159159

An Apparatus for guiding a Surgical Instrument

Field of the invention

The present invention relates to a surgical instrument guidance apparatus for guiding a surgical instrument.

Background of the Invention

In the surgical industry, there is often a need to position a surgical tool or an instrument in relation to a target in a human body to perform a surgical procedure. This need arises in the field of traditional drug injection, acupuncture treatment and advanced minimal invasive surgery. At the time being, most of such surgical procedures are carried out manually or are carried out using simple tools which do not provide sufficient precision. Furthermore, it is difficult to reach deep targets inside a patient's body using these simple tools alone.

With the help of modern technologies, it is now possible to view, diagnose and treat some small but important targets inside a patient's body through a small hole on the surface of the patient's body. Furthermore, in recent years, there has been an increase in the number of complex medical procedures carried out by means of needles, for example medical procedures for the delivery of medicine and radiation seeds to organs in a patient's body, medical procedures for carrying laser fibers to a tumor site in a patient's body to perform an ablate procedure, medical procedures to obtain tissue and liquid samples from important organs in a patient's body and medical procedures to perform acupuncture treatment with a system plan for multi-positioning of the acupuncture tools inside a patient's body. However, it is difficult to achieve satisfactory results in these medical procedures using the current needling procedures. There is thus a need to provide a new and useful needling procedure that will act as an effective minimal invasive procedure for diagnosis and treatment.

G00002

Summary of the invention

The present invention aims to provide an apparatus for guiding a surgical instrument.

In general terms, a first aspect of the present invention proposes a surgical instrument guidance apparatus used to define the path of an elongate surgical instrument (which is typically a portion of a larger surgical tool, e.g. one also having a handle). The apparatus includes a device guiding mechanism for defining a longitudinal path along which the surgical instrument is to be moved along its length direction (when the apparatus is in use, e.g. in surgery, the instrument may be manually moved along this path, or a drive mechanism may be provided to drive it along the path). The guidance apparatus includes two mechanisms which independently control two degrees of freedom in the position of the device guiding mechanism relative to a central axis of the apparatus which, in use, is to be directed generally towards the subject of the surgery: (i) a device swing mechanism which sets an angle between the longitudinal path and the central axis; and (ii) a device rotator which sets the rotational position of the longitudinal path about that central axis. In other words, using the device rotator the longitudinal path can sweep out a conical surface about the central axis, the semi-vertical angle of that cone being selected using the device swing mechanism. Thus, the apparatus manipulates the longitudinal path according to conical coordinates.

A second aspect of the invention proposes in general terms that a device guiding mechanism for guiding a surgical instrument along a longitudinal path includes two tubular sheaths: an inner sheath for insertion into an end of the outer sheath.

Thus, the device guiding mechanism can be used, for example in an apparatus according to the first aspect of the invention, and provides an easily cleaned or

disposable device guiding mechanism, making it possible to perform surgical or other procedures without adequate sterilization.

A depth control mechanism may be provided to control the degree of telescoping of the two sheaths. One of the depth control mechanism and the device guiding mechanism may be provided with a stopper for bearing on a surface of the surgical tool which comprises the surgical instrument, and thereby limiting the movement of the instrument along the path defined by the device guiding mechanism.

The surgical instrument may be an instrument used for laparoscopic surgery, a biopsy gun used for incision biopsy or an instrument used in diagnostic and treatment procedures performed through a small key-hole on the patient's body. The apparatus may be used for moving the surgical instrument or tool to a target in three-dimensional space through a small pin hole which can range from 0.5mm to 20mm in diameter.

The apparatus may be used in the following applications.

(a) Moving a solid needle towards a targeted position for acupuncture treatment.

(b) Moving a hollow needle towards a targeted position to deliver drugs for treatment of a disease, for example, to deliver radiation seeds to the prostrate gland for focal therapy.

(c) Manipulating an injector to perform programmable vein injection or fine needle aspiration biopsy.

(d) Manipulating an instrument for minimal invasive treatment, for example, an instrument for laparoscopic surgery.

(e) Manipulating a biopsy needle to perform a targeted incision biopsy for an organ in a human body or a saturation biopsy.

