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(54) **Title:** SURGICAL ROBOTIC SYSTEMS

(57) **Abstract:** An instrument drive unit for use in a robotic surgical system includes a carriage configured to be coupled to a robotic arm, a plurality of drive shafts rotationally supported in the carriage, a plurality of electric motors, and a plurality of concentric, tubular shafts extending through the plurality of electric motors. Each electric motor includes a stator and a rotor disposed within the stator. Each drive shaft is configured for interfacing with a corresponding driven member of the electromechanical surgical instrument. A rotation of a rotor of an electric motor rotates a corresponding tubular shaft, which, in turn, rotates a corresponding drive shaft to actuate a function of the electromechanical surgical instrument.

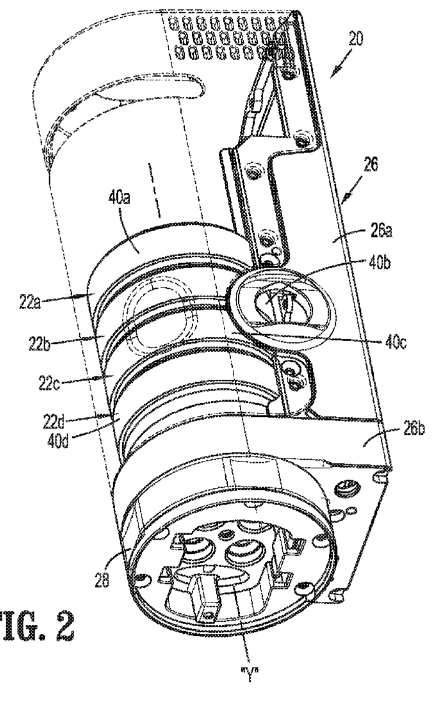


FIG. 2

WO 2020/060789 A1

SURGICAL ROBOTIC SYSTEMS

BACKGROUND

[0001] Surgical robotic systems have been used in minimally invasive medical procedures. Some surgical robotic systems included a console supporting a surgical robotic arm and a surgical instrument having at least one end effector (e.g., forceps or a grasping tool) mounted to the robotic arm. The robotic arm provided mechanical power to the surgical instrument for its operation and movement.

[0002] Manually-operated surgical instruments often included a handle assembly for actuating the functions of the surgical instrument. However, when using a robotic surgical system, no handle assembly was typically present to actuate the functions of the end effector. Accordingly, to use each unique surgical instrument with a robotic surgical system, an instrument drive unit was used to interface with the selected surgical instrument to drive operations of the surgical instrument.

[0003] The instrument drive unit was typically coupled to the robotic arm via a slide. The slide allowed the instrument drive unit and the attached surgical instrument to move along an axis of the slide, providing a means for adjusting the axial position of the end effector of the surgical instrument.

SUMMARY

[0004] In accordance with an aspect of the present disclosure, an instrument drive unit for use in a robotic surgical system is provided and includes a carriage configured to be coupled to a robotic arm, a plurality of drive shafts rotationally supported in the carriage, a plurality of electric motors, and a plurality of drive gears. Each electric motor includes a stator and a rotor disposed within the stator. Each drive gear is fixed to a corresponding drive shaft and is operably coupled to a corresponding rotor. Each rotor is configured to rotate a corresponding drive shaft in response to an activation of a respective electric motor to actuate a function of the electromechanical surgical instrument.

[0005] In aspects, each stator may be fixed relative to the carriage, and each rotor may be rotatable relative to and within a corresponding stator.

[0006] In some aspects, the electric motors may be vertically stacked within the carriage.

[0007] In other aspects, the instrument drive unit may further include a sleeve, and a drive motor. The sleeve may be rotationally coupled to a distal end portion of the carriage and configured to non-rotationally retain the electromechanical surgical instrument. The drive motor may include a stator fixed within the carriage, and a rotor disposed within the stator of the drive motor and non-rotatably coupled to the sleeve. The rotor of the drive motor may be configured to rotate the sleeve about a central longitudinal axis defined by the carriage.

[0008] In further aspects, the instrument drive unit may further include a plurality of concentric, tubular shafts. Each tubular shaft may have a proximal end portion non-rotationally

coupled to a corresponding rotor, and a distal end portion operably coupled to a corresponding drive gear of the plurality of drive gears.

[0009] In aspects, the proximal end portion of each tubular shaft may be concentrically disposed within a corresponding rotor, such that rotation of the rotor of one of the electric motors results in a rotation of a corresponding tubular shaft.

[0010] In some aspects, the proximal end portion of each tubular shaft may have a disc-shaped member fixed thereabout and non-rotationally coupled to a corresponding rotor.

[0011] In other aspects, the distal end portion of each tubular shaft may have a ring gear fixed thereabout. The ring gears may interface with a corresponding drive gear.

[0012] In further aspects, the ring gears may be stacked along a central longitudinal axis defined by the tubular shafts.

[0013] In aspects, the proximal end portion of a first tubular shaft may extend proximally beyond the proximal end portion of a second tubular shaft, and the distal end portion of the first tubular shaft may extend distally beyond the distal end portion of the second tubular shaft.

[0014] In some aspects, a first electric motor and a first drive gear may be operably coupled to one another via a first tubular shaft and vertically spaced from one another along a longitudinal axis defined by the first tubular shaft.

[0015] In other aspects, the tubular shafts may be independently rotatable relative to one another.

[0016] In further aspects, the drive gears may be vertically offset from one another.

[0017] In aspects, each drive shaft may have a distal end portion configured for interfacing with a corresponding driven member of the electromechanical surgical instrument.

