

HAPTIC INPUT DEVICE FOR REMOTE SURGICAL INSTRUMENTS

TECHNICAL FIELD

[0001] The present invention relates generally, but not exclusively, to a haptic input device for remote surgical instruments.

BACKGROUND OF THE DISCLOSURE

[0002] Remote surgical instruments are generally used in minimally invasive surgery which allow surgeons to operate on patients with less damage to the body, leading to less pain, and fewer complications. An example of a minimally invasive surgery is endoscopy, where cameras and surgical instruments are passed through small incisions into the body via small narrow tubes for surgeons to operate. The cameras and surgical instruments are connected to a console or a control module with hand and foot controls that allow the surgeon to remotely and precisely control the surgical instruments. The cameras provide the surgeon a magnified view of the operative field inside the patient on a high-definition visual display at the control module. The surgeon is usually assisted by a system operator who can control the instruments' other functions so that the surgeon can focus on the surgical procedure.

[0003] Current controllers at the control module include input devices that provide force-feedback information on the motion and/or force input by the surgeon. However, current input devices have pinching mechanisms to control the surgical instruments, such as the gripping action of a grasper. This may cause difficulties in cleaning the pinching mechanisms of the input device as cleanliness is an important factor in the operating environment.

[0004] Further, current controllers do not have the option to lock movement in various degrees of freedom when in use, which increases the risk of undesired accidental movement of the surgical instrument and may injure the patient. Unintentional motion of the controllers

caused by accidental knocking can also lead to undesired movement of the surgical instruments and thus increases the risk of injury to the patient.

[0005] Thus, what is needed is a haptic input device for remote surgical instruments that overcomes the above drawbacks. Furthermore, other desirable features and characteristics will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and this background of the disclosure.

SUMMARY

[0006] According to a first aspect of the present invention, there is provided a haptic input device for a remote surgical instrument comprising: a handle portion having at least an area configured to contact a user's hand, the handle portion configured to be rotatable about its vertical axis, wherein movements of the handle portion about a horizontal pitch axis are constrained confining the handle portion into a constant pitch orientation; a trigger mechanism having a trigger operatively coupled to the handle portion and configured to activate or deactivate the remote surgical instrument by displacement of the trigger; a wrist mechanism coupled to the handle portion and operatively connected to the remote surgical instrument to control a yaw of the remote surgical instrument at a distal end, wherein the wrist mechanism is adapted to maintain the pitch orientation of the handle portion about the horizontal pitch axis; and one or more sensors disposed on a surface of the handle portion, the one or more sensors configured to gather sensor data to determine a presence of the user's hand based on the sensor data.

[0007] In an embodiment, the wrist mechanism comprises locking means to selectively lock the handle portion at a roll orientation of the remote surgical instrument.

[0008] In an embodiment, the wrist mechanism is further configured to selectively restrain movement of the handle portion to one degree of freedom.

[0009] In an embodiment, the haptic input device further comprises an array of operational buttons disposed on the handle portion, the array of operational buttons being located to enable operation by a digit of the user's hand when the user's hand is in contact with the handle portion.

[0010] In an embodiment, the array of operational buttons is operable when a digit of the user's hand is in contact with the trigger.

[0011] In an embodiment, the array of operational buttons is configured to control one or more functions of the remote surgical instrument.

[0012] In an embodiment, the trigger mechanism is biased in the deactivated position of the remote surgical instrument.

[0013] In an embodiment, the trigger is disposed on the handle portion.

[0014] In an embodiment, the haptic input device further comprises one or more actuators coupleable to the remote surgical instrument to generate force feedback to the user via the handle portion and/or the wrist mechanism and/or the trigger.

[0015] In an embodiment, the force feedback comprises a force constraint based on a position error between a position of the haptic input device in a master workspace and the remote surgical instrument in a slave workspace.

[0016] In an embodiment, displacement of the trigger comprises movement of the trigger in a linear direction that is substantially perpendicular to the vertical axis of the handle portion.

[0017] In an embodiment, the one or more sensors is configured to determine the presence of the user's hand on the handle portion and/or the trigger based on the sensor data.

[0018] In a second aspect of the present invention, there is provided a method of manufacturing a haptic input device for a remote surgical instrument, the method comprising:

providing a handle portion having at least an area configured to contact a user's hand, the handle portion configured to be rotatable about its vertical axis, wherein movements of the handle portion about a horizontal pitch axis are constrained confining the handle portion into a constant pitch orientation; disposing a trigger mechanism having a trigger operatively coupled to the handle portion, the trigger mechanism configured to activate or deactivate the remote surgical instrument by displacement of the trigger; coupling a wrist mechanism to the handle portion; operatively connecting the wrist mechanism to the remote surgical instrument to control a yaw of the remote surgical instrument at a distal end, wherein the wrist mechanism is adapted to maintain the pitch orientation of the handle portion about the horizontal pitch axis; and disposing one or more sensors on a surface of the handle portion, the one or more sensors configured to gather sensor data to determine a presence of the user's hand based on the sensor data.

