

FLEXIBLE GUIDANCE AND PRECISE POSITIONING MECHANISM AND APPLICATIONS THEREOF

Field of the Invention

[0001] The present invention generally relates to devices and methods for guidance and positioning, and more particularly to a flexible guidance and precise positioning mechanism and its applications including minimally invasive surgical instruments such as endoscopic system and laparoscopic system, and other engineering inspection systems.

Background of the Invention

[0002] Endoscopic and laparoscopic surgeries are common samples for minimally invasive surgical techniques that have received wide acceptance among patients and doctors. The minimally invasive surgical techniques cause reduced incision trauma, resulting in quicker recovery, less patient monitoring, and shorter hospital stays and consequent reductions in medical costs. Furthermore, the minimally invasive surgical techniques have significantly lower incidence of post-operative complications. Despite all these advantages, minimally invasive surgical techniques still present a surgeon with several formidable challenges due to the limitations of available instruments. For example, the rigid elongated body of an endoscope has reduced dexterity due to its length and limited freedom of movement. When the rigid elongated body is extended, it has reduced feel due to poor force feedback. Furthermore, about 70% of the applied manipulator force is lost due to inherently high friction of the operating mechanism. Therefore, tactile and haptic feedbacks are needed in order to achieve good eye-hand coordination.

[0003] During endoscopic and laparoscopic surgeries, the surgeons observe and operate a patient indirectly through minimally invasive surgical instruments. However, this indirect nature may impair the depth perception and eye-hand coordination of a surgeon. Important factors that impair depth perception include the absence of shadows in endoscopic camera pictures and the restricted ability to observe organs from different sides. Important factors that impair eye-hand coordination include the unnatural

endoscopic line-of-sight, which results in mis-orientation between the surgeon's hand movements and the instrument movements on the screen.

[0004] Attempts have been made to address the issues of the movement and operation of minimally invasive surgical instruments in the prior arts. For example, a flexible guide could be rigidized through the use of special thermal sensitive materials joined by miniature linear spring elements. In addition, mechanical linkages such as universal joints could be activated by means of cables that are operably coupled with a control knob.

[0005] Certain endoscopic surgical techniques such as those in laparoscopic and orthoscopic surgeries require a surgeon to operate in a counter-intuitive manner. For example, when the distal tip inside the body must be moved upward and to the right, the surgeon's hand outside the body must then move downwards and to the left. As the distal end of the endoscope is inserted into and maneuvered within the patient, the counter-intuitive manner causes mismatched eye-hand coordination. This mismatch in orientation is further complicated by attempts to coordinate these motions against an image being displayed on a display monitor, which itself may change in orientation as the camera is rotated. This difficulty represents a major obstacle to widespread use of this surgical method.

[0006] In all endoscopic systems, the distal end of an endoscope during surgical procedure can only be manipulated with 1 or 2 degree of freedom (DOF). It creates serious problems in situations where the distal end of the endoscope has to be precisely positioned in certain locations for better views. Usually, to ensure precise positioning of the distal end of an endoscope requires a surgeon to move the distal end around a designated region of interest. It is evident that this creates difficulty for the surgeon and complicates the operation procedure.

Summary of the Invention

[0007] In one embodiment of the present invention, there is provided a flexible guidance and precise positioning mechanism. The flexible guidance and precise positioning mechanism comprises a spring having one distal end and one proximal end, a distal means integrally coupled with the distal end of the spring; a proximal means

integrally coupled with the proximal end of the spring; and a plurality of longitudinal control means having one distal end and one proximal end, wherein the plurality of longitudinal means are evenly positioned around the spring, and wherein each of the plurality of longitudinal control means is controllably coupled with the pitches of the spring; thereby when any of the plurality of longitudinal control means causes the spring to deflect in one direction, it provides guidance; and when the spring is compressed to a predetermined state by the plurality of longitudinal control means, the release of the compressed spring will cause a forward movement with a fixed length so that it achieves precise positioning.

[0008] In another embodiment of the mechanism, it further comprises a flexible and compressible sheath covering the spring, reducing the friction at the interface between the mechanism and its surrounding environment. In yet another embodiment of the mechanism, the spring has a cylindrical configuration.

[0009] In another embodiment of the present invention, there is provided an endoscopic system. The endoscopic system comprises an elongated body having a distal end and a proximal end; a flexible guidance and precise positioning mechanism disposed at the distal end for providing flexible guidance and precise positioning to the endoscopic system; and a control module disposed at the proximal end of the elongated body for controlling the directions and movements of the endoscopic system.