[0018] In another aspect of the present disclosure, an instrument drive unit for use in a robotic surgical system is provided and includes a carriage configured to be coupled to a robotic arm, a plurality of electric motors supported in the carriage, a plurality of drive shafts configured for interfacing with a corresponding driven member of an electromechanical surgical instrument, and a plurality of concentric, tubular shafts extending through the electric motors. Each electric motor includes a stator and a rotor disposed within the stator. Each tubular shaft has a proximal end portion non-rotationally coupled to a corresponding rotor, and a distal end portion operably coupled to a corresponding drive shaft. Each rotor is configured to rotate a corresponding drive shaft in response to an activation of a respective electric motor to actuate a function of the electromechanical surgical instrument.

[0019] In aspects, each drive shaft may have a drive gear fixed thereabout, and each drive gear may be disposed at a discrete vertical location relative to one another.

[0020] Further details and aspects of exemplary embodiments of the present disclosure are described in more detail below with reference to the appended figures.

[0021] As used herein, the terms parallel and perpendicular are understood to include relative configurations that are substantially parallel and substantially perpendicular up to about + or – 10 degrees from true parallel and true perpendicular.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] Embodiments of the present disclosure are described herein with reference to the accompanying drawings, wherein:

[0023] FIG. 1 is a schematic illustration of a surgical robotic system including an instrument drive unit coupled to a slide in accordance with the present disclosure;

[0024] FIG. 2 is a perspective view of the instrument drive unit of the surgical robotic system of FIG. 1 with parts of a carriage of the instrument drive unit shown in phantom, illustrating a plurality of electric motors of the instrument drive unit;

[0025] FIG. 3 is a perspective view of the electric motors of the instrument drive unit of FIG. 2 with some of the stators thereof removed;

[0026] FIG. 4 is a side cross-sectional view of the instrument drive unit of FIG. 2;

[0027] FIG. 5 is a front view of the instrument drive unit, with a drive motor removed, thereby revealing the internal gear system of the instrument drive unit; and

[0028] FIG. 6 is a front view of the instrument drive unit of FIG. 5, with the electric motors removed, thereby revealing a plurality of concentric, tubular shafts coupled to the internal gear system.

DETAILED DESCRIPTION

[0029] Embodiments of the presently disclosed surgical robotic system and instrument drive units thereof are described in detail with reference to the drawings, in which like reference numerals designate identical or corresponding elements in each of the several views. As used herein, the term "distal" refers to that portion of the surgical robotic system or component thereof that is closest to the patient, while the term "proximal" refers to that portion of the surgical robotic system or component thereof further from the patient. As used herein, the term "vertical" refers to a direction defined along a longitudinal axis of a portion of the surgical robotic system, while the term "horizontal" refers to a direction defined along a transverse axis of a portion of the surgical robotic system.

[0030] As will be described in detail below, provided is an instrument drive unit of a surgical robotic system configured to allow for a bottom-loading of a surgical instrument. The instrument drive unit has a plurality of drive shafts each configured to be coupled to a corresponding driven member of the surgical instrument for carrying out a discrete function of the surgical instrument. The drive shafts of the instrument drive unit are operably coupled to a discrete electric motor of the instrument drive unit via an internal gear system and a plurality of concentric, tubular shafts. The configuration of the tubular shafts and the gear system allows for greater freedom for rotation and a reduction in the overall height of the instrument drive unit (e.g., the instrument drive unit is more compact). Other features and benefits of the disclosed instrument drive units are further detailed below.

[0031] Referring initially to FIG. 1, a surgical system, such as, for example, a surgical robotic system 1, generally includes a plurality of surgical robotic arms 2, 3; an elongated slide 13 coupled to an end of each of the robotic arms 2, 3; an instrument drive unit 20 and an electromechanical instrument 10 removably attached to the slide 13 and configured to move along the slide 13; a control device 4; and an operating console 5 coupled with control device 4. The operating console 5 includes a display device 6, which is set up in particular to display three-dimensional images; and manual input devices 7, 8, by means of which a person (not shown), for example a surgeon, is able to telemanipulate robotic arms 2, 3 in a first operating mode, as known in principle to a person skilled in the art.

[0032] Each of the robotic arms 2, 3 may be composed of a plurality of members, which are connected through joints. Robotic arms 2, 3 may be driven by electric drives (not shown) that are connected to control device 4. Control device 4 (e.g., a computer) is set up to activate the drives, in particular by means of a computer program, in such a way that robotic arms 2, 3, the attached instrument drive units 20, and thus electromechanical instrument 10 execute a desired movement according to a movement defined by means of manual input devices 7, 8. Control device 4 may also be set up in such a way that it regulates the movement of the instrument drive unit 20 along the slide 13, movement of the robotic arms 2, 3, and/or movement of the drives.

[0033] Surgical robotic system 1 is configured for use on a patient “P” lying on a surgical table “ST” to be treated in a minimally invasive manner by means of a surgical instrument, e.g., electromechanical instrument 10. Surgical robotic system 1 may also include more than two robotic arms 2, 3, the additional robotic arms likewise being connected to control device 4 and being telemanipulatable by means of operating console 5. A surgical instrument, for example, an electromechanical surgical instrument 10 (including an electromechanical end effector), may also be attached to the additional robotic arm.

[0034] Control device 4 may control a plurality of motors, e.g., motors (Motor 1 . . . n), with each motor configured to drive movement of robotic arms 2, 3 in a plurality of directions. Further, control device 4 may control a plurality of electric motors 22 (FIG. 2) of the instrument drive unit 20 to drive various operations of the surgical instrument 10. The instrument drive unit 20 transfers power and actuation forces from its motors to driven members (not shown) of the electromechanical instrument 10 to ultimately drive movement of components of the end effector of the electromechanical instrument 10, for example, a movement of a knife blade (not shown) and/or a closing and opening of jaw members of the end effector.