[0019] In an embodiment, connecting the wrist mechanism to the remote surgical instrument further comprises selectively restraining movement of the handle portion to one degree of freedom.

[0020] In an embodiment, the method further comprises disposing an array of operational buttons on the handle portion, the array of operational buttons being located to enable operation by a digit of the user's hand when the user's hand is in contact with the handle portion.

[0021] In an embodiment, disposing the array of operational buttons on the handle portion further comprises controlling one or more functions of the remote surgical instrument.

[0022] In an embodiment, disposing the trigger mechanism on the handle portion further comprises biasing the trigger mechanism in the deactivated position of the remote surgical instrument.

[0023] In an embodiment, disposing the trigger mechanism comprises disposing the trigger on the handle portion.

[0024] In an embodiment, the method further comprises coupling one or more actuators to the remote surgical instrument to generate force feedback to the user via the handle portion and/or the wrist mechanism and/or the trigger.

[0025] In an embodiment, generating the force feedback comprises providing a force constraint based on a position error between a position of the haptic input device in a master workspace and the remote surgical instrument in a slave workspace.

[0026] In an embodiment, disposing one or more sensors on the surface of the handle portion comprises determining the presence of the user's hand on the handle portion and/or the trigger based on the sensor data.

[0027] In a third aspect of the present invention, there is provided an endoscope system comprising the haptic input device according to the first aspect and a control module, wherein the haptic input device is operatively coupled to the control module to control a remote surgical instrument.

[0028] In an embodiment, the remote surgical instrument comprises a proximal end and a distal end, the proximal end configured to be detachably coupled to the control module.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] The accompanying figures, where like reference numerals refer to identical or functionally similar elements throughout the separate views and which together with the detailed description below are incorporated in and form part of the specification, serve to illustrate various embodiments and to explain various principles and advantages in accordance with present embodiments.

[0030] Figs. 1A and 1B show side perspective views of a haptic input device for a remote surgical instrument in accordance with a present embodiment.

[0031] Fig. 2 shows a side view of the haptic input device of Fig. 1A in accordance with the present embodiment.

[0032] Fig. 3 shows a close-up view of the trigger mechanism of the haptic input device of Fig. 1A in accordance with the present embodiment.

[0033] Figs. 4A and 4B show top views of the haptic input device of Fig. 1A in accordance with the present embodiment.

[0034] Fig. 5A shows a perspective view of a Surgeon Console Unit (SCU) with the haptic input device of Fig. 1A in accordance with the present embodiment.

[0035] Fig. 5B shows a perspective view of an endoscope system with the SCU of Fig. 5A in accordance with the present embodiment.

[0036] Fig. 6A shows a perspective side view of the haptic input device of Fig. 1A connected to a base mechanism in accordance with the present embodiment.

[0037] Fig. 6B shows a rear view of the haptic input device and base mechanism of Fig. 6A in accordance with the present embodiment.

[0038] Fig. 7A shows a side view of a remote surgical instrument in accordance with the present embodiment.

[0039] Fig. 7B shows a flowchart illustrating communication between a master section and a slave section of an endoscope system in accordance with the present embodiment.

[0040] Figs. 7C and 7D show schematic diagrams illustrating how a change in position of the haptic device of Fig. 1A leads to a change in position of the remote surgical instrument of Fig. 7A.

[0041] Fig. 8 shows a flowchart illustrating a method of configuring the haptic input device of Fig. 1A to an existing endoscope system in accordance with the present embodiment.

[0042] Fig. 9 shows a flowchart illustrating a method of manufacturing a haptic input device for a remote surgical instrument in accordance with the present embodiment.

[0043] Example embodiments of the invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings. The drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention.

DETAILED DESCRIPTION

[0044] In the following description, various embodiments are described with reference to the drawings, where like reference characters generally refer to the same parts throughout the different views.

[0045] Figs. 1A and 1B show side perspective views of a haptic input device 100 for a remote surgical instrument in accordance with a present embodiment. The haptic input device 100 includes a handle portion 102 having at least an area 104 configured to contact a user's hand. The handle portion 102 is configured to be rotatable about its vertical axis 106 and movements of the handle portion 102 about a horizontal pitch axis (not shown) are constrained confining the handle portion 102 into a constant pitch orientation. The haptic input device 100 also includes a trigger mechanism 108 having a trigger 110 operatively coupled to the handle portion 102 and configured to activate or deactivate the remote surgical instrument by displacement of the trigger 110. A detailed description of the trigger mechanism 108 will be described in Fig. 3 below. The haptic input device 100 includes a wrist mechanism coupled to the handle portion 102 and operatively connected to the remote surgical instrument to control a yaw of the remote surgical instrument at a distal end. The wrist mechanism is also adapted to maintain the pitch orientation of the handle portion 102 about the horizontal pitch axis. A detailed description of the wrist mechanism

will be described in Figs. 4A to 4B below. The haptic input device 100 also includes one or more sensors 112 (as shown in Fig. 1B) disposed on a surface of the handle portion 102. The one or more sensors 112 may be configured to gather sensor data to determine a presence of the user's hand based on the sensor data.