(f) Providing guidance for the position of a biopsy device in a 3D space

Brief Description of the Figures

An embodiment of the invention will now be illustrated for the sake of example only with reference to the following drawings, in which:

Fig. 1(a) is a perspective view of an apparatus according to an embodiment of the present invention and Fig. 1(b) is a cross-sectional top view of a portion of the apparatus of Fig. 1(a);

Fig. 2(a) is a perspective view of a device rotator of the apparatus of Fig. 1(a), Fig. 2(b) is a cross-sectional side view of the device rotator of Fig. 2(a) and Fig. 2(c) is a cross-sectional back view of the device rotator of Fig. 2(a);

Fig. 3(a) is a cut away perspective view of a device swing mechanism of the apparatus of Fig. 1(a), Fig. 3(b) is a cross-sectional side view of the device swing mechanism of Fig. 3(a) and Fig. 3(c) is a cross-sectional top view of the device swing mechanism of Fig. 3(a);

Fig. 4(a) is a perspective view of a device guiding mechanism of the apparatus of Fig. 1(a), and Fig. 4(b) is a cross-sectional side view of the device guiding mechanism of Fig. 4(a);

Fig. 5(a) is a perspective view of a device depth control mechanism of the apparatus of Fig. 1(a), and Fig. 5(b) is a cross-sectional side view of the device depth control mechanism of Fig. 5(a);

Fig. 6(a) is a perspective view of a device positioning frame of the apparatus of Fig. 1(a), Fig. 6(b) is an example ultrasound probe which may be placed on the device positioning frame of Fig. 6(a), and Fig. 6(c) is a cross-sectional side view of the device positioning frame of Fig. 6(a);

Fig. 7(a) is a perspective view of a device controller of the apparatus of Fig. 1(a), and Fig. 7(b) is a cross-sectional top view of the device controller of Fig. 7(a);

Fig. 8 is an overview of the components of the device controller of Fig. 7(a); and

Fig. 9 is an example of using the apparatus of Fig. 1(a) with the example ultrasound probe of Fig. 6(b) for breast biopsy.

Detailed Description of the Embodiments

An apparatus 100 which is an embodiment of the invention will now be described with reference to Figs. 1 – 10. The apparatus 100 serves to guide an elongate surgical instrument (not shown), which may be an elongate portion of a surgical tool further comprising a handle for moving the surgical instrument along a path defined by the apparatus 100.

Fig. 1(a) is a perspective view of the apparatus 100 whereas Fig. 1(b) is a cross-sectional top view of a portion of the apparatus 100.

The apparatus 100 comprises an elongate, generally-tubular device guiding mechanism 106 in the form of a slide sheath for defining a longitudinal path for the surgical instrument. The slide sheath serves to maintain the movement of the surgical instrument along a straight line which is the length direction of the device guiding mechanism; in other words, serves to keep the surgical instrument in a straight trajectory. The slide sheath also serves to provide a sterilized environment for the surgical instrument to avoid cross infection.

As illustrated in Fig. 1(a), the longitudinal path defined by the device guiding mechanism 106 lies along a central axis 116 of the apparatus 100, but as described below it can be displaced from the central axis 116. The device guiding mechanism 106 passes through a fulcrum 214 which lies on the central axis 116.

The apparatus 100 further comprises a device swing mechanism 104 for swinging the longitudinal path away from or towards the central axis 116, that is pivoting the device guiding mechanism 106 with respect to the fulcrum 214 (as shown in Fig. 1(b)) within the plane containing the longitudinal path and the central axis 116. Since the device guiding mechanism 106 defines a path for the surgical instrument, the path is tilted together with the device guiding mechanism 106.

The apparatus 100 further comprises a device rotator 102 for rotating the device guiding mechanism 106 through 360 degrees about the central axis 116. This central axis 116 may extend through a small key-hole on the patient's body. Thus, the longitudinal path sweeps out a conical surface, such as the one shown by dashed lines in Fig. 1(a). This conical surface has the central axis 116 as its axis. The semi-vertical angle of the cone (that is, the angle between the dashed side surfaces of the cone and the central axis 116 where they intersect at the fulcrum 214) is selectively fixed by the device swing mechanism 104. (Note that the word "semi-vertical" is used in its mathematical sense, and is not intended to imply that the central axis 116 is vertical; usually it is not, and in fact in use the central axis 116 is usually approximately horizontal).

The apparatus further comprises a device depth control mechanism 108 which serves to regulate the extent the surgical instrument protrudes from the device guiding mechanism, hence regulating the depth of insertion of the surgical instrument into a patient's body in one example.

The apparatus further comprises a device positioning frame 110 in the form of an ultrasound probe holder which is a hand-held frame with one linear positioning mechanism for holding and positioning an ultrasound probe.