[0035] For a detailed description of the construction and operation of a robotic surgical system, reference may be made to U.S. Patent No. 8,828,023, entitled “Medical Workstation,” the entire contents of which are incorporated by reference herein.

[0036] With reference to FIGS. 2-6, the instrument drive unit 20 will now be described in detail. The instrument drive unit 20 includes a carriage 26 and a coupling or sleeve 28 rotatably coupled to a distal end portion 26b of the carriage 26 for connecting a surgical instrument 10 (FIG. 1) to the instrument drive unit 20. The carriage 26 of the instrument drive unit 20 is configured to be slidably coupled to a linear track (not shown) defined longitudinally along the slide 13 (FIG. 1). A proximal end portion 26a of the carriage 26 houses a plurality of electric motors 22a, 22b, 22c, 22d, 22d (collectively referred to herein as “22”) for carrying out various functions of an attached surgical instrument 10.

[0037] The electric motors 22 of the instrument drive unit 20 are concealed within the carriage 26. The electric motors 22 are vertically stacked on one another and are independently actuatable via the control device 4 (FIG. 1). A fifth electric motor or drive motor 22e is provided and is configured to effectuate a rotation of the surgical instrument 10 when the surgical instrument 10 is coupled to the instrument drive unit 20. The remaining electric motors 22a, 22b, 22c, 22d are configured to actuate functions of the surgical instrument 10, as will be described.

[0038] The electric motors 22 are integrated AC motors. In embodiments, the electric motors 22 may be any suitable type of electric motor such as an AC brushless motor, a DC brushed motor, a DC brushless motor, a direct drive motor, a servo motor, a stepper motor, or the like. It is contemplated, and within the scope of the present disclosure, that electric motors 22 are in the form of hollow core motors, or the like. Other types of motors are also contemplated. While the instrument drive unit 20 is illustrated as having five electric motors, it is contemplated that the instrument drive unit 20 may have more or less than five electric motors. The electric motors 22 are interlinked, thereby providing an infinite range of motion along the longitudinal axis “X” of the instrument drive unit 20.

[0039] The electric motors 22 each have a stator 40a, 40b, 40c, 40d, 40e (collectively referred to herein as “40”) fixed within the carriage 26 and relative to one another, and a rotor 42a, 42b, 42c, 42d, 42e (collectively referred to herein as “42”) rotationally disposed within a corresponding stator 40. Each of the stators 40 may be annularly shaped and stacked on top of one another to form a hollow cylinder, as best shown in FIG. 5. The stators 40 are rotationally fixed relative to one another by a rod or a plurality of rods (not explicitly shown) that extend through each of the stators 40. The stators 40 may be configured to receive an electric current from a power source (not explicitly shown) to produce a rotating magnetic field that drives a rotation of the rotors 42.

[0040] Each of the rotors 42 may be configured as a permanent magnetic, an electromagnet, or any other suitable conductor. The rotors 42 are vertically stacked within the hollow cylinder formed by the stators 40 and are independently rotatable relative to one another about a central longitudinal axis “X” defined by the motors 22. The rotors 42 are each non-rotationally fixed about a corresponding disc-shaped member 62a, 62b, 62c, 62d (collectively referred to herein with reference character "62") of a tubular shaft 60a, 60b, 60c, 60d (collectively referred to herein with reference character "60"), such that rotation of the rotors 42 results in a rotation of a corresponding tubular shaft 60.

[0041] The tubular shafts 60 extend through a central passageway defined through the stacked electric motors 22a, 22b, 22c, 22d and are configured to operably couple each electric motor 22a, 22b, 22c, 22d with a corresponding drive shaft 64a, 64b, 64c, 64d (collectively referred to herein with reference character "64"), as will be described. The tubular shafts 60 are concentric with one another and independently rotatable relative to one another. The tubular shafts 60a, 60b, 60c, 60d each respectively have proximal end portions 70, 76, 80, 84 exposed for operable engagement with a corresponding electric motor 22 and distal end portions 72, 78, 82, 86 exposed for operable engagement with a corresponding drive gear 66a, 66b, 66c, 66d (collectively referred to herein with reference character "66").

[0042] With particular reference to FIGS. 3-6, the first or proximal-most tubular shaft 60a has a proximal end portion 70 disposed within the rotor 42a, and a distal end portion 72. The proximal end portion 70 of the first tubular shaft 60a has the disc-shaped member fixed 62a thereabout. The disc-shaped member 62a is received in the rotor 42a and non-rotationally coupled thereto. In embodiments, the disc-shaped member 62a may be a gear operably coupled to one or more both of the first tubular shaft 60a or the rotor 42a. The distal end portion 72 of the first tubular shaft 60a has a ring gear 74a fixed thereabout.

[0043] The second tubular shaft 60b receives the first tubular shaft 60a and has a proximal end portion 76 disposed within the rotor 42b, and a distal end portion 78. The proximal end portion

70 of the first tubular shaft 60a extends proximally beyond the proximal end portion 76 of the second tubular shaft 60b, and the distal end portion 72 of the first tubular shaft 60a extends distally beyond the distal end portion 78 of the second tubular shaft 60b. The proximal end portion 76 of the second tubular shaft 60b has a disc-shaped member 62b fixed thereabout. The disc-shaped member 62b is received in the rotor 42b and non-rotationally coupled thereto. The distal end portion 78 of the second tubular shaft 60b has a ring gear 74b fixed thereabout.