[0046] The device 100 can maneuver in three degrees-of-freedom for three-dimensional positioning and a one degree-of-freedom movement when controlling the yaw of the remote surgical instrument. The device 100 can have an additional degree-of-freedom movement when controlling the roll of the remote surgical instrument. The trigger 110 may be displaced with a one degree-of-freedom movement. The device 100 may be a position-input device that can move in a Cartesian Space and one or multiple joint spaces. The device 100 may also be able to change configuration to suit the type of remote surgical instrument to be controlled.

[0047] Fig. 2 shows a side view of the haptic input device 100 of Fig. 1A in accordance with the present embodiment. As shown in Fig. 2, the device 100 may include a base 202 which the handle portion 102 can be removably mounted thereon. A wrist joint or wrist yaw joint (not shown) may be provided as connecting means between the handle portion 102 and the base 202. The base 202 may include a wall 204. The wall 204 may contain one or more actuators to move the trigger 108 or lock the handle portion 102. Having one or more actuators in the wall 204 can reduce the temperature of the handle portion 102. The handle portion 102 may include a lower border having an overhanging circular portion 206 positioned above a raised circular ridge 208 of the base 202. The resulting gap shape can reduce the risk of small liquid quantities, e.g. liquid from the user's hands, entering the wrist joint. The handle portion 102 may be manufactured using machining before it is painted to reduce gaps between mating parts (e.g., an array of operational buttons) and to obtain accurate edges around recessed portions.

[0048] As shown in Fig. 1B and Fig. 2, the one or more sensors 112 may be disposed in a through hole of the handle portion 102. The one or more sensors 112 can be an optical sensor that is configured to gather sensor data to determine the presence of the user's hand on the handle portion 102 and/or the trigger 110 based on the obtained sensor data. The one or more sensors 112 can allow activation of the device 100 only after a positive determination of the presence of the user's hand, regardless if the user is wearing gloves or not wearing gloves. The one or more sensors 112 can ensure that any accidental motion on the device 100 would not be transferred to the remote surgical instrument when the user has no intention to remotely control the surgical instruments. As such, unintended motion of the device 100 or otherwise would not cause movement of the remote surgical instrument. This can reduce the risk of accidental motion of the remote surgical instrument which may cause injury to the patient.

[0049] In an implementation, the one or more sensors 112 may detect the presence of the user's thumb and index finger on the area 104 of the handle portion 102 to improve safety. The one or more sensors 112 can be mounted on a curved rectangular plate (not shown) and disposed in a Velcro loop of the device 100. The height of the Velcro loop can be adjustable, and a user's finger can be fitted after the one or more sensors 112 is mounted on the plate. The one or more sensors 112 may detect the presence of a user's thumb and index finger on the device 100. Detection of the finger presence can be achieved even when the user wears medical gloves. The one or more sensors 112 can function normally without interference even with the presence of an electrosurgical unit and can be cleaned easily (e.g., by anti-septic wipes) and not affect their functionality.

[0050] In Figs. 1B and 2, the device 100 is configured to be operated using a user's left hand. As such, the one or more sensors 112 is angled outwards and located at the handle portion 102 facing a palm of the user's left hand. In this way, the user's hand remains in contact with the handle portion 102 when the user operates the trigger mechanism 108 or operates an

array of buttons positioned on the handle portion 102 (shown in Figs. 4A and 4B). It can be appreciated that the device 100 can be configured to be operated using a user's right hand and the one or more sensors 112 on the device 100 is angled outwards facing the palm of the user's right hand. The device 100 configured to be operated using a user's right hand is symmetrical to the design of the device 100 configured to be operated using a user's left hand.

[0051] A sticker (not shown in the Figures) may be provided on the handle portion 102 to cover a removable internal window member that allows direct access to the one or more sensors 112 during manufacturing and maintenance. The sticker can have a transparent circular section for the one or more sensors 112. The sensitivity of the one or more sensors 112 can be individually predetermined for each device 100 to detect handle release of the user's hand at a distance between 5 mm and 10 mm from the area 104. This distance takes into account the size of a human hand. The detection time of the one or more sensors 112 can be below 0.1 second. The one or more sensors 112 may have an active optical operating principle to provide consistent results even with different skin types and when the user's hand wears common surgical gloves.

[0052] The one or more sensors 112 may include a vertical support member which holds a hand detection printed circuit board (PCB) and located internally within the handle portion 102. The one or more sensors 112 can be mechanically secured to the hand detection PCB to prevent any misalignment over time. In an embodiment, a second PCB may be provided which includes a plurality of connectors for connection to an array of buttons, an actuator, a position sensor and a device control unit connection cable. The second PCB may be connected to the hand detection PCB by means of a flexible PCB. This may allow the mounting of the hand detection PCB and the second PCB with an angular offset to the vertical support member to fit in the tight space between the actuator and an inner surface of the handle portion 102. An inner layer

of transparent plastic sheet shielding may be provided within the handle portion 102 to fulfil Electrostatic Discharge (ESD) requirements.

