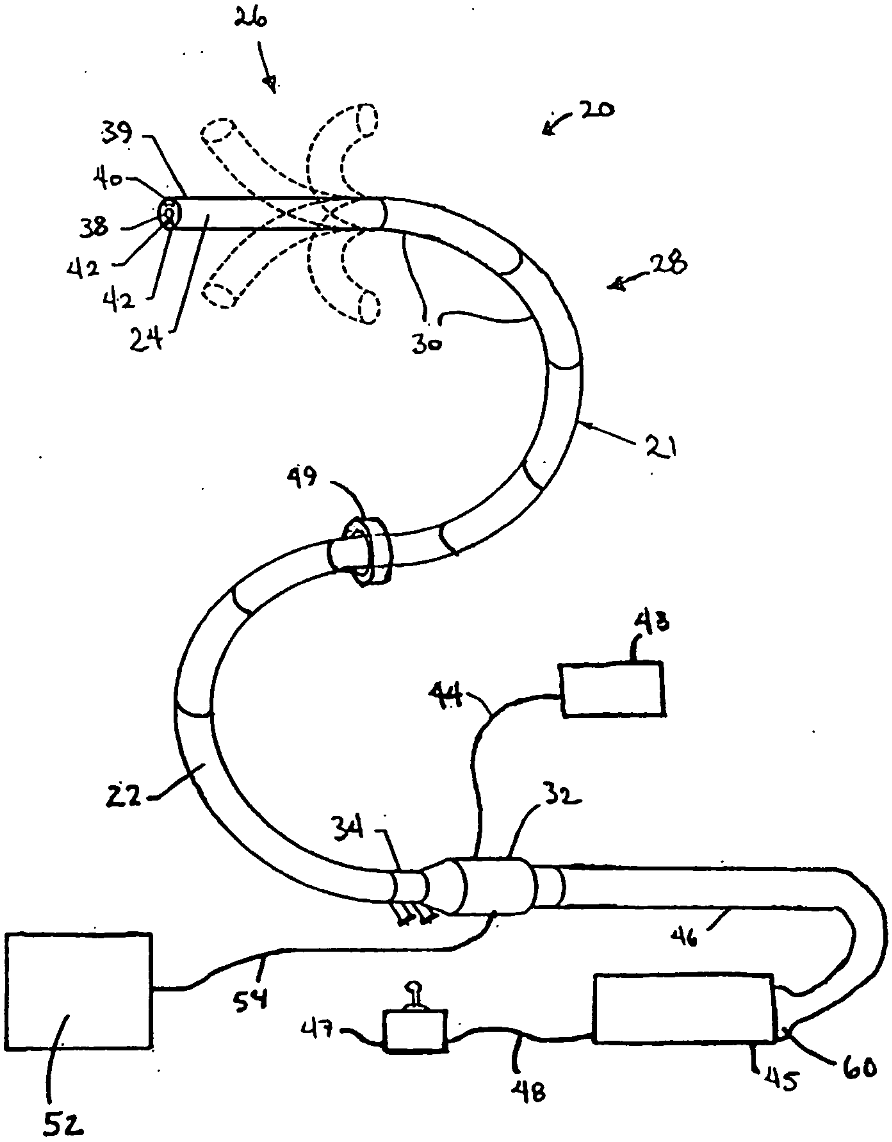


FIG. 1
(Prior Art)

Fig. 2



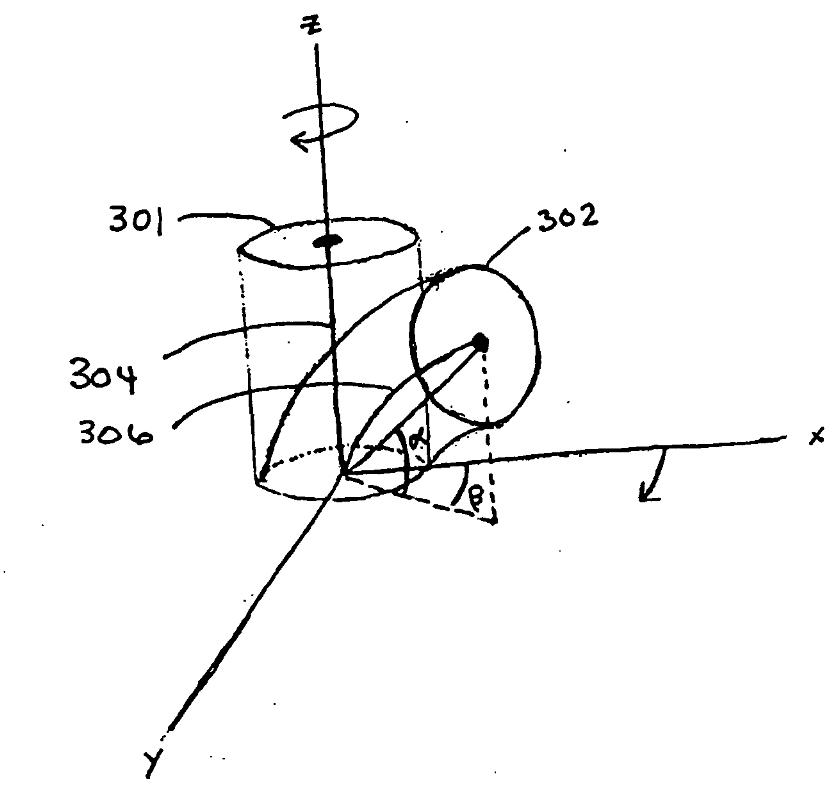


Fig. 3A

Fig. 3B

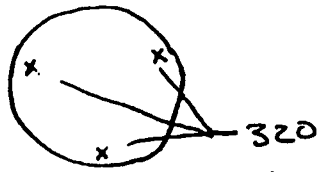
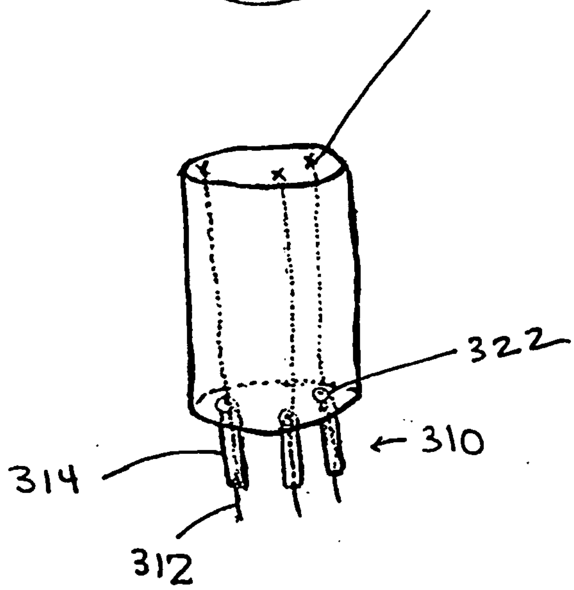