[0044] The third tubular shaft 60c receives the second tubular shaft 60b and has a proximal end portion 80 disposed within the rotor 42c, and a distal end portion 82. The proximal end portion 76 of the second tubular shaft 60b extends proximally beyond the proximal end portion 80 of the third tubular shaft 60c, and the distal end portion 78 of the second tubular shaft 60b extends distally beyond the distal end portion 82 of the third tubular shaft 60c. The proximal end portion 80 of the third tubular shaft 60c has a disc-shaped member 62c fixed thereabout. The disc-shaped member 62c is received in the rotor 42c and non-rotationally coupled thereto. The distal end portion 82 of the third tubular shaft 60c has a ring gear 74c fixed thereabout.

[0045] The fourth or distal-most tubular shaft 60d receives the third tubular shaft 60c and has a proximal end portion 84 disposed within the rotor 42d, and a distal end portion 86. The proximal end portion 80 of the third tubular shaft 60c extends proximally beyond the proximal end portion 84 of the fourth tubular shaft 60d, and the distal end portion 82 of the third tubular shaft 60c extends distally beyond the distal end portion 86 of the fourth tubular shaft 60d. The proximal end portion 84 of the fourth tubular shaft 60d has a disc-shaped member 62d fixed thereabout. The disc-shaped member 62d of the fourth tubular shaft 60d is received in the rotor 42d and non-rotationally coupled thereto. The distal end portion 86 of the fourth tubular shaft 60d has a ring gear 74d fixed thereabout. The ring gears 74a, 74b, 74c, 74d (collectively referred to herein as "74") of the tubular shafts 60 are vertically stacked along a central longitudinal axis defined by the tubular shafts 60 and interface with a corresponding drive gear 66, as will be described.

[0046] The drive shafts 64 extend between a pair of proximal and distal plates 88, 90 rotationally supported in the carriage 26. The drive shafts 64 each have a distal end portion configured to operably couple to a driven member (not explicitly shown) of the surgical instrument 10. For example, the distal end portion of each of the drive shafts 64 may have a coupler (e.g., a gear) for coupling with a corresponding coupler of a driven member of the surgical instrument 10. Accordingly, upon bottom-loading of the electromechanical instrument 10 into the instrument drive unit 20, the distal end portions of the drive shafts 64 of the instrument drive unit 20 operably couple to the gears/couplers in a distal end of the main body portion (not shown) of the electromechanical instrument 10, such that a rotation of each drive shaft 64 rotates a correspondingly coupled driven member of the surgical instrument 10 to effectuate a discrete function of the surgical instrument (e.g., opening/closing of the end effector, articulation of the end effector, etc.)

[0047] The drive shafts 64 each have a drive gear 66 such as, for example, a spur gear, rotationally fixed thereabout. Each of the drive gears 66 are positioned at a discrete vertical location on their respective drive shaft 64, such that the drive gears 66 are vertically offset a selected distance from one another. Since the drive gears 66, in addition to being vertically offset, are also circumferentially spaced from one another, the drive gears 66 are offset from one another in all three dimensions. As mentioned above, the drive gears 66 each interface or intermesh with a ring gear 74 of a corresponding tubular shaft 60 and receive torque therefrom originating from the respective rotor 42.

[0048] In operation, the electromechanical instrument 10 is coupled to the instrument drive unit 20 by passing the main body portion of the electromechanical instrument 10 through the sleeve 28 of the instrument drive unit 20 in a proximal direction. With the main body portion of the electromechanical instrument 10 attached to the sleeve 28 of the instrument drive unit 28, the distal end portion of each of the drive shafts 64 interfaces with corresponding gears/couplers (not shown) in the proximal end of the main body portion of the electromechanical instrument 10.

[0049] With the electromechanical instrument 10 coupled to the instrument drive unit 20, to actuate a particular function of the surgical instrument 10, such as, for example, an opening or closing of an end effector of the surgical instrument 10, one of the electric motors 22 of the instrument drive unit 20, such as the first electric motor 22a, is activated via the control device 4 (FIG. 1). An activation of the first electric motor 22a includes supplying an electric current to the stator 40a thereof, which drives a rotation of the rotor 42a thereof. It is contemplated that the control device 4 or a processor (not shown) of the electric motor 22a generates a rotating magnetic field about the stator 40a to drive the rotation of the rotor 42a.

[0050] Since the proximal end portion 70 of the first tubular shaft 60a is fixed to the rotor 42a, the first tubular shaft 60 rotates with the rotor 42a. The ring gear 74a fixed about the distal end portion 72 of the first tubular shaft 60a also rotates, which, in turn, rotates the first drive gear 66a. Due to the first drive gear 66a being non-rotationally fixed about the first drive shaft 64a, and the distal end portion of the first drive shaft 64a being operably coupled to the proximal end of the first driven member of the surgical instrument 10 (FIG. 1), a rotation of the first drive gear

66a causes the first drive shaft 64a to rotate, thereby rotating the first driven member of the electromechanical instrument 10 to actuate an associated function of the surgical instrument 10.

[0051] To rotate the electromechanical instrument 10 about its longitudinal axis, the drive motor 22e of the instrument drive unit 20 is activated by the control device 4 (FIG. 1). An activation of the drive motor 22e includes supplying an electric current to the stator 40e thereof, which drives a rotation of the rotor 42e thereof. Since the rotor 42e is non-rotationally coupled to the proximal and distal plates 88, 90, rotation of the rotor 42e rotates the plates 88, 90 along with the drive shafts 64 and the attached sleeve 28. Given that the electromechanical instrument 10 is non-rotationally supported in the sleeve 28, the electromechanical instrument 10 rotates with the sleeve 28 relative to the carriage 26 to change a rotational orientation of the electromechanical instrument 10.