[0053] Fig. 3 shows a close-up view of the trigger mechanism 108 of the haptic input device 100 of Fig. 1A in accordance with the present embodiment. In the Figure, the trigger mechanism 108 includes a trigger 110 disposed and operatively coupled to the handle portion 102. The trigger 110 can be displaced linearly to control a remote surgical instrument. The displacement of the trigger 110 may include moving the trigger 110 in a linear direction 302 that is substantially perpendicular to the vertical axis 106 of the handle portion 102. In an embodiment, linear movement 302 of the trigger 110 may control a pinching motion of the remote surgical instrument, for example a grasper. Therefore, by moving the trigger 110 forwards and backwards using the user's index finger, the trigger mechanism 110 can open and close the grasper. The trigger mechanism 108 may also electromechanically lock a pinching point of the remote surgical instrument.

[0054] The trigger mechanism 108 may include a passive locking mechanism, such that the trigger mechanism 108 is biased in the deactivated position of the remote surgical instrument. In an implementation, the trigger mechanism 108 may be mechanically constrained by a spring (not shown) when deactivated, thereby defining a naturally closed state or default position. An external force acts against the spring force to activate the trigger mechanism 108 by applying a force in a direction opposite to the spring force in order to compensate it. The external force may be a force exerted on the trigger mechanism 108 by an actuator to push the trigger 110 outwards from the handle portion 102 when in use, thereby unlocking the trigger 110 to activate control of the remote surgical instrument. This may be achieved by using a spring mechanism such that the trigger joint is closed when the spring is unstretched and the trigger joint opens when a user compresses or extends the spring. It can be appreciated other mechanisms may be possible to achieve the above. The external force can be predetermined

and the position behavior of the trigger 110 can be pre-programmed to suit the requirements of the remote surgical instrument. In an alternative embodiment, the trigger 110 may include overhanging ridges 306 that allows the user to pull it outwards (i.e., away from the handle portion 102) with two fingers during functional check and cleaning of the device 100. When pulled out manually, a spring force may pull the trigger 110 back towards the handle portion 102 to a default position. The trigger mechanism 108 may include shafts 308 made from high performance stainless steel to aid in the linear motion 302. The shafts 308 can have a mirror polished surface treatment for reduced friction and improved corrosion resistance.

[0055] As the trigger mechanism 108 has no pivot points and uses linear shafts, it can allow for easier and thorough cleaning of the mechanism while maintaining user intuitiveness at the same time. This may be of particularly importance as the device 100 is used regularly in surgical theatres and operating rooms where cleanliness is a top priority.

[0056] Figs. 4A and 4B show top views of the haptic input device 100 of Fig. 1A in accordance with the present embodiment. It can be appreciated that the device 100 shown in Fig. 4A can be adapted for use of a user's left hand while the device 100 shown in Fig. 4B can be adapted for use of a user's right hand. The haptic input device 100 includes a wrist mechanism coupled to the handle portion 102 and operatively connected to the remote surgical instrument to control a yaw of the remote surgical instrument at a distal end. The wrist mechanism may be disposed within the handle portion 102 or the base 202 and may include locking means to selectively lock the handle portion 102 at a position relative to its vertical axis 106 (as shown in Figs. 1A and 3). The wrist mechanism may be further configured to selectively restrain movement of the handle portion 102 to one degree of freedom, i.e., the handle portion 102 can only rotate about its vertical axis. The wrist mechanism may also maintain the pitch orientation of the handle portion 102 about the

horizontal pitch axis. In an embodiment, the handle portion 102 can also rotate about its roll axis to control the roll orientation of the remote surgical instrument. In a preferred embodiment, the rotational motion range of the handle portion 102 can be asymmetrical and takes into account the mounting angles of the base 202 as well as ergonomic requirements of the human hand. Each handle portion 102 can rotate outwards and inwards with respect to the base 202 in an asymmetrical fashion. For example and referencing Fig. 4A, the handle portion 102 may rotate up to 170° about its vertical axis. In this embodiment, the user holds the handle portion 102 using his left hand and rotates his wrist counter-clockwise up to 60° or clockwise up to 110° to control the yaw of the remote surgical instrument at the distal end.

[0057] The wrist mechanism may be electromechanically locked at the wrist yaw joint (an interface between the handle portion 102 and the base 202) when there is no corresponding yaw joint that does not exist in the remote surgical instrument. Locking and unlocking of the wrist yaw joint can be controlled using software. For example, when the handle portion 102 is to be locked, the software may rotationally drive the handle portion 102 to an angular lock position located closest to the current handle position and subsequently engages the lock. The angular lock positions of the handle portion 102 may be equally spaced and symmetrically distributed, starting from the centered position at 0° (or default position). In an embodiment, the lock positions of the handle portion 102 may be equally spaced by 12° .