Each of the device rotator 102, the device swing mechanism 104, the device depth control mechanism 108 and the device positioning frame 110 can be controlled manually by a respective manual controller, but each also contains a respective servo-motor. Each of the mechanisms 102, 104, 108, 110 can be

independently controlled by either of the respective manual controller or respective servo-motor. Note that in other embodiments of the invention only one of the manual controller or the corresponding servo-motor may be provided.

The apparatus further comprises a device controller 112 which serves to control one or more of the movement of the device rotator 102, the device swing mechanism 104, the device depth control mechanism 108 and the device positioning frame 110, by controlling the respective servo-motor. The device controller 112 may comprise a tablet computer, a frame grabber for capturing images from an imaging device (for example, an ultrasound system) and a motion control module. Information related to the surgical procedure may be displayed together with user friendly GUI on a colour touch screen monitor of the device controller 112 to help the surgeon perform more complex surgical procedures. Furthermore, the surgical procedure performed may be stored in the device controller 112 for repeated operations or for further treatment assessment.

The device rotator 102, the device swing mechanism 104, the device guiding mechanism 106, the device depth control mechanism 108, the device positioning frame 110 and the device controller 112 will now be described in more detail with reference to Figs. 1(b) and 2 – 9.

Fig. 2(a) is a perspective view of the device rotator 102. Figs. 2(b) and 2(c) are respectively a cross-sectional side view and a cross-sectional back view of the device rotator 102.

As shown in Figs. 2(a) – 2(c), the device rotator 102 comprises a base 202 for holding other parts of the device rotator 102 and for holding the device positioning frame 110. The device rotator 102 also comprises two cable holders 208 and 216.

The device rotator 102 further comprises a first swing part 218 which serves to hold the device guiding mechanism 106 which in turn guides the surgical instrument. The first swing part 218 is arranged to tilt with respect to a part 214 which serves as a fulcrum for the tilt. For the part 214 to function as a fulcrum, two fixed support shafts are arranged to secure the position of the part 214.

The device rotator 102 also comprises a worm wheel 212 for rotating the device swing mechanism 104 (and hence, the device guiding mechanism 106) and a worm gear 210 for driving the worm wheel 212. The device rotator 102 further comprises a servo motor 206 and a handle 204 arranged on the base 202. The servo motor 206 and the handle 204 are arranged to drive the worm gear 210 independently. In other words, the worm gear 210 can either be driven by the servo motor 206 or be manually rotated by turning the handle 204. The worm gear 210 is meshed with the worm wheel 212 such that the worm wheel 212 rotates when the worm gear 210 rotates and the worm wheel 212 is locked in a stationary position when the worm gear 210 is stationary. Hence, the use of the worm gear 210 ensures that the device guiding mechanism 106 can only rotate when the servo motor 206 is powered on or when the handle 204 is turned.

Fig. 3(a) is a cut away perspective view of the device swing mechanism 104. Figs. 3(b) and 3(c) are respectively a cross-sectional side view and a cross-sectional top view of the device swing mechanism 104.

As shown in Figs. 3(a) – 3(c), the device swing mechanism 104 comprises a second swing part 308 which serves to hold the device guiding mechanism 106 which in turn guides the surgical instrument. The second swing part 308 is arranged to tilt with respect to the fulcrum 214. As shown in Fig. 1(b), the second swing part 308 of the device swing mechanism 104 is arranged within the first swing part 218 of the device rotator 102. The second swing part 308 is further arranged to be slidable within the first swing part 218 to allow the first swing part 218 to tilt together with the second swing part 308. This also allows the second swing part 308 to move along the same central line as the first

swing part 218. This keeps the trajectory of the surgical instrument along a single axis line.

The device swing mechanism 104 further comprises a linear moving mechanism 304 for moving the second swing part 308. The linear moving mechanism 304 is arranged with the second swing part 308 such that when the linear moving mechanism 304 moves linearly along an axis (defined by a linear guide 310 as shown in Figs. 3(a) – 3(c)), the second swing part 308 tilts along the axis in the direction of movement of the linear moving mechanism 304. The device swing mechanism 104 further comprises a servo motor 306 to drive the linear moving mechanism 304.

As shown in Figs. 3(a) – 3(c), the device swing mechanism 104 further comprises a side block 302 which comprises a curved support slot 312.

Fig. 4(a) is a perspective view of the device guiding mechanism 106 according to an embodiment of the present invention whereas Fig. 4(b) is a cross-sectional side view of the device guiding mechanism 106. In one example, the device guiding mechanism 106 is a single use component and is sealed in a sterilized bag prior to using it.

