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(71) Applicants: NATIONAL UNIVERSITY OF SINGAPORE [SG/SG]; 21 Lower Kent Ridge Road, Singapore 119077 (SG). NATIONAL UNIVERSITY OF SINGAPORE SUZHOU RESEARCH INSTITUTE [CN/CN]; Block 3, Level 2, Public Academy, No. 377, Linqun Street, Suzhou Industrial Park, Suzhou, Jiangsu 215123 (CN).

(72) Inventors: REN, Hongliang; c/o National University of Singapore, Faculty of Engineering, Department of Biomedical Engineering, 21 Lower Kent Ridge Road, Singapore 119077 (SG). XIAO, Xiao; c/o National University of Singapore, Faculty of Engineering, Department of Biomed-

ical Engineering, 21 Lower Kent Ridge Road, Singapore 119077 (SG).

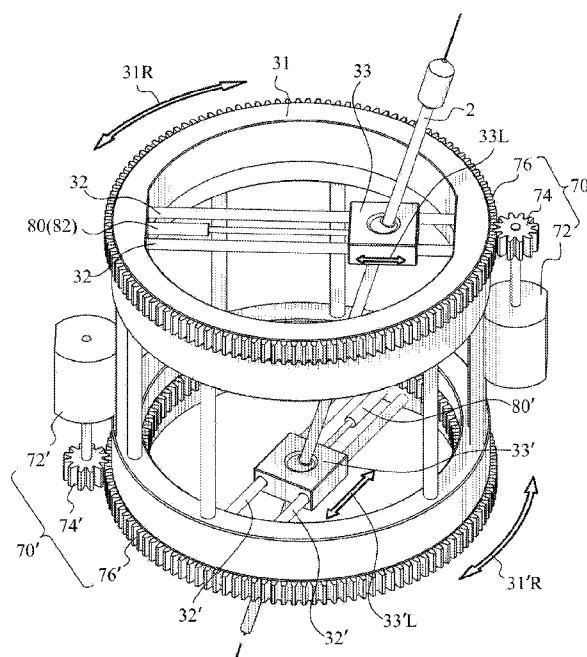
(74) Agent: CHINA SINDA INTELLECTUAL PROPERTY PTE LTD; 133 Cecil Street, #12-01A, Keck Seng Tower, Singapore 069535 (SG).

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(54) Title: ROBOTIC LINKAGE APPARATUS

[Fig. 10A]



(57) Abstract: Embodiments of the present invention provide a robotic linkage apparatus for used in a medical robot or similar applications. In one aspect, a robotic linkage apparatus comprises a base, a first connecting member movably coupled to the base, a first support member movably coupled to the first connecting member, a second connecting member movably coupled to the base, a second support member movably coupled to the second connecting member, and an executing member movably coupled to the first support member and the second support member. Movement of at least one of the first support member and the second support member relative to the base varies a postural orientation of the executing member relative to the base.

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Description

Title of Invention: ROBOTIC LINKAGE APPARATUS

Technical Field

[0001] The present invention relates to robotics, and in particular to a robotic linkage apparatus for medical applications.

Background Art

[0002] Cancer is a major threat to human health. As one of the commonly used diagnostic measure, biopsy operation is one of the most commonly used procedure for cancer diagnostics. Biopsy operation procedures are typically performed by a surgeon manually using a biopsy needle, a biopsy gun or the like. As some of the lesions are located in the subcutaneous tissue or organ, it is difficult for the surgeon to accurately locate the target site. This often leads to false or negative results, which adversely affecting medical control and treatment of the medical condition in a timely manner.

[0003] Medical robots are increasingly used in various surgical and diagnostics operations due to their accuracy and stability. With the advancement of technology development, medical robots may gradually become the basic configuration of hospitals. Biopsy robots with guided positioning capabilities can improve the accuracy and effectiveness of cancer diagnosis. presently, many biopsy robots are based on traditional tandem robots which has a complex system structure, inconvenient for operation, at high cost and poor versatility.

Summary of Invention

[0004] Embodiments of the present invention provide a robotic linkage apparatus for used in a medical robot or similar applications. In one aspect, a robotic linkage apparatus comprises a base, a first connecting member movably coupled to the base, a first support member movably coupled to the first connecting member, a second connecting member movably coupled to the base, a second support member movably coupled to the second connecting member, and an executing member movably coupled to the first support member and the second support member. Movement of at least one of the first support member and the second support member relative to the base varies a postural orientation of the executing member relative to the base.

[0005] Preferably, the first support member is movable relative to the base within a first plane, and the second support member is movable relative to the base within a second plane spaced apart from the first plane.