[0052] The drive motors 22a, 22b, 22c, 22d may be configured to concurrently rotate the rotors 42a, 42b, 42c, 42d, and in turn the drive gears 66a, 66b, 66c, 66d, with the sleeve 28 rotation. This would prevent rotation of the drive shafts 64a, 64b, 64c, 64d relative to the ring gears 74a, 74b, 74c, 74d during rotation of the sleeve 28, which may otherwise occur if the drive gears 66 were allowed to rotate relative to the ring gears 74 during rotation of the sleeve 28. Conversely, the fifth motor 22e may be configured to counteract any torque output by the other four drive motors 22a, 22b, 22c, 22d to prevent the inadvertent rotation of the sleeve 28.

[0053] As can be appreciated, the instrument drive unit 20 described above improves usability of the surgical robotic system 1, reduces a foot-print of the overall system 1, improves safety architecture, reduces the time required to remove surgical instruments in case of an emergency, and simplifies the electronics used in the instrument drive unit 20.

[0054] It will be understood that various modifications may be made to the embodiments disclosed herein. Therefore, the above description should not be construed as limiting, but merely as exemplifications of various embodiments. Those skilled in the art will envision other modifications within the scope and spirit of the claims appended thereto.

IN THE CLAIMS:

1. An instrument drive unit for use in a robotic surgical system, the instrument drive unit comprising:

a carriage configured to be coupled to a robotic arm;

a plurality of drive shafts rotationally supported in the carriage;

a plurality of electric motors, each electric motor of the plurality of electric motors including a stator and a rotor disposed within the stator; and

a plurality of drive gears, each drive gear of the plurality of drive gears fixed to a corresponding drive shaft of the plurality of drive shafts and operably coupled to a corresponding rotor, wherein each rotor is configured to rotate a corresponding drive shaft of the plurality of drive shafts in response to an activation of a respective electric motor of the plurality of electric motors to actuate a function of the electromechanical surgical instrument.

2. The instrument drive unit according to claim 1, wherein each stator is fixed relative to the carriage, and each rotor is rotatable relative to and within a corresponding stator.

3. The instrument drive unit according to claim 2, wherein the plurality of electric motors are vertically stacked within the carriage.

4. The instrument drive unit according to claim 1, further comprising:

a sleeve rotationally coupled to a distal end portion of the carriage and configured to non-rotationally retain the electromechanical surgical instrument; and a drive motor including:

a stator fixed within the carriage; and

a rotor disposed within the stator of the drive motor and non-rotatably coupled to the sleeve, wherein the rotor of the drive motor is configured to rotate the sleeve about a central longitudinal axis defined by the carriage.

5. The instrument drive unit according to claim 1, further comprising a plurality of concentric, tubular shafts, each tubular shaft of the plurality of tubular shafts having a proximal end portion non-rotationally coupled to a corresponding rotor, and a distal end portion operably coupled to a corresponding drive gear of the plurality of drive gears.

6. The instrument drive unit according to claim 5, wherein the proximal end portion of each tubular shaft of the plurality of tubular shafts is concentrically disposed within a corresponding rotor, such that rotation of the rotor of one of the plurality of electric motors results in a rotation of the corresponding tubular shaft of the plurality of tubular shafts.

7. The instrument drive unit according to claim 6, wherein the proximal end portion of each tubular shaft of the plurality of tubular shafts has a disc-shaped member fixed thereabout and non-rotationally coupled to a corresponding rotor.

8. The instrument drive unit according to claim 5, wherein the distal end portion of each tubular shaft of the plurality of tubular shafts has a ring gear fixed thereabout and interfacing with a corresponding drive gear of the plurality of drive gears.

9. The instrument drive unit according to claim 8, wherein the ring gears are stacked along a central longitudinal axis defined by the plurality of tubular shafts.

10. The instrument drive unit according to claim 5, wherein the proximal end portion of a first tubular shaft of the plurality of tubular shafts extends proximally beyond the proximal end portion of a second tubular shaft of the plurality of tubular shafts, and the distal end portion of the first tubular shaft extends distally beyond the distal end portion of the second tubular shaft.

11. The instrument drive unit according to claim 5, wherein a first electric motor of the plurality of electric motors and a first drive gear of the plurality of drive gears are operably coupled to one another via a first tubular shaft of the plurality of tubular shafts and vertically spaced from one another along a longitudinal axis defined by the first tubular shaft.

12. The instrument drive unit according to claim 5, wherein the plurality of tubular shafts are independently rotatable relative to one another.

13. The instrument drive unit according to claim 1, wherein the plurality of drive gears are vertically offset from one another.

14. The instrument drive unit according to claim 1, wherein each drive shaft of the plurality of drive shafts has a distal end portion configured for interfacing with a corresponding driven member of the electromechanical surgical instrument.

15. An instrument drive unit for use in a robotic surgical system, the instrument drive unit comprising:

a carriage configured to be coupled to a robotic arm;

a plurality of electric motors supported in the carriage, each electric motor of the plurality of electric motors including a stator and a rotor disposed within the stator;

a plurality of drive shafts configured for interfacing with a corresponding driven member of an electromechanical surgical instrument; and

a plurality of concentric, tubular shafts extending through the plurality of electric motors, each tubular shaft of the plurality of tubular shafts having a proximal end portion non-rotationally coupled to a corresponding rotor, and a distal end portion operably coupled to a corresponding drive shaft of the plurality of drive shafts, wherein each rotor is configured to rotate a corresponding drive shaft of the plurality of drive shafts in response to an activation of a respective electric motor of the plurality of electric motors to actuate a function of the electromechanical surgical instrument.