As shown in Figs. 4(a) and 4(b), the device guiding mechanism 106 is in the form of a slide sheath comprising an outer sheath 402 and an inner sheath 404. The inner sheath 404 is arranged to be slidable within the outer sheath 402 and the length of the device guiding mechanism 106 is adjustable by sliding the inner sheath 404 within the outer sheath 402.

The inner sheath 404 is arranged to be inserted into an end of the outer sheath 402 and the device guiding mechanism 106 further comprises a protective member 410 covering this end of the outer sheath 402. The protective member 410 is removed prior to the insertion of the inner sheath 404. The protective member 410 serves to ensure that the interior of the outer sheath 402 remains

sterilized during the insertion of the outer sheath 402 into the first swing part 218.

The device guiding mechanism 106 also comprises a first locking mechanism 406 to lock the outer sheath 402 to the first swing part 218 of the device rotator 102 and a second locking mechanism 412 to lock the inner sheath 404 to a stopper of the device depth control mechanism 108 (to be elaborated later).

The device guiding mechanism 106 also comprises an insertion guide 416 which serves to guide the insertion of the inner sheath 404 into the outer sheath 402. This ensures that the inner sheath 404 is properly inserted into the outer sheath 402. In one example, the insertion guide 416 is placed on the inner sheath 404 and is arranged to be slidable along the inner sheath 404.

Because the inner and outer sheaths 402, 404, and the first and second locking mechanism 406, 412 are sterilized, the device guiding mechanism 106 is able to provide a sterilized environment for the surgical instrument placed through it. The device guiding mechanism 106 also serves to maintain the surgical instrument in a straight trajectory and this is especially useful if the surgical instrument is a very fine needle.

In one example, the device guiding mechanism 106 is assembled as follows.

After opening the sterilized bag, the outer sheath 402, together with the protective member 410 are inserted into the first swing part 218 of the device rotator 102 from the direction indicated by arrow "A" in Fig. 1(b)). The first locking mechanism 406 is then used to secure the outer sheath 402 and the protective member 410 to the first swing part 218 of the device rotator 102.

Next, the protective member 410 is removed from the end of the outer sheath 402. The outer sheath 402 is then aligned with the inner sheath 404 using the insertion guide 416. Next, the inner sheath 404 is inserted into the outer sheath

402 and this insertion urges the insertion guide 416 to slide along the inner sheath 404.

The second locking mechanism 412 is then used to lock the inner sheath 404 onto a stopper of the device depth control mechanism 108 so that the inner sheath 404 can move together with the stopper (to be elaborated later). This allows the inner sheath 404 to slide within the outer sheath 402 when the stopper is moved, hence changing the length of the device guiding mechanism 106.

Fig. 5(a) is a perspective view of the device depth control mechanism 108 according to an embodiment of the present invention. Fig. 5(b) is a cross-sectional side view of the device depth control mechanism 108. As shown in Figs. 5(a) and 5(b), the device depth control mechanism 108 comprises a stopper 508 arranged to lock with the inner sheath 404 of the device guiding mechanism 106 via the second locking mechanism 412 to urge the inner sheath 404 to slide within the outer sheath 402 when the stopper 508 is moved.

In one example, the extent the surgical instrument protrudes out of the device guiding mechanism 106 corresponds to the desired depth of insertion of the surgical instrument into a patient's body. In this example, one end of the surgical instrument is inserted through the device guiding mechanism 106 (in the direction from left to right in Fig. 1(a)) until a portion of the surgical tool which comprises the surgical instrument bears against a stopper 508. The extent the surgical instrument protrudes out of the device guiding mechanism 106 is hence dependent on the length of the device guiding mechanism 106 which is in turn dependent on the sliding of the inner sheath 404 within the outer sheath 402. The stopper 508 hence serves as an indicator to regulate the desired depth of insertion of a surgical instrument into a patient's body.

The device depth control mechanism 108 further comprises a linear moving member 502 for moving the stopper 508. The linear moving mechanism 502 is arranged to be driven by a servo motor 504.

The device depth control mechanism 108 is arranged to tilt with the second swing part 308 of the device swing mechanism 104. As shown in Figs. 5(a) and 5(b), the device depth control mechanism 106 further comprises a swing guide 506. The swing guide 506 is arranged to be slidable within the curved support slot 312 of the side block 302 of the device swing mechanism 104 as shown in Fig. 1(b). The position of the swing guide 506 may be measured by an encoder on the servo motor 306. Two support points, one between the second swing part 308 and the side block 302 of the device swing mechanism 104 and the other between curved support slot 312 of the side block 302 of the device swing mechanism 104 and the swing guide 506 of the device depth control mechanism 108 are present to enhance the reliability and accuracy of the apparatus 100.. The swing guide 506 is further arranged to cooperate with the second swing part 308 of the device swing mechanism 104 via a support part 510 to tilt the device depth control mechanism 108 with the second swing part 308.