Fig. 3C



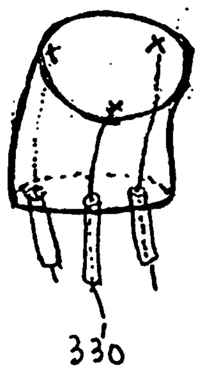


Fig. 3D

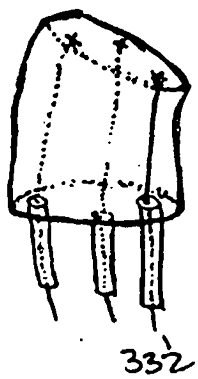


Fig. 3E

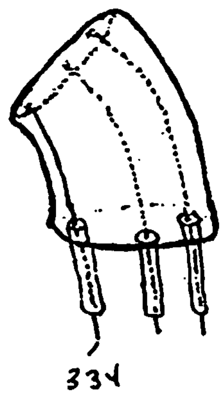


Fig. 3F.

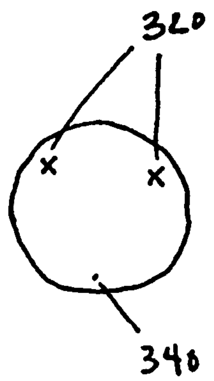


Fig 4A

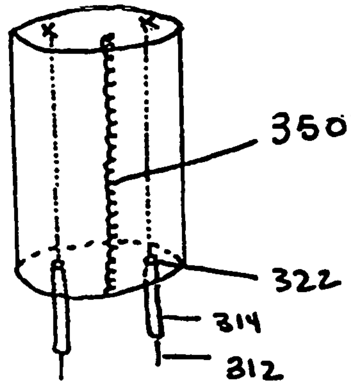


Fig 4B

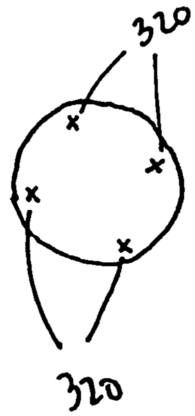


Fig 4C

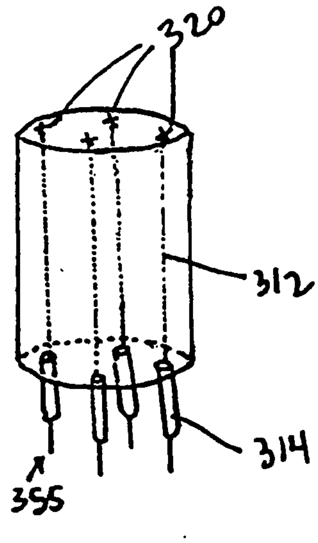


Fig 4D

Fig. 5

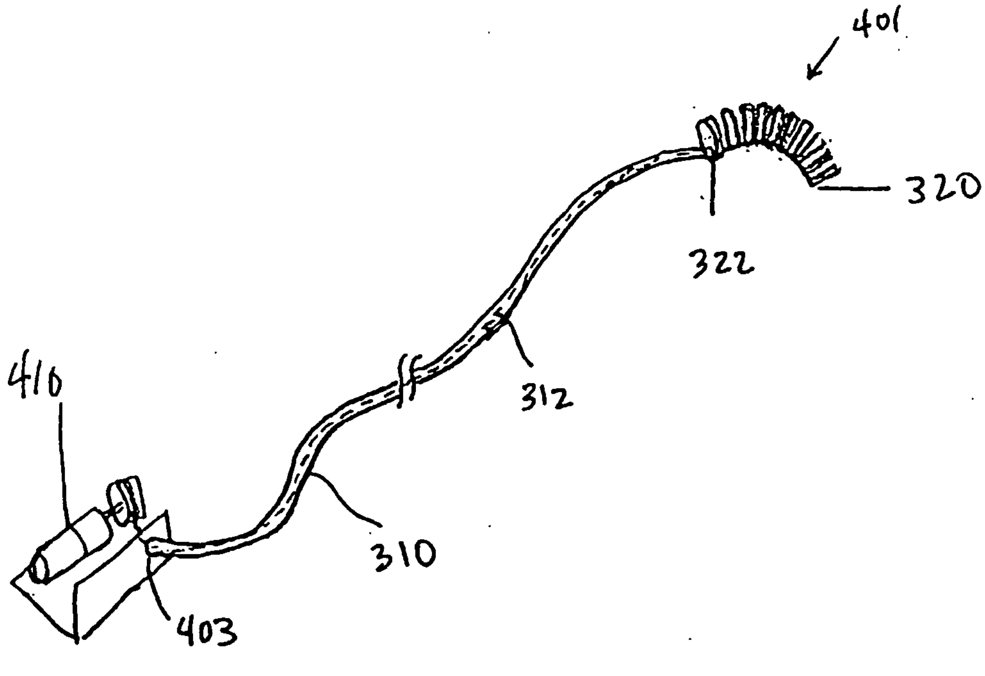


Fig. 6A

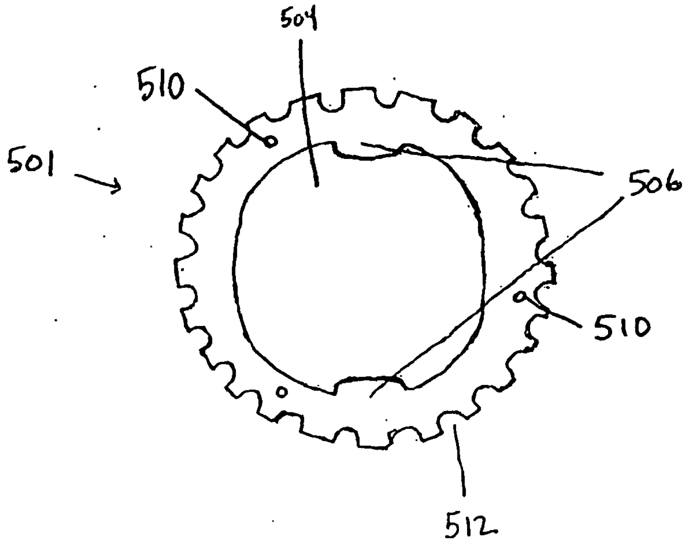
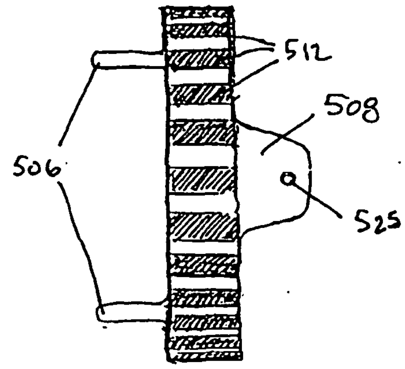