[0058] The trigger 110 is mounted on each handle portion 102 and provides one translational degree-of-freedom with the user's index finger. A trigger joint (not shown) may be provided to connect the trigger 110 and the handle portion 102. The trigger's linear motion range may be 12 mm from a fully retracted position to a fully extended position (or default position). The trigger's linear motion range is advantageously based on the length of a typical human finger. The trigger 110 may be mechanically locked in the form

of shaft clips to secure two of the three shafts 308 (see Fig. 3) of the trigger mechanism 108 to the trigger 110.

[0059] In an embodiment, the device 100 adapted for the user's left-hand has degrees of freedom to control three-dimensional position and a wrist yaw joint while a second device 100 adapted for the user's right-hand may have three-dimensional position control and a trigger joint. As the device 100 adapted for the user's left hand is symmetrical to the device 100 adapted for the user's right hand, the type of joint (wrist yaw or trigger joint) can be used interchangeably. The trigger joint of the right-hand device 100 and the wrist yaw joint of the left-hand device 100 can be locked accordingly using electromechanical means. This can be achieved using a permanent magnet that can be mounted on a motor or using motors to hold the current position. In such an implementation, temperature of accessible areas may be 48 degrees Celsius or lower to avoid user discomfort during operation. Alternatively, mechanical locking can be used such that a lock switch includes a sensor to identify the degrees of freedom configuration of the device 100. The wrist mechanism may also include an actuator so that the haptic device 100 can auto-calibrate itself and also allows force feedback to be provided to the user at the wrist yaw joint.

[0060] The wrist mechanism can help to intuitively control the distal yaw motion of a remote surgical instrument and wrist movement of the device 100 can provide more intuitive control of the distal yaw motion of the remote surgical instrument. The ability to be locked at various orientations of the handle portion 102 reduces possibility of undesired accidental movement that may injure the patient.

[0061] The device 100 may include an array of operational buttons 402 disposed on the handle portion 102. The array of operational buttons 402 are located to enable operation by a digit of the user's hand when the user's hand is in contact with the handle portion 102. For example, the array of operational buttons 402 can be easily accessed by the user's thumb,

middle and/or ring fingers during operation. The array of operational buttons 402 can also be operable when a digit of the user's hand is in contact with the trigger 110. One of the arrays of operation buttons 402 may be located at the top of the handle portion 102 and a second button may be located on a large thumb rest pad on the inner side of the handle portion 102 as shown in the Figs. The array of operational buttons 402 may be configured to control one or more functions of the remote surgical instrument such as but not limited to air feeding, water feeding, and/or suction. A membrane may be included to cover the array of operational buttons 402 for cleaning. Each of the array of operational buttons 402 may be composed of a metal dome switch covered by a non-flammable plastic film overlay.

[0062] The device 100 may also include one or more actuators to generate force feedback to the user via the handle portion 102 and/or the wrist mechanism and/or the trigger 110. In other words, the user can receive force feedback when adjusting the device 100 for three-dimensional positioning, controlling the yaw of the remote surgical instrument and operating the pinching motion of the remote surgical instrument. In an example embodiment, the force feedback can be generated in Cartesian space of at least 6 N in every direction. The continuous torque of the device 100 in the wrist joint space can be at least 0.25 Nm along the vertical axis of the device 100 in both directions. The force feedback in the pinching joint space can be along the linear motion 302 in both directions.

[0063] Fig. 5A shows a perspective view of a Surgeon Console Unit (SCU) 500 with the haptic input device of Fig. 1A in accordance with the present embodiment. The SCU 500 includes the haptic input device 100 as previously described and a control module (not shown). The haptic input device 100 is operatively coupled to the control module to control a remote surgical instrument. As shown in the figure, the SCU 500 may include two haptic input devices 100 adapted for a left-hand and a right-hand respectively and may be controlled by a user (for example a surgeon) to manipulate the remote surgical instrument

at a remote site. In an implementation, the two haptic input devices 100 may be a bimanual pair of haptic device with each device controlling a different surgical instrument. In an implementation, the left haptic device may control a cautery instrument while the right haptic device may control a grasper instrument. In another implementation, the left haptic device may control a grasper instrument while the right haptic device may control a cautery instrument. It can be appreciated that other types of remote surgical instruments (e.g., needles, forceps and clamps) can also be controlled by a haptic device.

[0064] Fig. 5B shows a perspective view of an endoscope system 550 with the SCU of Fig. 5A in accordance with the present embodiment. The endoscope system 550 includes a surgical platform 502 adapted to hold a patient for endoscopy. The endoscope system 550 also includes a movable slave system 504 and the SCU 500 of Fig. 5A. The movable slave system 504 may include a transport endoscope 506 with a flexible elongate shaft and a docking station 508 to selectively couple with the transport endoscope 506. It can be appreciated that the slave system 504 may include other features to control and manipulate the transport endoscope as well as receiving commands from the SCU 500. For example, the slave system 504 may include but not limited to an imaging system, a valve control unit, an activation unit and / or a main control unit. The SCU 500 includes the haptic input device 100 as previously described.