16. The instrument drive unit according to claim 15, wherein each drive shaft of the plurality of drive shafts has a drive gear fixed thereabout, each drive gear being disposed at a discrete vertical location relative to one another.

17. The instrument drive unit according to claim 16, wherein the distal end portion of each tubular shaft of the plurality of tubular shafts has a ring gear fixed thereabout and interfacing with a corresponding drive gear of the plurality of drive gears.

18. The instrument drive unit according to claim 15, wherein the proximal end portion of each tubular shaft of the plurality of tubular shafts is concentrically disposed within a corresponding rotor of one of the plurality of electric motors, such that rotation of the rotor results in a rotation of the corresponding tubular shaft of the plurality of tubular shafts.

19. The instrument drive unit according to claim 15, wherein the proximal end portion of each tubular shaft of the plurality of tubular shafts has a disc-shaped member fixed thereabout and non-rotationally coupled to a corresponding rotor.

20. The instrument drive unit according to claim 15, wherein the proximal end portion of a first tubular shaft of the plurality of tubular shafts extends proximally beyond the proximal end portion of a second tubular shaft of the plurality of tubular shafts, and the distal end portion of the first tubular shaft extends distally beyond the distal end portion of the second tubular shaft.

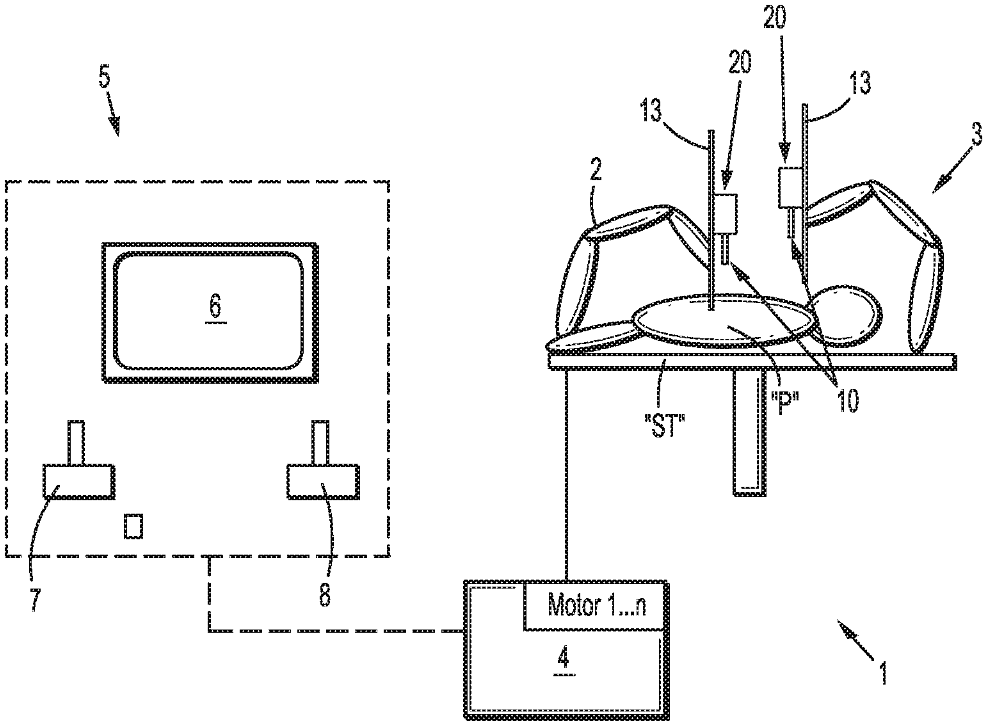


FIG. 1

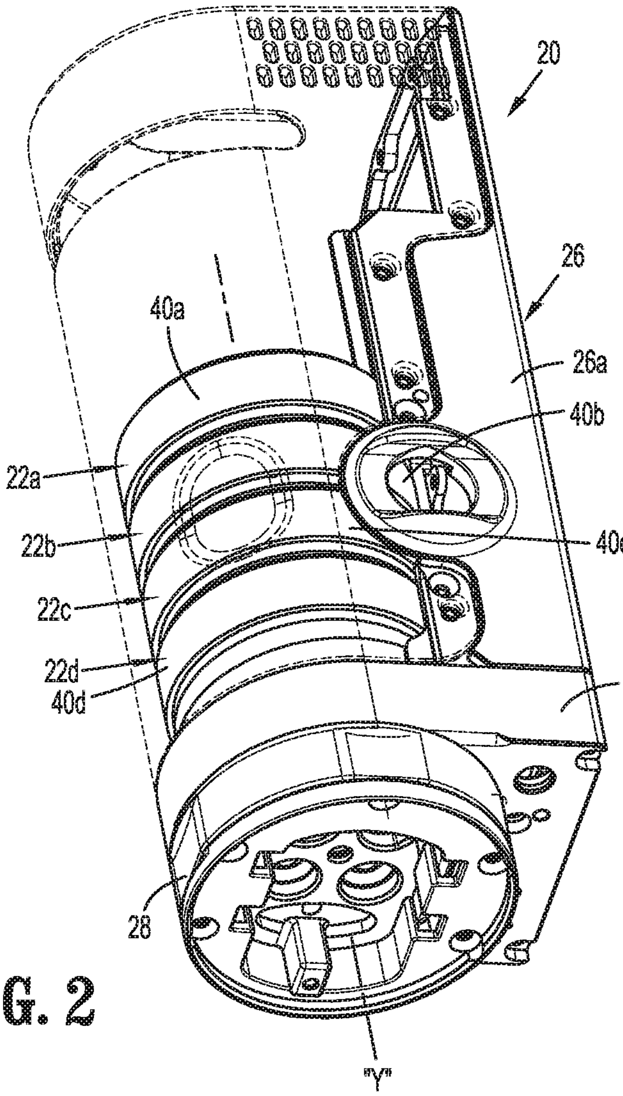

20
26
26a
40a
40b
22a
22b
40c
22c
22d
40d
26b
28
"Y"