Fig. 6B



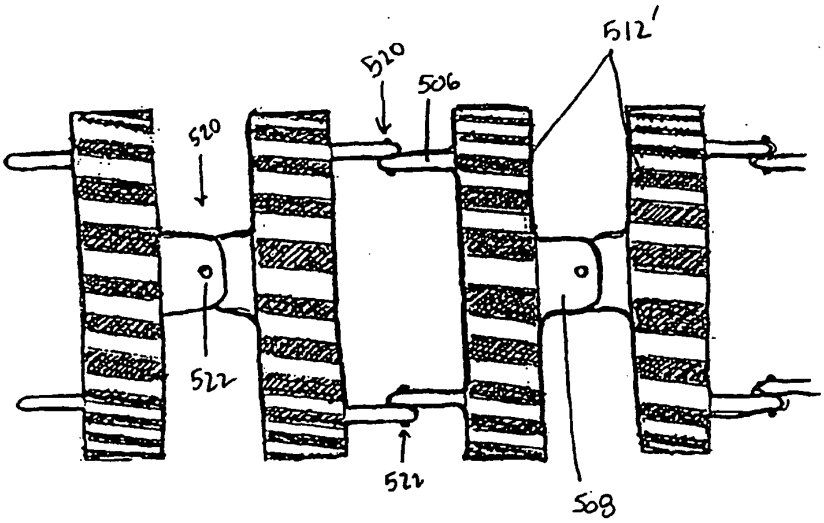


Fig. 6C

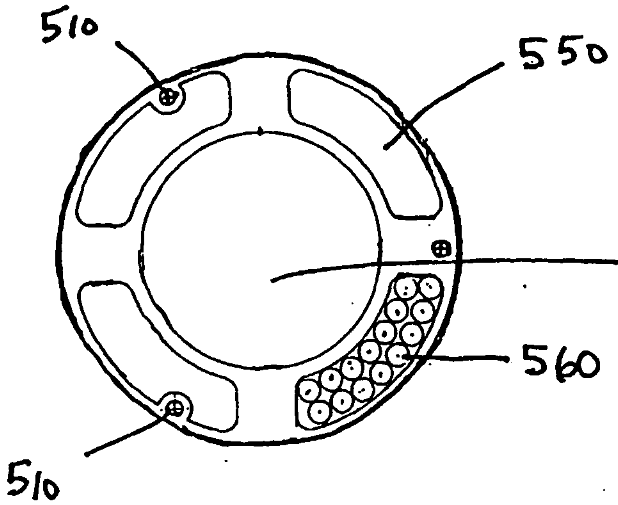


Fig. 6D

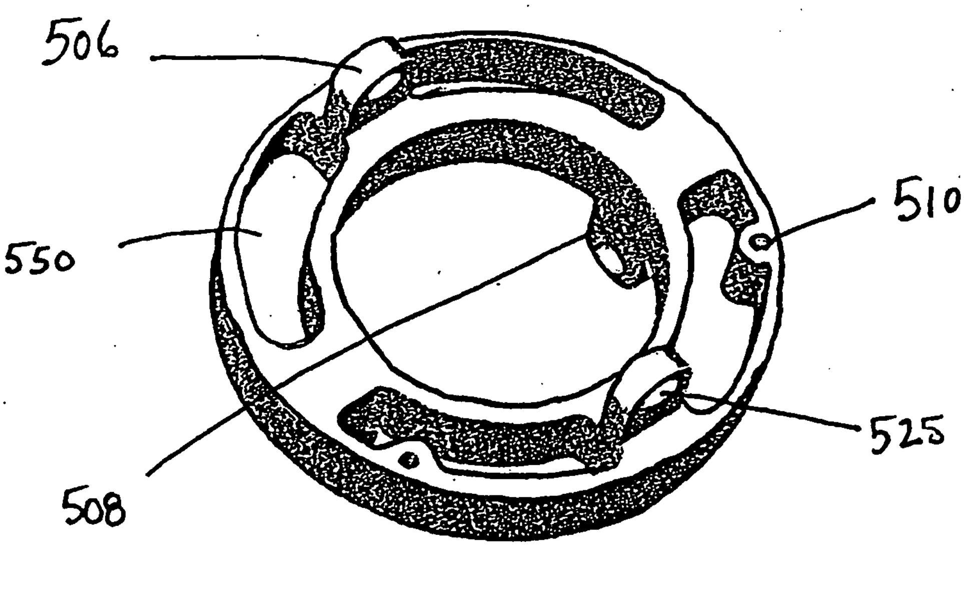


Fig. 6E

Fig. 7A

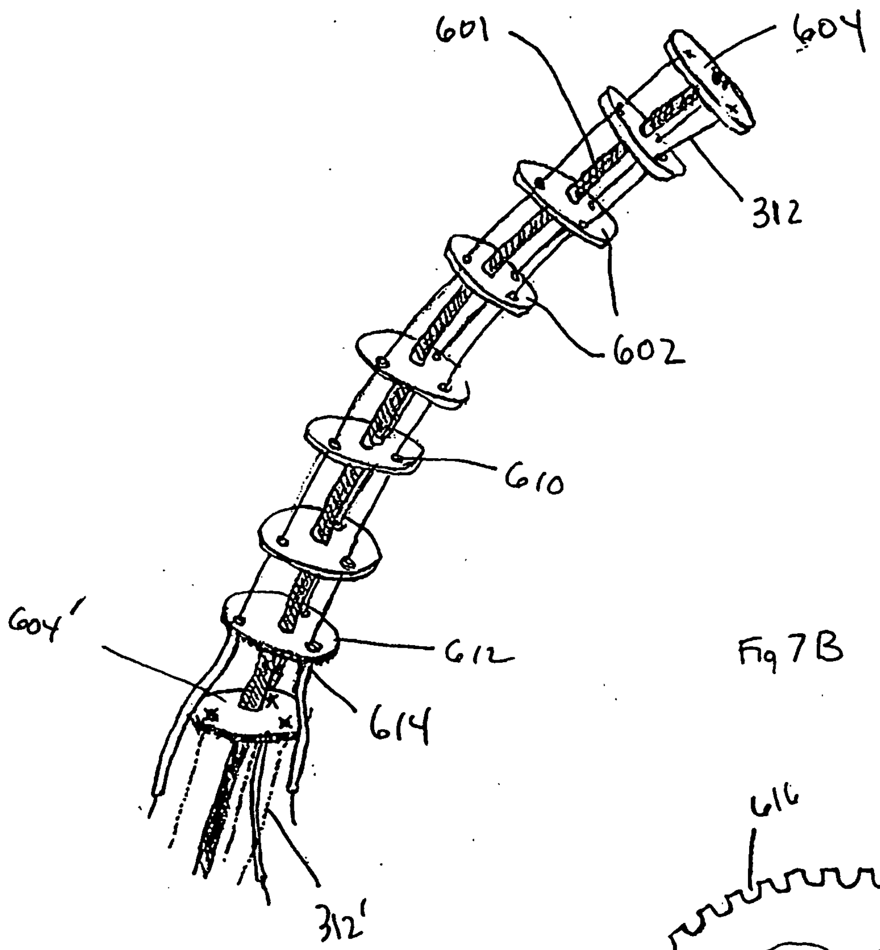
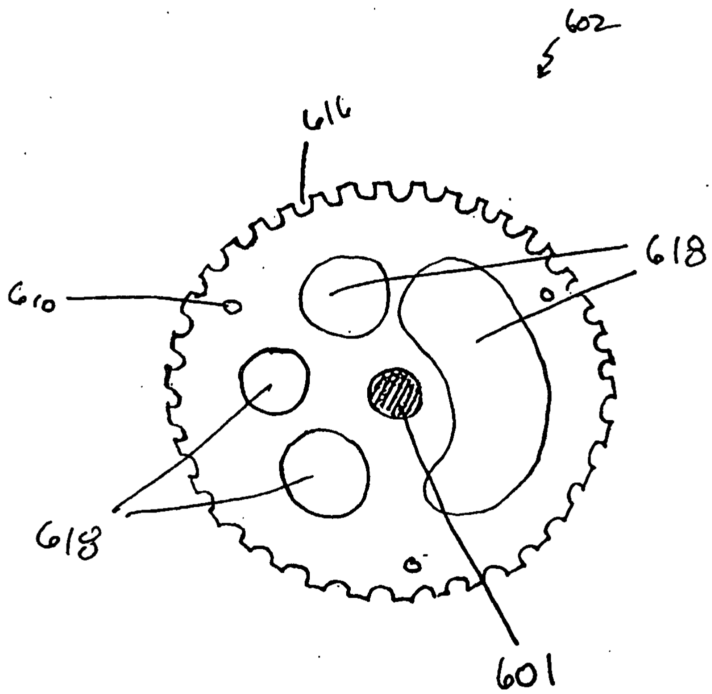