[0065] Fig. 6A shows a perspective side view of the haptic input device 100 of Fig. 1A connected to a base mechanism 600 in accordance with the present embodiment. The base mechanism 600 may be interfaced to the control module 502 of Fig. 5 via a metal sheet back shroud or shrouds 602 and translationally moving the device 100. The haptic input device 100 may include a vertical base plate, a mechanical interface to the control module 502, passive gravity compensation means, a plurality of plastic and metal shrouds 602 and an electrical interface for printed circuit boards. The base plate of the device 100 may use a delta parallel kinematics structure that provides three active translational degrees of freedom to the device

100 for movements in three-dimensional Cartesian space with mechanically constrained constant orientation.

[0066] The device 100 and base mechanism 600 may be moved in a hemispherical translational workspace. The gravity compensation means may include a gravity compensation algorithm that takes into account the full weight of the device 100 and base mechanism 600 so that the device 100 can float freely without displaying any restoring forces. The SCU 500 may include a mechanical interface for connecting the device 100 to the control module 502. The mechanical interface may include an interface plate 604 (see Fig. 6B) that is permanently mounted on the control module 502. The device 100 can be installed on the interface plate 604 guided by pins (e.g., three) protruding the plate and secured in place by means of screws and washers (e.g., four).

[0067] Fig. 6B shows a rear view of the haptic input device 100 and base mechanism 600 of Fig. 6A in accordance with the present embodiment. The interface plate 604 plate may be mounted to the control module 502 using an asymmetrical pattern of three pins that protrude on both sides (above and below) to prevent incidental mis-mounting between the left-hand and right-hand devices 100. The electrical interface 606 of each device 100 may be located on the lower part at the back of the device 100 as shown in the Figure. A customized USB cable retainer may be included to prevent unintentional detachment of connection cables. The customized USB cable retainer may have two mating parts which are installed on the USB cable of the control module 502 by fastening screws. Two internal screws may be trapped within the USB cable retainer and accessible from the rear by a screwdriver to lock the retainer on the metal cover of the control module 502. The SCU 500 may also include a power cable securely attached to the device 100 using a threaded ring of a power connector.

[0068] Fig. 7A shows a side view of a remote surgical instrument 700 in accordance with the present embodiment. The remote surgical instrument 700 comprises a proximal end 702

and a distal end 704. The remote surgical instrument 700 is flexible and at least a portion of the remote surgical instrument 700 can be inserted into and withdrawn from the transport endoscope 506. The distal end 704 comprises a robot arm (not shown) and a corresponding end effector (not shown). The proximal end 702 is configured to be detachably coupled to a motor box (not shown). The remote surgical instrument 700 also comprises flexible control elements, tendon elements, or tendons by which the robot arm and the end effector can be positioned or manipulated in accordance with a predetermined number of Degrees Of Freedom (DOF). In a number of embodiments, the remote surgical instrument 700 can be disposable. The device 100 is configured to control a yaw and/or a roll at the distal end 704 of the remote surgical instrument 700. In alternate embodiments, a pitch orientation and translation of the remote surgical instrument 700 may be controlled by other means and/or devices.

[0069] Fig. 7B shows a flowchart 750 illustrating communication between a master section and a slave section of an endoscope system in accordance with the present embodiment. A user or surgeon 706 provides input to the master section 708, and the master section 708 and slave section 710 are configured for signal communication with each other such that the master section 708 can issue commands to the slave section 710 and the slave section 710 can precisely control, maneuver, manipulate, position, and/or operate, in response to master section inputs. The user or surgeon 706 provides input to the master section 708 by manipulating the haptic input device 100. A signal resulting from movement of the haptic input device 100 is transmitted to the slave section 710 via communication between the master control module and the slave control module 502. Upon receiving the signal at the slave control module 502, a motion controller sends commands to a motor box and controls the one or more actuators housed within the motor box. In turn, the one or more actuators act to control, maneuver, manipulate, position, and/or operate the remote surgical instrument 700.

[0070] Figs. 7C and 7D show schematic diagrams illustrating how a change in position of the haptic device of Fig. 1A leads to a change in position of the remote surgical instrument of Fig. 7A. As described above, when the haptic input device 100 is moved by a user or surgeon 706, a signal is transmitted from the master section 708 and received by the slave section 710. The signal provides a Cartesian position in a master workspace **P** to which the haptic input device 100 has been moved. This master workspace **P** provides a boundary within which the haptic input device 100 can be moved, i.e., the master workspace **P** stores all possible positions of the haptic input device 100. The received Cartesian position is processed against a database (not shown) that comprises Cartesian positions for the master workspace **P**. Cartesian positions for a slave workspace **Q** providing a boundary within which the remote surgical instrument 700 can be actuated and a mapping table (not shown) that maps each Cartesian position in the master workspace **P** to at least one Cartesian position in the slave workspace. In an embodiment, the master workspace is generally larger than the slave workspace **Q**. As shown in Fig. 7C, when the user or surgeon moves the haptic input device 100 within the master workspace **P** which coincides with the slave workspace **Q**, the position 712 of the haptic input device 100 will be identical to the position of the remote surgical instrument 700. Accordingly, there is no constraining force applied to the user or surgeon.