[0006] Preferably, the first plane and the second plane are parallel to each other.

[0007] Preferably, the first connecting member is positioned between the base and the first support member.

- [0008] Preferably, the first connecting member is a first rotating seat coupled to the base, and is rotatable relative to the base about a longitudinal axis of the base.
- [0009] Preferably, the robotic linkage apparatus comprises a first driving device coupled to the base and the first rotating seat to rotate the first rotating seat relative to the base.
- [0010] Preferably, the first driving device comprises a first motor mounted to the base, a first driving gear coupled to an output shaft of the first motor and a first follower gear coupled to the first rotating seat and meshed to the first driving gear.
- [0011] Preferably, the first driving device comprises a flexible cable having a sleeve and a core movably disposed in the sleeve, the sleeve being fixed to the base and a housing of a driving apparatus, the core being engaged to the first rotating seat and a first outer pulley coupled to the housing of the driving apparatus, wherein rotation of the first outer pulley moves the core relative to the sleeve to rotate the first rotating seat relative to the base.
- [0012] Preferably, the robotic linkage apparatus comprises a first guide rail fixed to the first rotating seat, wherein the first support member is a first slider coupled to the first guide rail and linearly slidable along the first guide rail relative to the first rotating seat.
- [0013] Preferably, the first guide rail is oriented along a direction orthogonal to the longitudinal axis.
- [0014] Preferably, the robotic linkage apparatus comprises a first actuator coupled to the first slider and the first rotating seat to move the first slider relative to the first rotating seat.
- [0015] Preferably, the first actuator is a first lead screw movably coupled to the first rotating seat and the first slider.
- [0016] Preferably, the first lead screw is positioned to pass through the first slider and parallel to the first guide rail.
- [0017] Preferably, the executing member is movably coupled to the first support member and positioned between the first guide rail and the first lead screw.
- [0018] Preferably, the first actuator comprises a flexible cable having a sleeve and a core movably disposed in the sleeve, the sleeve being fixed to the first rotating seat and a housing of a driving apparatus, the core being connected to the first slider and a first inner pulley coupled to the housing of the driving apparatus, wherein rotation of the first inner pulley moves the core relative to the sleeve to cause a linear sliding movement of the first slider relative to the first rotating seat.
- [0019] Preferably, the second connecting member is positioned between the base and the second supporting member.
- [0020] Preferably, the second connecting member is a second rotating seat coupled to the base, and is rotatable relative to the base about a longitudinal axis of the base.
- [0021] Preferably, the robotic linkage apparatus comprises a second driving device coupled

to the base and the second rotating seat to rotate the second rotating seat relative to the base.

- [0022] Preferably, the second driving device comprises a second motor mounted to the base, a second driving gear coupled to an output shaft of the second motor and a second follower gear coupled to the second rotating seat and meshed to the second driving gear.
- [0023] Preferably, the second driving device comprises a flexible cable having a sleeve and a core movably disposed in the sleeve, the sleeve being fixed to the base and a housing of a driving apparatus, the core being engaged to the second rotating seat and a second outer pulley coupled to the housing of the driving apparatus, wherein rotation of the second outer pulley moves the core relative to the sleeve to rotate the second rotating seat relative to the base.
- [0024] Preferably, the robotic linkage apparatus comprises a second guide rail fixed to the second rotating seat, wherein the second support member is a second slider coupled to the second guide rail and linearly slidable along the second guide rail relative to the second rotating seat.
- [0025] Preferably, the second guide rail is oriented along a direction orthogonal to the longitudinal axis.
- [0026] Preferably, the robotic linkage apparatus comprises a second actuator coupled to the second slider and the second rotating seat to move the second slider relative to the second rotating seat.
- [0027] Preferably, the second actuator includes a second lead screw movably coupled to the second rotating seat and the second slider.
- [0028] Preferably, the second lead screw is positioned to pass through the second slider and parallel to the second guide rail.
- [0029] Preferably, the executing member is movably coupled to the second support member and positioned between the second guide rail and the second lead screw.
- [0030] Preferably, wherein the second actuator comprises a flexible cable having a sleeve and a core movably disposed in the sleeve, the sleeve being fixed to the second rotating seat and a housing of a driving apparatus, the core being connected to the second slider and a second inner pulley coupled to the housing of the driving apparatus, wherein rotation of the second inner pulley moves the core relative to the sleeve to cause a linear sliding movement of the second slider relative to the second rotating seat.
- [0031] Preferably, the first connecting member is movable relative to the base with a first degree of freedom, the first support member is movable relative to the first connecting member with a second degree of freedom, the second connecting member is movable relative to the base with a third degree of freedom, and the second support member is movable relative to the second connecting member with a fourth degree of freedom.