FIG. 2

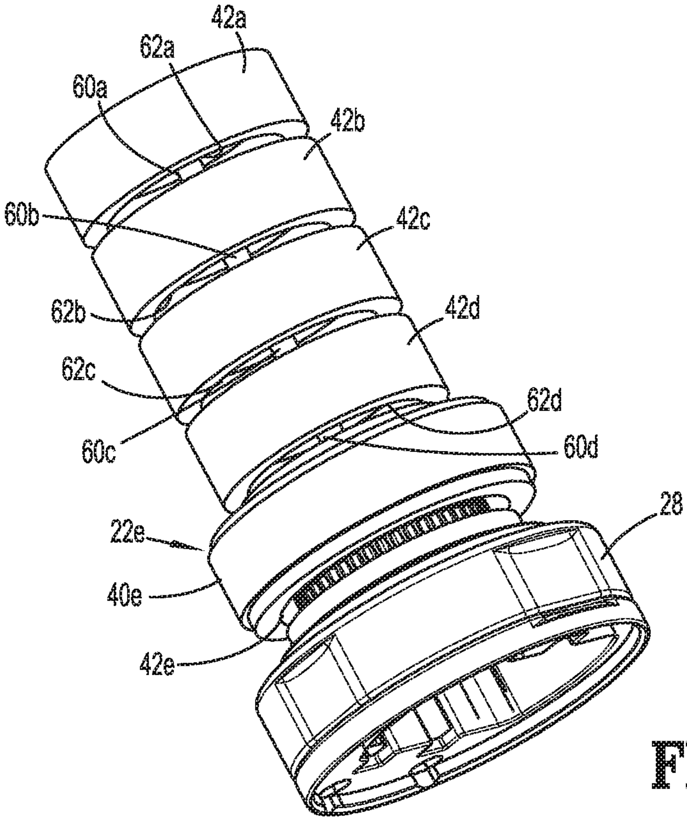

42a
62a
60a
42b
60b
42c
62b
42d
62c
62d
60c
60d
22e
28
40e
42e

FIG. 3

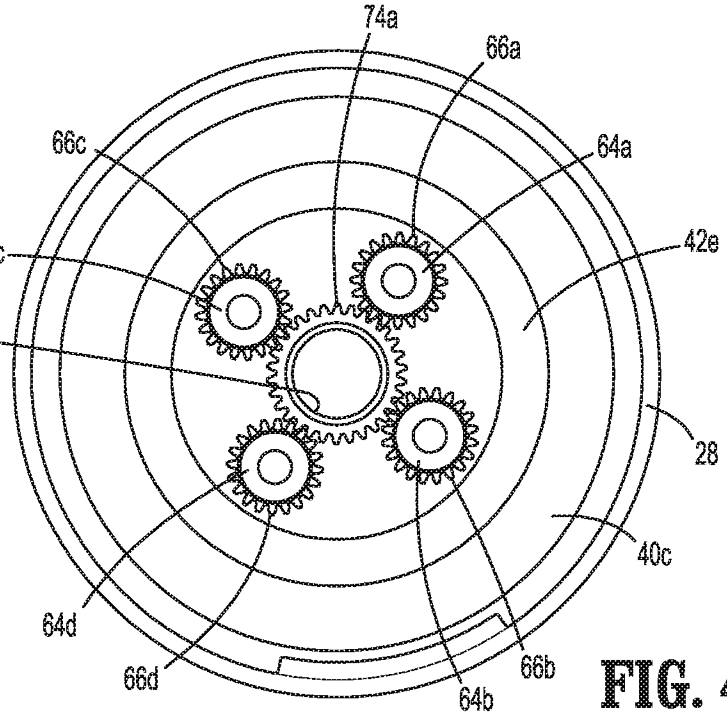
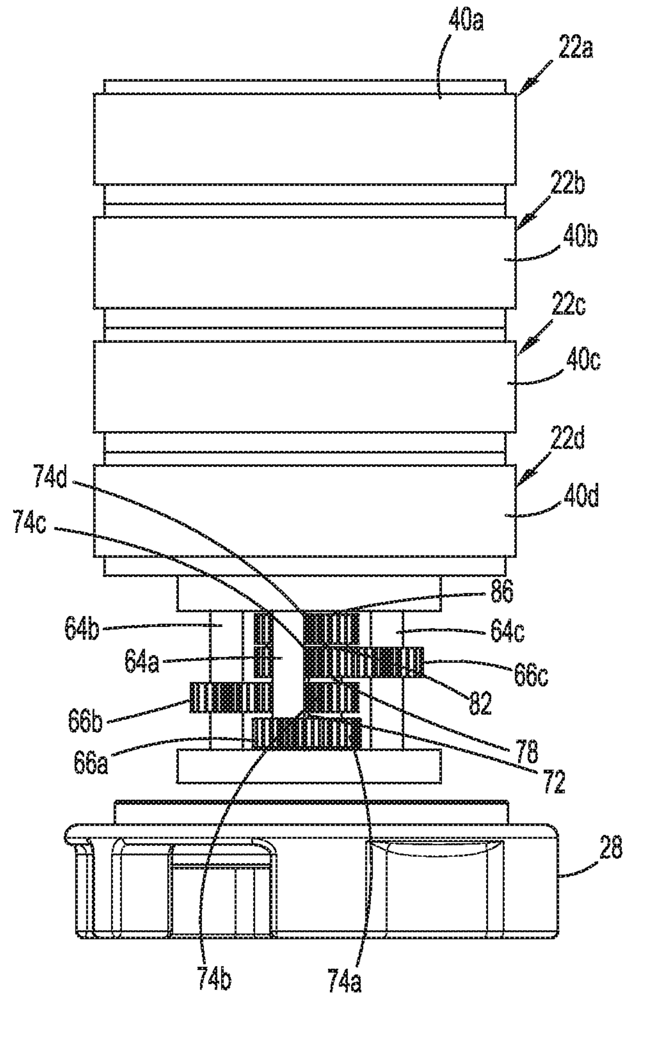