Fig 7B



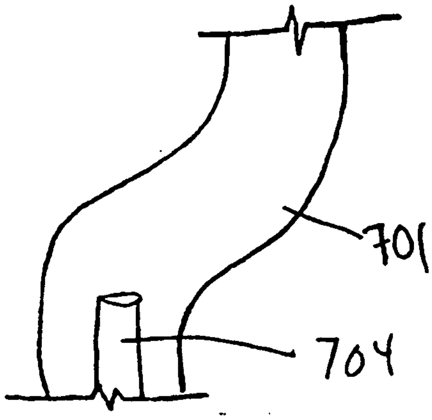


Fig. 8A

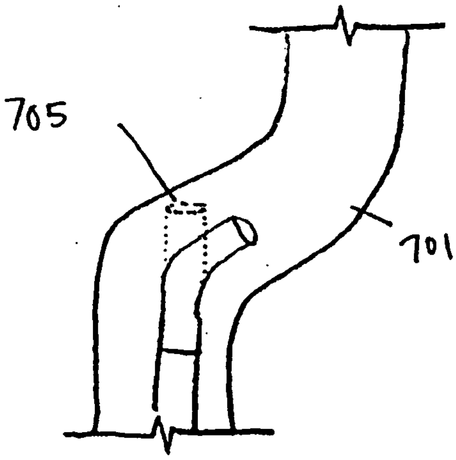


Fig. 8B

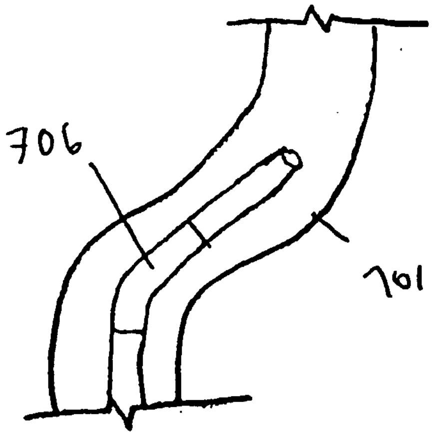


Fig. 8C

Fig. 9

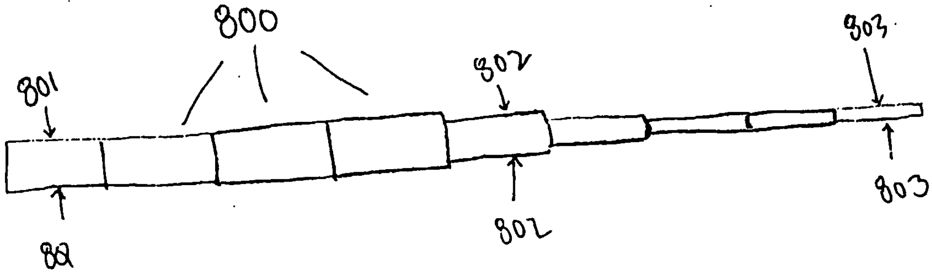
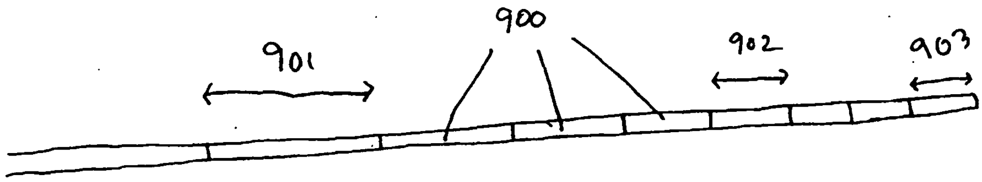