The device rotator 102, the device swing mechanism 104 and the device depth control mechanism 108 may be collectively known as a surgical wrist.

Fig. 6(a) is a perspective view of the device positioning frame 110. Fig. 6(b) shows an example ultrasound probe which may be placed on the device positioning frame 110 and Fig. 6(c) shows a cross-sectional side view of the device positioning frame 110.

As shown in Fig. 6(c), the device positioning frame 110 further comprises a linear movement element which is in turn driven by a servo motor 602. The linear movement element comprises a gear 610 and a rack 612. The linear movement element is arranged to move a moving member 604 of the device

positioning frame 110 linearly along an axis 606 as shown in Figs 6(a) and (c) which is an axis perpendicular to the length of the device guiding mechanism 106. A longitudinal groove 614 as shown in Fig. 6(c) is present in the arrangement between the moving member 604 and the linear movement element. In one example, the device rotator 102 is locked on the moving member 604 of the device positioning frame 110 and an imaging device such as an ultrasound probe with an ultrasound system (for example a B&K 8553 probe 608 as shown in Fig. 6(b)) is fixed onto the device positioning frame 110. This allows the imaging device to be movable relative to the device rotator. The imaging device serves to acquire images inside a patient's body. The position of a desired target in the patient's body may be located on the acquired image(s) and may be incorporated into a physical coordinate system via a calibration system.

Fig. 7(a) is a perspective view of the device controller 112 according to an embodiment of the present invention. Fig. 7(b) is a cross-sectional top view of the device controller 112.

As shown in Figs. 7(a) and 7(b), the device controller 112 comprises a control computer 702 which may be in the form of a tablet computer with a touch screen monitor 704. The device controller 112 further comprises a robotic control system which in turn comprises a servo motor control system and an imaging acquirement system. A box 706 serves to hold the control computer 702 and the robotic control system.

Fig. 8 is an overview of the components of the device controller 112 according to an embodiment of the present invention. The core component of the controller 112 is the control computer 702. The device controller 112 further comprises an integrated user interface for receiving user inputs. The integrated user interface in turn comprises the touch screen monitor 704, a keyboard and/or mouse 802, a graphic user interface (GUI), a voice interface (comprising a voice control 804) and a joypad interface (comprising a joypad control 806).

The touch screen monitor 704 and the keyboard and/or mouse 802 may be integrated into the tablet computer serving as the control computer 702.

The device controller 112 further comprises a servo motor control system in the form of a motion control module 814 for controlling the movement of one or more of the device rotator 102, the device swing mechanism 104, the device depth control mechanism 108 and the device positioning frame 110. This in turn controls the movement of the surgical instrument. In one example as shown in Fig. 8, the motion control module controls a four channel servo motion system 810 comprising the servo motors 206, 306, 504 and 602 of the device rotator 102, the device swing mechanism 104, the device depth control mechanism 106 and the device positioning frame 110 respectively.

Furthermore, the device controller 112 comprises an imaging acquirement system in the form of a frame grabber 812 for capturing image signals from a medical imaging system, for example an ultrasound system. The image signals may be used to enable three-dimensional (3D) motion tracking and positioning of the surgical instrument.

In one example, the control computer 702 controls the motion control module 808 based on the user inputs and the captured image signals. Some application programs may be preloaded into the control computer 702 and the motion control module 808 may be controlled based on the outputs from the application programs. The application programs may be based on 3D modelling and planning or an artificial intelligent system. The application programs may also provide real time feedback. For example, the user inputs and the captured image signals may be processed using the application programs to determine how far the surgical instrument is from the target and how the surgical instrument should be moved to reach the target. These outputs may in turn be used to control the motion control module 808 which will in turn control the movement of one or more of the device rotator 102, the device swing

mechanism 104, the device depth control mechanism 108 and the device positioning frame 110 to move the path of the surgical instrument to the target.

As shown in Fig. 8, the device controller 112 also comprises a web camera 818 and an amplifier 820 which serves to amplify the signals from the motion control module 808. In addition, the device controller 112 comprises a DC power supply 822 which serves to supply power to the frame grabber 812, the motion control module 808 and the amplifier 820.