[0010] In another embodiment of the endoscopic system, it further comprises a plurality of functional fibers disposed within the lumen of the elongated body, wherein the movements of the plurality of functional fibers are controlled by the control module.

[0011] In another embodiment of the endoscopic system, the elongated body comprises segments of small polymerized spring elements in series.

[0012] In another embodiment of the endoscopic system, the flexible guidance and precise positioning mechanism comprises a spring having one distal end and one proximal end; a distal means integrally coupled with the distal end of the spring; a proximal means integrally coupled with the proximal end of the spring; and a plurality of longitudinal control means having one distal end and one proximal end, wherein the plurality of longitudinal means are evenly positioned around the spring, and wherein each of the plurality of longitudinal control means is controllably coupled with the pitches of the spring; thereby when any of the plurality of longitudinal control means causes the spring to

deflect in one direction, it provides guidance; and when the spring is compressed to a predetermined state by the plurality of longitudinal control means, the release of the compressed spring will cause a forward movement with a fixed length so that it achieves precise positioning.

[0013] In another embodiment of the endoscopic system, it further comprises a sheath covering the spring, reducing the friction at the interface between the mechanism and its surrounding environment.

[0014] In another embodiment of the endoscopic system, the spring has a cylindrical configuration.

[0015] In another embodiment of the endoscopic system, the control module comprises a guide controller operably coupled with the elongated body via a channel embedded with a plurality of guide cables, where the guide controller operates on the flexible guidance and precise positioning mechanism through the plurality of guide cables. In a further embodiment of the endoscopic system, the control module further comprises a connection operably coupled with an electronic motion controller via a controller cable to control the manipulating forces for the movement of the elongated body. In another further embodiment of the endoscopic system, the control module further comprises an illumination source via an illumination cable to provide illumination for imaging the pathway and checking site. In yet another further embodiment of the endoscopic system, the electronic motion controller is a remote wireless control system.

[0016] In another embodiment of the present invention, there is provided a process for flexible guidance and precise positioning. The process comprises providing a spring disposed at a distal end of a movable object; providing a plurality of controlling cables, wherein one end of the plurality of controlling cables is operably coupled with the spring and the other end is operably coupled with a remote controller; causing the spring to deflect in one direction by pulling one or two of the controlling cables so as to provide flexible guidance for the moving object; and precise positioning the movable object by releasing the spring from a preloaded state.

[0017] The objectives and advantages of the invention will become apparent from the following detailed description of preferred embodiments thereof in connection with the accompanying drawings.

Brief Description of the Drawings

[0018] Preferred embodiments according to the present invention will now be described with reference to the Figures, in which like reference numerals denote like elements.

[0019] FIG 1 shows a schematic view of an endoscopic system having a mechanism for flexible guidance and precise positioning in accordance with one embodiment of the present invention.

[0020] FIG 2 shows an enlarged schematic view of the flexible guidance and precise positioning mechanism in accordance with one embodiment of the present invention.

[0021] FIG 3 shows an exploded schematic view of the flexible guidance and precise positioning mechanism shown in FIG 2.

[0022] FIG 4 is an exemplary configuration of the distal end 21 in accordance with one embodiment of the present invention.

[0023] FIG 5 illustrates the operation of the flexible guidance and precise positioning mechanism for changing directions where the distal end is bent by pulling one or two of the guide cables 6.

[0024] FIGS 6A and 6B show schematic diagrams of the flexible guidance and precise positioning mechanism illustrating the operation of precise positioning in accordance with one embodiment of the present invention.

Detailed Description of the Invention

[0025] The present invention may be understood more readily with reference to the following detailed description of certain embodiments of the invention.

[0026] Throughout this application, where publications are referenced, the disclosures of these publications are hereby incorporated by reference, in their entireties, into this application in order to more fully describe the state of art to which this invention pertains.

[0027] In the following detailed description, specific details are set forth in order to provide a thorough understanding of the invention. However, it will be understood by

those skilled in the relevant art that the present invention may be practiced without these specific details. In other instances, well-known methods, procedures, components, and materials have not been described in detail so as not to obscure the present invention.

[0028] The present invention provides a flexible guidance and precise positioning mechanism and its applications. While the flexible guidance and precise positioning mechanism will be described in detail in the context of an endoscopic system, it is to be appreciated that the flexible guidance and precise positioning mechanism can be used in any situations where flexible guidance for moving an elongated object within tunnels/channels and precise positioning of the distal end of the elongated object are required, e.g., inspection of cylinder head conditions of marine engines in ships and other civil, mechanical and architectural engineering applications.