[0071] On the other hand, when the user or surgeon moves the haptic input device 100 such that the master workspace **P** is outside of slave workspace **Q**, the position 714 of the haptic input device 100 will be projected onto the slave workspace **Q**. In an embodiment and as shown in Fig. 7D, the position 714 of the haptic input device 100 can be projected onto the slave workspace **Q** at the nearest point 716 on the boundary of the slave workspace **Q**. This leads to a position ‘error’ between the position 714 of the haptic input device 100 in the master workspace **P** and the remote surgical instrument 700 in the slave workspace **Q**. In such a circumstance, the haptic input device 100 can provide a force feedback to alert the user or

surgeon that the haptic input device 100 is outside of the slave workspace **Q**. The position 'error' between the position 714 of the haptic input device 100 in the master workspace **P** and the remote surgical instrument 700 in the slave workspace **Q** can be used to calculate the force (for example, Force = - spring constant k multiplied by displacement x) to be fed back to the user via the haptic input device 100. The force feedback can be in the form of force constraints such as a virtual spring force although other forms can also work.

[0072] Fig. 8 shows a flowchart illustrating a method of configuring the haptic input device 100 of Fig. 1A to an existing endoscope system in accordance with the present embodiment. At step 802, a remote surgical instrument is attached to a Motor Box and connects to the endoscope system. At step 804, the system detects and recognizes the type of remote surgical instrument by communicating with and retrieving information from a chip in a surgical instrument adapter. In an implementation, two types of remote surgical instruments may be used with the system, a grasper instrument and a cautery instrument, which have different mechanical structures from one another. The grasper instrument provides a pinching (or jaw) mechanism and the cautery instrument offers a wrist joint while both instruments have the base yaw and pitch joints. Based on this difference, the system can identify the type of remote surgical instrument at steps 806 and 808. After a positive identification of the type of instrument, the configuration data of the remote surgical instrument can be sent from the Motor Box to the device 100 (or Surgeon Control Manipulator) at step 810 so that the system can activate relevant joints of the device 100 and deactivate unnecessary joints depending on the configuration. In this way, the device 100 can automatically calibrate itself upon boot-up of the system without much user intervention. It can be appreciated that other types of remote surgical instruments (e.g., needles, forceps and clamps) can be used with the system. The system can identify the other types of remote surgical instruments according to the different configurations of the remote surgical instruments in a similar way.

[0073] Fig. 9 shows a flowchart illustrating a method of manufacturing a haptic input device 100 for a remote surgical instrument in accordance with the present embodiment. At step 902, the method includes providing a handle portion having at least an area configured to contact a user's hand, the handle portion configured to be rotatable about its vertical axis, wherein movements of the handle portion about a horizontal pitch axis are constrained confining the handle portion into a constant pitch orientation. At step 904, the method includes disposing a trigger mechanism having a trigger operatively coupled to the handle portion, the trigger mechanism configured to activate or deactivate the remote surgical instrument by displacement of the trigger. At step 906, the method includes coupling a wrist mechanism to the handle portion. At step 908, the method includes operatively connecting the wrist mechanism to the remote surgical instrument to control a yaw of the remote surgical instrument at a distal end, wherein the wrist mechanism is adapted to maintain the pitch orientation of the handle portion about the horizontal pitch axis. At step 910, the method includes disposing one or more sensors on a surface of the handle portion, the one or more sensors configured to gather sensor data to determine a presence of the user's hand based on the sensor data.

[0074] The haptic input device 100 as described herein can allow easier and better cleaning and still maintains user intuitiveness. The haptic input device 100 can be locked at various orientations and thus may reduce the possibility of undesired accidental movement that may injure the patient. The haptic input device 100 can allow configurability such that the device can be used with a variety of instruments. An array of operational buttons on the haptic input device 100 are located in positions within reaching distance of user's thumbs for better usability and can be cleaned effectively. The haptic input device 100 may also allow the user to control the necessary endoscopy functions remotely and gives the user better control of the remote surgical instrument. Priority algorithms in the haptic input device 100 can reduce occurrences

where the endoscopy functions are activated by both surgeons and system operator. The haptic input device 100 can also ensure that unintended motion would not cause movement of the remote surgical instruments which may cause harm to the patient.