Fig. 9 is an example of using the apparatus 100 with the B&K 8553 probe 608 (as shown in Fig. 6(b)) for breast biopsy. As shown in Fig. 9, the B&K ultrasound probe 608 is arranged with the device rotator 102 such that it moves relative to the device rotator 102 along an axis perpendicular to the length of the device guiding mechanism 106. In one example, the B&K ultrasound probe 608 is fixed on the device positioning frame 110 for acquiring images. The images acquired using this B&K ultrasound probe 608 may be transferred to the device controller 112 and the target may be shown on the touch screen monitor 704 of the device controller 112. This enables a fully programmable breast biopsy.

In one example, the following steps are performed for breast biopsy using the apparatus 100 and the ultrasound probe 608.

(i) The device guiding mechanism 106 is removed from its sterilized bag and the outer sheath 402 of the device guiding mechanism 106 is inserted into the first swing part 218 of the device rotator 102. The outer sheath 402, together with the protective member 410 of the device guiding mechanism 106 are then fixed on the first swing part 218 of the device rotator 102 using the first locking mechanism 406 as described above.

(ii) The protective member 410 is then removed from the end of the outer sheath 402 and the inner sheath 404 is then inserted into the outer

sheath 402 as described above. The insertion guide 416 is urged by the insertion to slide freely along the inner sheath 404.

(iii) The ultrasound system of the ultrasound probe 608 then acquires images of the interior of the breast. Using these images, a target in the breast (which may be for example, a tumour) is then located.

(iv) The surgeon then confirms the location of the target using the touch screen monitor 704 or the keyboard and/or mouse 802 of the device controller 112. Alternatively, the surgeon can confirm the location of the target using any other components of the integrated user interface of the device controller 112.

(v) The apparatus 100 is then used to insert the biopsy needle into the breast until it reaches the target in the breast according to the following steps.

(v-i) The first swing part 218 of the apparatus 100 is first aligned with an insertion point on the surface of the breast.

(v-ii) The device rotator 102 then rotates the device swing mechanism 104 until the swing plane of the device swing mechanism 104 crosses the target, in other words, until the target intersects with a plane along which the second swing part 308 tilts. Note that the device guiding mechanism 106 and the device depth control mechanism 108 are rotated together with the device swing mechanism 104.

(v-iii) The device swing mechanism 104 then swings (i.e. tilts) the device guiding mechanism 106. The device depth control mechanism 108 tilts together with the device guiding mechanism 106. This swing is performed until a center line (i.e. an axis) through the device guiding mechanism 106 passes through the target.

(v-iv) The stopper 508 of the device depth control mechanism 108 is then moved to slide the inner sheath 404 of the device guiding mechanism 106 into the outer sheath 402 of the device guiding mechanism 108 in the manner as described above to set a desired depth of insertion of the biopsy needle into the breast.

(v-v) A first end of the biopsy needle is then inserted into the breast through the device guiding mechanism 108 until a second end of the biopsy needle opposite to the first end is completely within the device guiding mechanism 108. This allows the biopsy needle to stop just at the target in the breast.

(vi) The surgeon then attaches a commercialized biopsy device, for example, a Bard biopsy system to the biopsy needle. A biopsy sample is then obtained using the Bard biopsy system.

Note that the linear movement element of the device positioning frame 110 allows the relative movement between the ultrasound probe 608 and the device rotator 102 (together with the device swing mechanism 104, the device guiding mechanism 106 and the device depth control mechanism 108).
The apparatus 100 provides the following advantages.

The apparatus 100 serves as a computerized surgical instrument manipulator which is capable of moving a surgical instrument to a target more safely and at a higher accuracy.

The apparatus 100 is driven by a servo motion system comprising the four servo motors 206, 306, 504 and 602 to place the tip of the surgical instrument to a target in a three-dimensional space inside a patient's body. This provides the apparatus 100 with four degrees of freedom (4DOF). Thus, the speed, force and placement range of the surgical instrument can be controlled when using the apparatus 100. This makes it possible to use the apparatus 100 to

manipulate a surgical instrument to perform a complex surgical procedure at a high positioning accuracy.

In comparison with current surgical instrument manipulators, the apparatus 100 provides a fully programmable procedure to help the surgeon perform the surgical procedure faster and better. As compared to prior art systems in which a robot merely mimics the movement of a surgeon to manipulate a surgical instrument, the apparatus 100 can achieve a more accurate manipulation of the surgical instrument since it controls the surgical instrument using application programs which may be preloaded into the device controller and which may be run based on user inputs and/or captured image signals from inside the patient's body. Furthermore, the application programs may be based on 3D modelling and planning or an artificial intelligent system and may provide real time feedback. This reduces inaccuracies caused by human errors.