[0029] Now referring to FIG 1, there is provided a schematic view of an endoscopic system having a mechanism for flexible guidance and precise positioning in accordance with one embodiment of the present invention. The endoscopic system **1** comprises a flexible guidance and precise positioning mechanism **2**, an elongated body **3**, and a controlling module **4**. The flexible guidance and precise positioning mechanism **2** will be described in detail hereinafter. The elongated body **3** usually has a cylindrical configuration with an outer layer and a lumen, where the lumen receives the fibers including optic fibers and the outer layer isolates and protects the fibers from friction from the external environment. The elongated body **3** can be made of any suitable material. In one embodiment, the entire length of the elongated body **3** comprises segments of small polymerized spring elements in series. It has 3 DOF including forward/retractable displacement both linear or axially and is programmable curvature of bend radius from distal end up to an estimated 20 mm or more, thereby provision of accommodation to the types of surgical operations that it may undertake.

[0030] The controlling module **4** is not restricted to any particular configuration or design. As shown in FIG 1, the controlling module **4** controls the moving direction of the elongated body and the movement (back/forth) of the elongated body. The moving direction of the elongated body is executed by the flexible guidance and precise positioning mechanism **2** and controlled by a guide controller **5**. The guide controller **5** is operably coupled with the elongated body **3** via a channel **7** embedded with a plurality of guide

cables 6. The guide controller 5 operates on the flexible guidance and precise positioning mechanism 2 through the plurality of guide cables 6.

[0031] The controlling module 4 comprises a connection 8 that is operably coupled with an electronic motion controller 11 via a controller cable 12 to control the mechanic forces for the movement of the elongated body, and operably coupled with an illumination source 13 via an illumination cable 14 to provide illumination for imaging the pathway and checking site so that the images of the pathway and checking site can be acquired. In one embodiment, a remote wireless control system may be used to control the electronic motion controller 11. In one embodiment, the manipulating forces for the movement of the elongated body can be provided by means of electronic actuator devices that are aligned with respect to the direction of the endoscope motion in the body. Disposed within the lumen of the elongated body includes optical fibers for acquiring visual signals along the pathway and checking sites. All the cables 16 embedded within the lumen can be locked up near the connection 8 by any means, e.g., luer lock fittings 15. In addition, the connection may be operably coupled with other components including signal output means for outputting visual signals from the optic fibers. All the components of the controlling module 4 are well known to those skilled in the art; thus there is no more detailed description provided herein.

[0032] Now referring to FIG 2, there is provided an enlarged schematic view of the flexible guidance and precise positioning mechanism in accordance with one embodiment of the present invention. The flexible guidance and precise positioning mechanism 2 comprises a distal end 21, a spring 23, and a proximal end 22. The spring 23 is integrally coupled with the distal end 21 and the proximal end 22. The plurality of guide cables 6 are operably coupled with the spring 23, where the plurality of guide cables 6 are evenly disposed along the spring 23. In one embodiment, four guide cables are employed so that the four guide cables are inter-disposed at 90 degrees apart from each other. As shown in FIG 5, the spring 23 can be deflected in any direction in 3D space by pulling one or two of the guide cables 6 so that the directions of the moving elongated body can be controllably manipulated. In some embodiments, it requires a minimum of 2 wires or more for controlling the directions depending on the 2D or 3D manipulation.

[0033] Further referring to FIG 3, there is provided an exploded schematic view of the flexible guidance and precise positioning mechanism shown in FIG 2. The distal end **21** has a circular configuration for smooth movement within a body. It is to be noted that the present invention does not limit to any particular configuration. The distal end **21** has means for holding and securing the guide cables **6** and fibers **16** in-placed. As shown in FIG 4, there is provided an exemplary configuration of the distal end **21** in accordance with one embodiment of the present invention. The distal end **21** has channels for holding and securing four guide cables and four fibers in this instance. In addition, the distal end **21** also allows the fibers to illuminate the surroundings and acquire and output signals.

[0034] The proximal end **22** is integrally coupled with the outer layer of the elongated body **3**. The proximal end **22** can be formed with an open center so that all fibers can be passed through or with a plurality of small channels so that each fiber passes through one channel.

[0035] Still referring to FIGS 2 and 3, the flexible guidance and precise positioning mechanism **2** further comprises a plurality of holding means **24** for holding the guide cable onto the spring **23** and a sheath **25** for covering the spring **23** entirely. The sheath **25** is foldable so that when the spring is compressed, the sheath will be folded without being detrimental to the movement of the mechanism.