Fig. 10



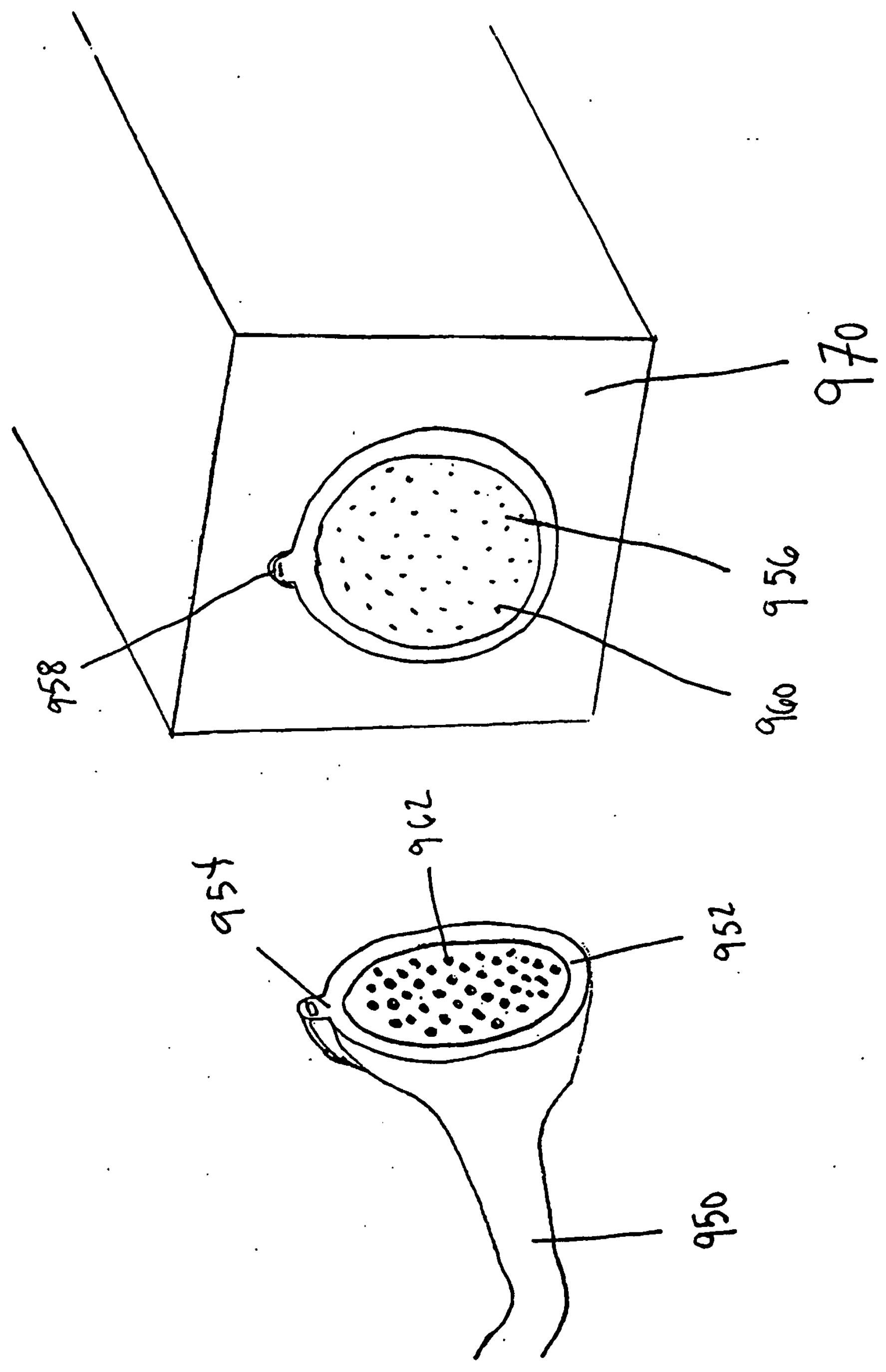


Fig. 11A

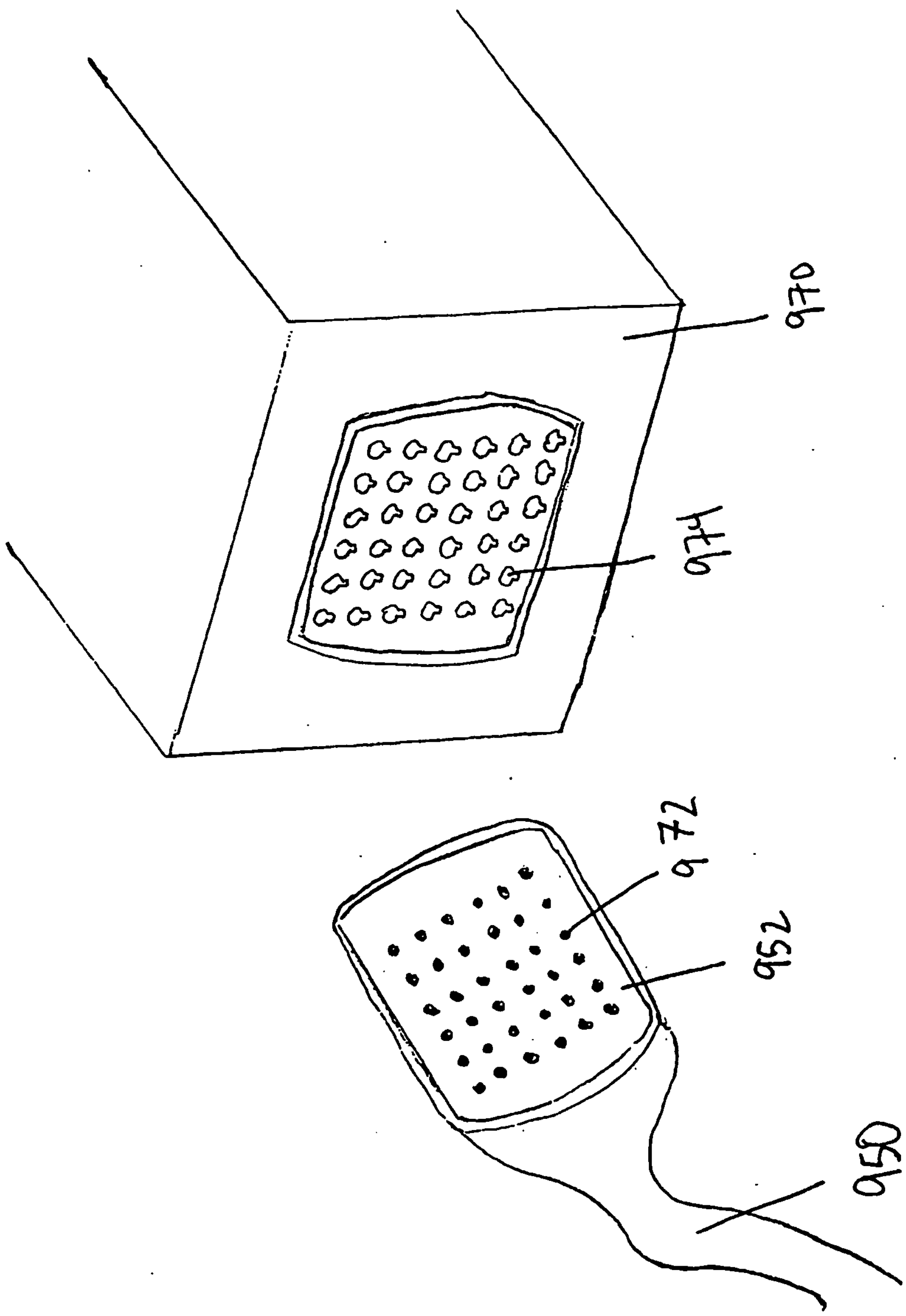


Fig. 11B

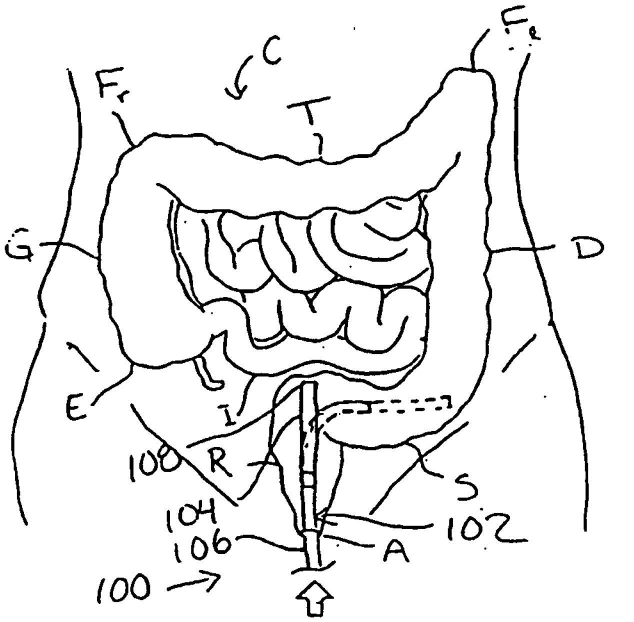


Fig. 12A

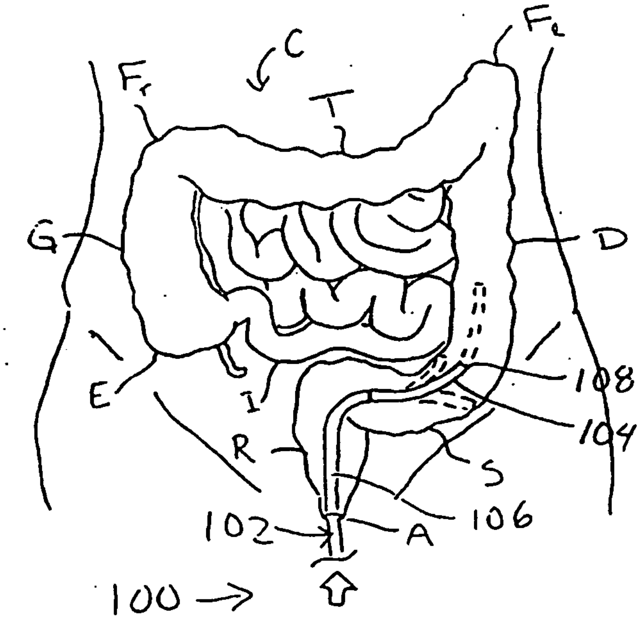


Fig. 12B

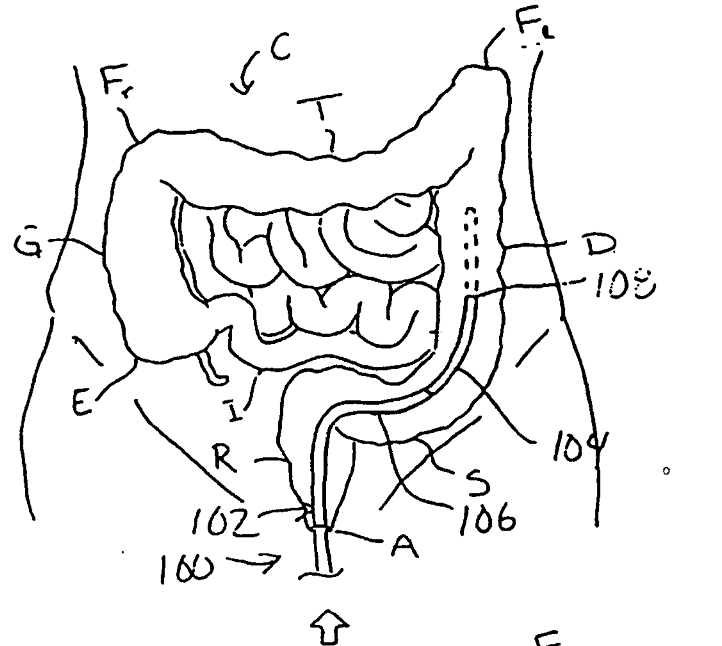


Fig. 12C

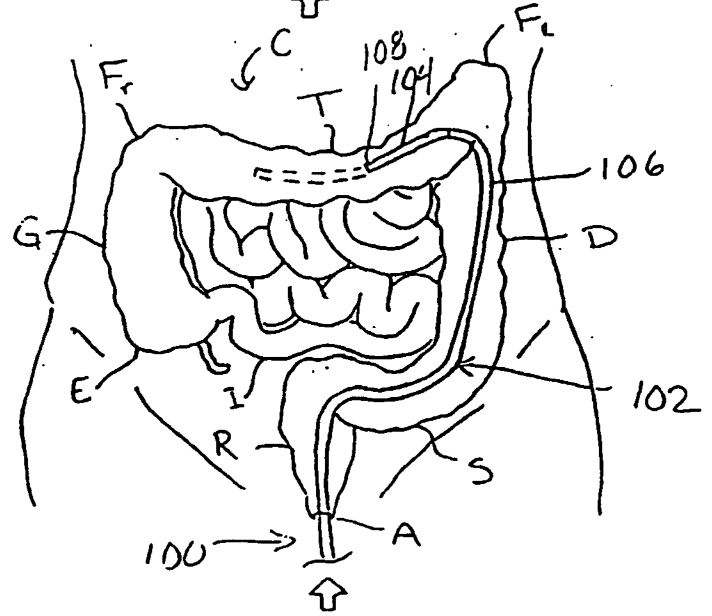


Fig. 12D

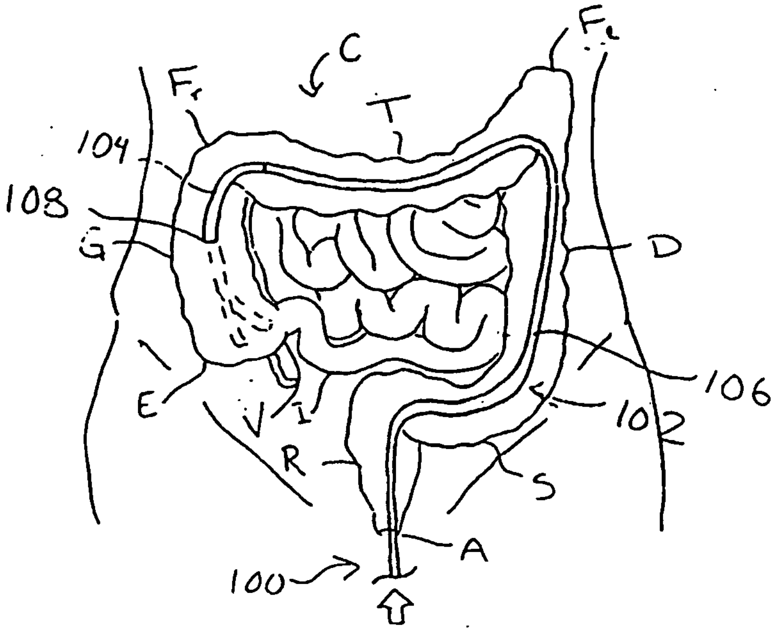


Fig. 12E

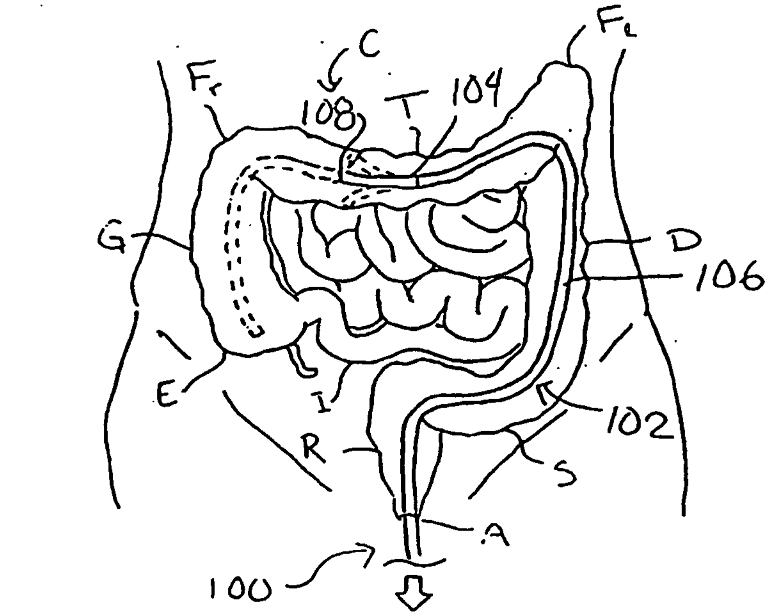


Fig. 12F

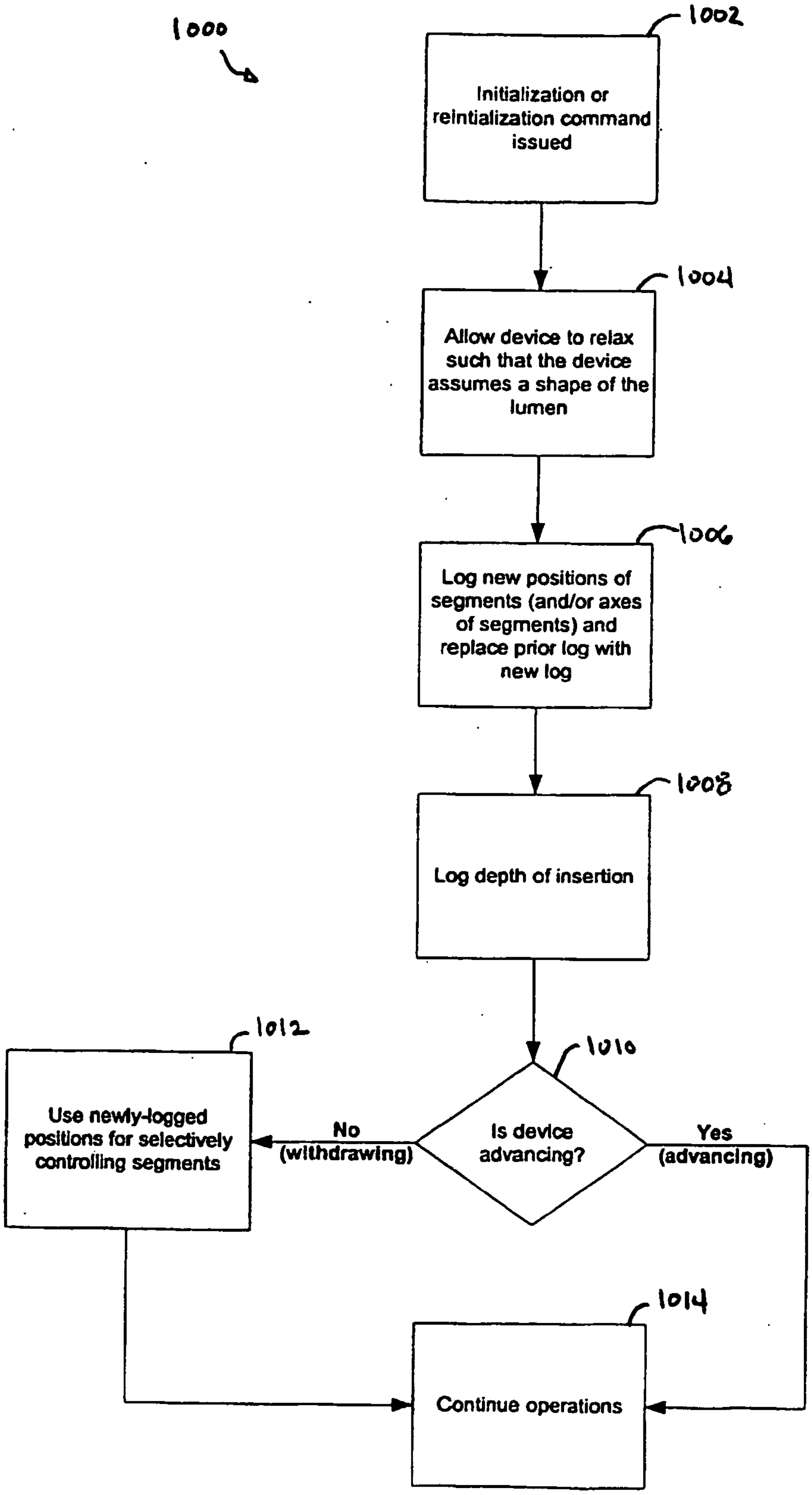

1000
1002
Initialization or reintialization command issued