As the apparatus 100 operates with conical coordinates, it is easier for one to manipulate a surgical instrument, for example, to move the surgical instrument to a target within a patient's body. The manipulation of the surgical instrument can also be more accurate. Furthermore, by achieving the conical movement of the surgical instrument using a rotating module providing a 360 degrees rotation, the desired positioning of the surgical instrument can be achieved in fewer steps and the size of the apparatus can be reduced.

The apparatus 100 is also advantageous as it does not require the use of any ball joints. Instead, it uses linear controllers which can provide a higher accuracy.

Also, the apparatus 100 allows the device rotator 102 to move relative to an imaging device which may be placed on the device positioning frame 110. Hence, the point of contact between the first swing part 218 of the device rotator 102 and the patient's body, in other words the pivoting point on the patient's body, can be adjusted.

The apparatus 100 thus serves as a useful tool to enable a precise handling of a surgical instrument. It can achieve better accuracy and precision than the manual handling of the surgical instrument. In summary, it provides a basic platform to bridge the gap between modern technologies and will hence benefit several patients.

Many variants of the embodiment are possible within the scope of the invention, as will be clear to a skilled reader. For example, a further drive mechanism (with a manual controller and/or a servo-motor) can be provided to move together all of the mechanisms 102, 104, 108, thereby moving the fulcrum 214 and the central axis 116. In this way, the fulcrum can be moved to a desired position relative to a patient.

Claims

1. A surgical instrument guidance apparatus for guiding an elongate surgical instrument, the apparatus comprising:

a device guiding mechanism for defining a longitudinal path for the surgical instrument, the longitudinal path passing through a fulcrum, the fulcrum being located on a central axis of the apparatus which in use is to be directed generally towards a subject of surgery;

a device swing mechanism for tilting the device guiding mechanism about the fulcrum within the plane including the central axis and the longitudinal path, thereby varying an angle between the longitudinal path and the central axis, and for selectively fixing the angle between the longitudinal path and the central axis, and

a device rotator for rotating the device guiding mechanism about the central axis, whereby the longitudinal path sweeps out a conical surface about the central axis, and for selectively fixing the rotational position of the device guiding mechanism about the central axis.

2. An apparatus according to claim 1, wherein the device rotator comprises:

a worm wheel for rotating the device guiding mechanism; and

a worm gear for driving the worm wheel, the worm gear being meshed with the worm wheel such that the worm wheel rotates when the worm gear rotates and the worm wheel is locked in a stationary position when the worm gear is stationary.

3. An apparatus according to claim 2, wherein the device rotator further comprises:

a servo motor; and

a handle;

wherein the servo motor and the handle are arranged to drive the worm gear independently.

4. An apparatus according to claim 3 or 4, wherein the device rotator further comprises:

a first swing part for holding the device guiding mechanism, the first swing part being arranged to tilt with respect to the fulcrum.

5. An apparatus according to claim 4, wherein the device swing mechanism comprises:

a second swing part for holding the device guiding mechanism, the second swing part being arranged to tilt with respect to the fulcrum and being further arranged to be slidable within the first swing part to allow the first swing part to tilt with the second swing part.

6. An apparatus according to claim 5, wherein the device swing mechanism further comprises:

a linear moving mechanism for moving the second swing part, the linear moving mechanism being arranged with the second swing part such that when the linear moving mechanism moves linearly along an axis, the second swing part tilts along the axis in the direction of movement of the linear moving mechanism.

7. An apparatus according to any preceding claim, wherein the device guiding mechanism further comprises:

an outer sheath; and

an inner sheath for insertion into an end of the outer sheath, the inner sheath being slidable within the outer sheath; and

wherein a length of the device guiding mechanism is adjustable by sliding the inner sheath within the outer sheath.

8. An apparatus according to claim 7, wherein the device guiding mechanism further comprises a protective member covering the end of the outer sheath, the protective member being removed from the outer sheath prior to the insertion of the inner sheath.

9. An apparatus according to claim 7 or 8, wherein the device guiding mechanism further comprises a locking mechanism for locking the device guiding mechanism to the first swing part of the device rotator.

10. An apparatus according any of claims 7 – 9, wherein the device guiding mechanism further comprises an insertion guide for guiding the insertion of the inner sheath into the outer sheath.

11. An apparatus according to claim 10, wherein the insertion guide is arranged to slide on the inner sheath after the inner sheath is inserted into the outer sheath.