[0036] Now referring to FIGS 6A and 6B, there are provided schematic diagrams of the flexible guidance and precise positioning mechanism illustrating the operation of precise positioning in accordance with one embodiment of the present invention. The spring **23** can be compressed by the guide cables **6** so that the length of the spring **23** can be varied by variable compression. As mentioned above, many situations require that the distal end of the endoscopic device be strategically and uniquely positioned in exact and particular location in 3D space. For example, when the distal end of the endoscopic device has reached a location, the signal acquiring fiber may not be able to obtain clear images. It would be desirable to fine tune the position of the signal acquiring fiber. As shown in FIGS 6A and 6B, the spring has its natural free length L when it is fully relaxed, and its fully compressed length l ; thus the maximum distance that can be controlled by compressing the spring is $(L-l)$.

[0037] While the present invention has been described with reference to particular embodiments, it is understood that the embodiments are illustrative and that the invention

scope is not so limited as such. Alternative embodiments of the present invention will become apparent to those having ordinary skill in the art to which the present invention pertains. Such alternate embodiments are considered to be encompassed within the spirit and scope of the present invention. Accordingly, the scope of the present invention is described by the appended claims and is supported by the foregoing description

CLAIMS

What is claimed is:

1. A flexible guidance and precise positioning mechanism, comprising:
 - a spring having one distal end and one proximal end;
 - a distal means integrally coupled with the distal end of the spring;
 - a proximal means integrally coupled with the proximal end of the spring; and
 - a plurality of longitudinal control means having one distal end and one proximal end, wherein the plurality of longitudinal means are evenly positioned around the spring, and wherein each of the plurality of longitudinal control means is controllably coupled with the pitches of the spring;thereby when any of the plurality of longitudinal control means causes the spring to deflect in one direction, it provides guidance; and when the spring is compressed to a predetermined state by the plurality of longitudinal control means, the release of the compressed spring will cause a forward movement with a fixed length so that it achieves precise positioning.
2. The mechanism of claim 1, further comprising a flexible and compressible sheath covering the spring, reducing the friction at the interface between the mechanism and its surrounding environment.
3. The mechanism of claim 1, wherein the spring has a cylindrical configuration.
4. An endoscopic system, comprising:
 - an elongated body having a distal end and a proximal end;
 - a flexible guidance and precise positioning mechanism disposed at the distal end for providing flexible guidance and precise positioning to the endoscopic system; and
 - a control module disposed at the proximal end of the elongated body for controlling the directions and movements of the endoscopic system.

5. The endoscopic system of claim 4, further comprising a plurality of functional fibers disposed within the lumen of the elongated body, wherein the movements of the plurality of functional fibers are controlled by the control module.
6. The endoscopic system of claim 4, wherein the elongated body comprises segments of small polymerized spring elements in series.
7. The endoscopic system of claim 4, wherein the flexible guidance and precise positioning mechanism, comprising:
 - a spring having one distal end and one proximal end;
 - a distal means integrally coupled with the distal end of the spring;
 - a proximal means integrally coupled with the proximal end of the spring; and
 - a plurality of longitudinal control means having one distal end and one proximal end, wherein the plurality of longitudinal means are evenly positioned around the spring, and wherein each of the plurality of longitudinal control means is controllably coupled with the pitches of the spring;thereby when any of the plurality of longitudinal control means causes the spring to deflect in one direction, it provides guidance; and when the spring is compressed to a predetermined state by the plurality of longitudinal control means, the release of the compressed spring will cause a forward movement with a fixed length so that it achieves precise positioning.
8. The endoscopic system of claim 7, further comprising a sheath covering the spring, reducing the friction at the interface between the mechanism and its surrounding environment.
9. The endoscopic system of claim 7, wherein the spring has a cylindrical configuration.
10. The endoscopic system of claim 4, wherein the control module comprises a guide controller operably coupled with the elongated body via a channel embedded with a

plurality of guide cables, where the guide controller operates on the flexible guidance and precise positioning mechanism through the plurality of guide cables.

11. The endoscopic system of claim 10, wherein the control module further comprises a connection operably coupled with an electronic motion controller via a controller cable to control the manipulating forces for the movement of the elongated body.

12. The endoscopic system of claim 11, wherein the control module further comprises an illumination source via an illumination cable to provide illumination for imaging the pathway and checking site.

13. The endoscopic system of claim 11, wherein the electronic motion controller is a remote wireless control system.

14. A process for flexible guidance and precise positioning, said process comprising the following of:

providing a spring disposed at a distal end of a movable object;

providing a plurality of controlling cables, wherein one end of the plurality of controlling cables is operably coupled with the spring and the other end is operably coupled with a remote controller;

causing the spring to deflect in one direction by pulling one or two of the controlling cables so as to provide flexible guidance for the moving object; and

precise positioning the movable object by releasing the spring from a preloaded state.