74a
66a
66c
64a
64c
42e
60a
28
40c
64d
66d
66b
64b

FIG. 4


40a
22a
22b
40b
22c
40c
22d
74d
40d
74c
86
64b
64c
64a
66c
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66b
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66a
72
28
74b
74a

FIG. 5

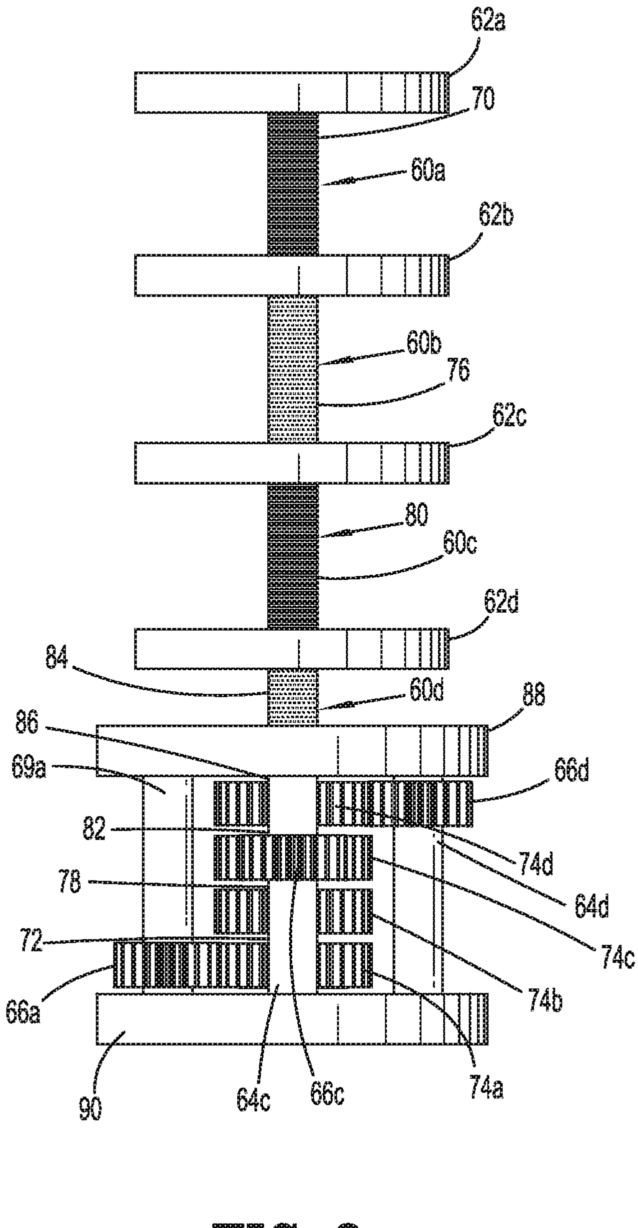
62a
70
60a
62b
60b
76
62c
80
60c
62d
84
60d
88
86
69a
66d
82
74d
64d
78
74c
72
74b
66a
90
64c
66c
74a

FIG. 6

INTERNATIONAL SEARCH REPORT	International application No. **PCT/US2019/050267**

A. CLASSIFICATION OF SUBJECT MATTER

A61B 34/30(2016.01)i, A61B 17/29(2006.01)i, A61B 17/00(2006.01)i, B25J 9/16(2006.01)i, B25J 9/10(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61B 34/30; A61B 17/00; A61B 17/16; A61B 17/29; A61B 17/295; A61B 19/00; B25J 17/00; B25J 9/16; B25J 9/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: robot surgery, carriage, stator, rotator, motor, shaft

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2018-0049812 A1 (ETHICON ENDO-SURGERY, LLC) 22 February 2018 claims 1, 6; paragraphs [0108], [0119]; figures 3, 7-10	1-20
A	US 9993313 B2 (AURIS HEALTH, INC.) 12 June 2018 the whole document	1-20
A	US 2018-0168748 A1 (COVIDIEN LP) 21 June 2018 the whole document	1-20
A	US 2014-0343567 A1 (CUREXO TECHNOLOGY CORPORATION) 20 November 2014 the whole document	1-20
A	US 8551114 B2 (RAMOS DE LA PENA, A) 08 October 2013 the whole document	1-20

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
03 January 2020 (03.01.2020)	**03 January 2020 (03.01.2020)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2019/050267

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