12. An apparatus according to any of claims 7 – 11, further comprising a device depth control mechanism for regulating the extent the surgical instrument protrudes from the device guiding mechanism.

13. An apparatus according to claim 12, wherein the device depth control mechanism is arranged to tilt with the second swing part.

14. An apparatus according to claim 12 or 13, wherein the device depth control mechanism further comprises:

a stopper arranged to lock with the inner sheath of the device guiding mechanism to urge the inner sheath of the device guiding mechanism to slide within the outer sheath of the device guiding mechanism when the stopper is moved.

15. An apparatus according to claim 14, wherein the device depth control mechanism further comprises a linear moving member for moving the stopper, the linear moving member being driven by a servo motor.

16. An apparatus according to any of claims 12 – 15, wherein the device depth control mechanism further comprises:

a swing guide arranged to cooperate with the second swing part to tilt the device depth control mechanism with the second swing part.

17. An apparatus according to any of claims 12 – 16, wherein the apparatus further comprises a device positioning frame, the device positioning frame comprising:

a moving member arranged to move along an axis perpendicular to the length of the device guiding mechanism; and

a linear movement element arranged to move the moving member along the axis perpendicular to the length of the device guiding mechanism.

18. An apparatus according to claim 17, wherein an imaging device is fixed onto the device positioning frame for acquiring images.

19. An apparatus according to claim 17 or 18, further comprising a device controller for controlling the movement of one or more of the device rotator, the device swing mechanism, the device guiding mechanism, the device depth control mechanism and the device positioning frame.

20. An apparatus according to claim 19, wherein the device controller further comprises:

an integrated user interface for receiving user inputs;

a motion control module for controlling the movement of one or more of the device rotator, the device swing mechanism, the device depth control mechanism and the device positioning frame; and

a control computer for controlling the motion control module based on the user inputs.

21. An apparatus according to claim 20, wherein the device controller further comprises:

a frame grabber for capturing image signals from an imaging system; and

the control computer controls the motion control module based on the user inputs and the captured images.

22. An apparatus according to claim 20 or 21, wherein application programs are preloaded into the control computer and the control computer controls the motion control module using the output from the application programs, the application programs being based on 3D modelling and planning or an artificial intelligent system.

23. A method of assembling the device guiding mechanism according to any of claims 7 – 11, the method comprising the steps of:

removing the protective member covering the end of the outer sheath;

aligning the outer sheath with the inner sheath using the insertion guide; and

inserting the inner sheath into the outer sheath, the insertion urging the insertion guide to slide along the inner sheath.

24. A method of guiding a surgical instrument to a target using the apparatus according to any of claims 20 – 22, wherein a surgical tool comprises the surgical instrument and the method comprises the steps of:

rotating the device guiding mechanism until the target intersects with a plane along which the second swing part tilts;

tilting the device guiding mechanism until an axis through the length of the device guiding mechanism passes through the target;

moving the stopper of the device depth control mechanism to slide the inner sheath of the device guiding mechanism into the outer sheath of the device guiding mechanism until a desired length of the device guiding mechanism is achieved; and

inserting a first end of the surgical instrument through the device guiding mechanism until a portion of the surgical tool comprising the surgical instrument bears against the stopper. .

25. A method according to claim 24, further comprising the following steps prior to the step of rotating the device guiding mechanism:

acquiring images in the patient's body using an imaging device fixed onto the device positioning frame; and

locating the target in the acquired images.

26. A device guiding mechanism for defining a path along which an elongate surgical instrument moves, the mechanism comprising:

an outer sheath; and

an inner sheath for insertion into an end of the outer sheath, the inner sheath being slidable within the outer sheath; and

wherein a length of the device guiding mechanism is adjustable by sliding the inner sheath within the outer sheath.

27. A device guiding mechanism according to claim 26, further comprising a protective member covering the end of the outer sheath, the protective member being removed from the outer sheath prior to the insertion of the inner sheath.

28. A device guiding mechanism according to claim 26 or 27, further comprising an insertion guide for guiding the insertion of the inner sheath into the outer sheath.

29. A device guiding mechanism according to claim 28, wherein the insertion guide is arranged to slide along the inner sheath after the inner sheath is inserted into the outer sheath.

30. A method of assembling the device guiding mechanism according to any of claims 26 – 29, the method comprising the steps of:

removing the protective member covering the end of the outer sheath;

aligning the outer sheath with the inner sheath using the insertion guide; and

inserting the inner sheath into the outer sheath, the insertion urging the insertion guide to slide along the inner sheath.