[0075] It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the embodiments without departing from a spirit or scope of the invention as broadly described. The embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

CLAIMS

What is claimed is:

1. A haptic input device for a remote surgical instrument comprising:
 - a handle portion having at least an area configured to contact a user's hand, the handle portion configured to be rotatable about its vertical axis, wherein movements of the handle portion about a horizontal pitch axis are constrained confining the handle portion into a constant pitch orientation;
 - a trigger mechanism having a trigger operatively coupled to the handle portion and configured to activate or deactivate the remote surgical instrument by displacement of the trigger;
 - a wrist mechanism coupled to the handle portion and operatively connected to the remote surgical instrument to control a yaw of the remote surgical instrument at a distal end, wherein the wrist mechanism is adapted to maintain the pitch orientation of the handle portion about the horizontal pitch axis; and
 - one or more sensors disposed on a surface of the handle portion, the one or more sensors configured to gather sensor data to determine a presence of the user's hand based on the sensor data.
2. The haptic input device of claim 1, wherein the wrist mechanism comprises locking means to selectively lock the handle portion at a roll orientation of the remote surgical instrument.
3. The haptic input device of claim 2, wherein the wrist mechanism is further configured to selectively restrain movement of the handle portion to one degree of freedom.

4. The haptic input device of claim 1, further comprising an array of operational buttons disposed on the handle portion, the array of operational buttons being located to enable operation by a digit of the user's hand when the user's hand is in contact with the handle portion.

5. The haptic input device of claim 4, wherein the array of operational buttons is operable when a digit of the user's hand is in contact with the trigger.

6. The haptic input device of claim 5, wherein the array of operational buttons is configured to control one or more functions of the remote surgical instrument.

7. The haptic input device of claim 1, wherein the trigger mechanism is biased in the deactivated position of the remote surgical instrument.

8. The haptic input device of claim 1, wherein the trigger is disposed on the handle portion.

9. The haptic input device of claim 1, further comprising one or more actuators coupleable to the remote surgical instrument to generate force feedback to the user via the handle portion and/or the wrist mechanism and/or the trigger.

10. The haptic input device of claim 9, wherein the force feedback comprises a force constraint based on a position error between a position of the haptic input device in a master workspace and the remote surgical instrument in a slave workspace.

11. The haptic input device of claim 1, wherein displacement of the trigger comprises movement of the trigger in a linear direction that is substantially perpendicular to the vertical axis of the handle portion.

12. The haptic input device of claim 1, wherein the one or more sensors is configured to determine the presence of the user's hand on the handle portion and/or the trigger based on the sensor data.

13. A method of manufacturing a haptic input device for a remote surgical instrument, the method comprising:

providing a handle portion having at least an area configured to contact a user's hand, the handle portion configured to be rotatable about its vertical axis, wherein movements of the handle portion about a horizontal pitch axis are constrained confining the handle portion into a constant pitch orientation;

disposing a trigger mechanism having a trigger operatively coupled to the handle portion, the trigger mechanism configured to activate or deactivate the remote surgical instrument by displacement of the trigger;

coupling a wrist mechanism to the handle portion;

operatively connecting the wrist mechanism to the remote surgical instrument to control a yaw of the remote surgical instrument at a distal end, wherein the wrist mechanism is adapted to maintain the pitch orientation of the handle portion about the horizontal pitch axis;
and

disposing one or more sensors on a surface of the handle portion, the one or more sensors configured to gather sensor data to determine a presence of the user's hand based on the sensor data.

14. The method of claim 13, wherein the wrist mechanism comprises locking means to selectively lock the handle portion at a roll orientation of the remote surgical instrument.

15. The method of claim 13, wherein connecting the wrist mechanism to the remote surgical instrument further comprises selectively restraining movement of the handle portion to one degree of freedom.

16. The method of claim 13, further comprising disposing an array of operational buttons on the handle portion, the array of operational buttons being located to enable operation by a digit of the user's hand when the user's hand is in contact with the handle portion.

17. The method of claim 16, wherein the array of operational buttons is operable when a digit of the user's hand is in contact with the trigger.

18. The method of claim 16, wherein disposing the array of operational buttons on the handle portion further comprises controlling one or more functions of the remote surgical instrument.

19. The method of claim 13, wherein disposing the trigger mechanism on the handle portion further comprises biasing the trigger mechanism in the deactivated position of the remote surgical instrument.

20. The method of claim 13, wherein disposing the trigger mechanism comprises disposing the trigger on the handle portion.

21. The method of claim 13, further comprising coupling one or more actuators to the remote surgical instrument to generate force feedback to the user via the handle portion and/or the wrist mechanism and/or the trigger.

22. The method of claim 21, wherein generating the force feedback comprises providing a force constraint based on a position error between a position of the haptic input device in a master workspace and the remote surgical instrument in a slave workspace.

23. The method of claim 13, wherein displacement of the trigger comprises moving the trigger in a linear direction that is substantially perpendicular to the vertical axis of the handle portion.

24. The method of claim 13, wherein disposing one or more sensors on the surface of the handle portion comprises determining the presence of the user's hand on the handle portion and/or the trigger based on the sensor data.

25. An endoscope system comprising:
the haptic input device of any one of claims 1-12; and

a control module;

wherein the haptic input device is operatively coupled to the control module to control a remote surgical instrument.

26. The endoscope system of claim 25, wherein the remote surgical instrument comprises a proximal end and a distal end, the proximal end configured to be detachably coupled to the control module.