1004
Allow device to relax such that the device assumes a shape of the lumen
1006
Log new positions of segments (and/or axes of segments) and replace prior log with new log
1008
Log depth of insertion
1010
Is device advancing?
No (withdrawing)
Yes (advancing)
1012
Use newly-logged positions for selectively controlling segments
1014
Continue operations

FIG. 13

REFERENCES CITED IN THE DESCRIPTION

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patsnap

专利名称(译)	肌腱驱动的内窥镜		
公开(公告)号	[EP1534118B1](EP1534118B1)	公开(公告)日	2013-10-02
申请号	EP2003791924	申请日	2003-08-27
[标]申请(专利权)人(译)	新引导系统公司		
申请(专利权)人(译)	NEOGUIDE系统公司.		
当前申请(专利权)人(译)	Intuitive Surgical公司运营，INC.		
[标]发明人	OHLINE ROBERT M TARTAGLIA JOSEPH M BELSON AMIR ROTH ALEX T KELLER WADE A ANDERSON SCOTT C JULIAN CHRIS A		
发明人	OHLINE, ROBERT M. TARTAGLIA, JOSEPH M. BELSON, AMIR ROTH, ALEX T. KELLER, WADE, A. ANDERSON, SCOTT, C. JULIAN, CHRIS, A.		
IPC分类号	A61B1/00 A61B1/04 G02B23/24 A61B1/005 A61B1/008 A61B1/01 A61B1/31 G02B23/26		
CPC分类号	A61B1/00128 A61B1/00006 A61B1/00057 A61B1/0016 A61B1/0053 A61B1/0057 A61B1/0058 A61B1/01 A61B1/31 A61B5/065 A61B2034/301 A61B2034/741 A61B2034/742		
优先权	10/229577 2002-08-27 US		
其他公开文献	EP1534118A4 EP1534118A1		
外部链接	Espacenet		

摘要(译)

本文描述了可操纵的肌腱驱动的内窥镜。内窥镜具有细长主体，其具有手动或选择性可操纵的远端部分和自动控制的分段近端部分。可操纵的远端部分和可控部分的区段由至少两个肌腱致动。随着内窥镜前进，使用者操纵远端部分，并且运动控制器致动分段的近端部分中的肌腱，使得近端部分呈现选择性可操纵的远端部分的选定曲线。通过该方法，所选择的曲线沿着内窥镜主体传播，使得内窥镜基本上符合所选择的路径。当内窥镜向近侧撤回时，所选择的曲线可以沿着内窥镜主体向远侧传播。这允许内窥镜沿着期望的路径通过身体内的器官或周围和之间的曲折曲线。

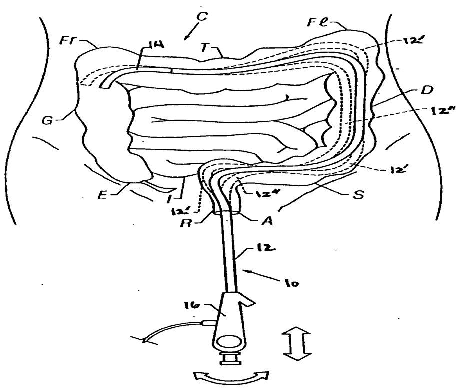

FIG. 1
(Prior Art)