[0032] Preferably, the robotic linkage apparatus comprises a first sphere and a second sphere, the first sphere being enclosed by and rotatably coupled to the first support member, the second sphere being enclosed by and rotatably coupled to the second support member. The executing member is movably coupled to the first support member via the first sphere, and movably coupled to the second support member via the second sphere.

[0033] Preferably, the executing member is fixed to the first sphere and passing through the first support member, and the executing member is slidably coupled to the second sphere and passing through the second support member.

[0034] Alternatively, the executing member is slidably coupled to the first sphere and passing through the first support member, and the executing member is fixed to the second sphere and passing through the second support member.

[0035] Preferably, the first sphere having a threaded hole formed thereon, the apparatus further comprising a fastening member movably coupled to the first sphere via the threaded hole to lock the executing member to the first sphere and to unlock the executing member from the first sphere.

[0036] Other aspects and advantages of the present invention will become apparent from the following detailed description, illustrating by way of example the inventive concept and technical solution of the present invention.

[0037] Preferably, the second sphere having a threaded hole formed thereon, the apparatus further comprising a fastening member movably coupled to the second sphere via the threaded hole to lock the executing member to the second sphere and to unlock the executing member from the second sphere.

Brief Description of Drawings

[0038] Embodiments of the invention are disclosed hereinafter with reference to the drawings, in which:

Fig.1

[0039] [Fig.1] is a schematic perspective view of a robotic linkage apparatus according to one embodiment of the present invention.

Fig.2

[0040] [Fig.2] is a perspective view showing further details of the robotic linkage apparatus of Fig. 1;

Fig.3

[0041] [Fig.3] is an exploded perspective view of Fig. 2;

Fig.4

[0042] [Fig.4] is a perspective view illustrating one postural orientation of the robotic linkage apparatus of Fig. 2;

Fig.5

[0043] [Fig.5] is an enlarged view showing a first slider of the robotic linkage apparatus of Fig. 4;

Fig.6

[0044] [Fig.6] is a perspective view illustrating another postural orientation of the robotic linkage apparatus of Fig. 2;

Fig. 7

[0045] [Fig.7] is an enlarged view showing a second slider of the robotic linkage apparatus of Fig. 6;

Fig.8

[0046] [Fig.8] is a partial exploded view of Fig. 2 viewing from a top-front angle;

Fig.9

[0047] [Fig.9] is a partial exploded view of Fig. 2 viewing from a bottom-front angle;

Fig.10A

[0048] [Fig.10A] is a perspective view showing further details and features of a robotic linkage apparatus of Fig. 2;

Fig.10B

[0049] [Fig.10B] is another perspective view showing further details and features of a robotic linkage apparatus of Fig. 2;

Fig.11

[0050] [Fig.11] is a schematic diagram illustrating a postural orientation of a robotic linkage apparatus shown in Fig. 2;

Fig.12

[0051] [Fig.12] is a schematic diagram illustrating a postural orientation of a robotic linkage apparatus shown in Fig. 2;

Fig.13

[0052] [Fig.13] is a schematic diagram illustrating a postural orientation of a robotic linkage apparatus shown in Fig. 2;

Fig.14

[0053] [Fig.14] is a schematic diagram illustrating another postural orientation of a robotic linkage apparatus shown in Fig. 2;

Fig.15

[0054] [Fig.15] is a schematic diagram illustrating another postural orientation of a robotic linkage apparatus shown in Fig. 2;

Fig.16

[0055] [Fig.16] is a schematic diagram illustrating another postural orientation of a robotic linkage apparatus shown in Fig. 2;

Fig.17

[0056] [Fig.17] is a schematic diagram illustrating another postural orientation of a robotic linkage apparatus shown in Fig. 2;

Fig.18

[0057] [Fig.18] is a schematic diagram illustrating another postural orientation of a robotic linkage apparatus shown in Fig. 2;

Fig.19

[0058] [Fig.19] is a schematic diagram illustrating another postural orientation of a robotic linkage apparatus shown in Fig. 2;

Fig.20

[0059] [Fig.20] is a partial perspective cross sectional view showing a slider and a sphere configuration of a robotic linkage apparatus according to another embodiment of the present invention;

Fig.21

[0060] [Fig.21] is a front view showing various axial positions of the executing member of a robotic linkage apparatus with the slider and the sphere configuration shown in Fig. 20;

Fig.22

[0061] [Fig.22] is a perspective viewing showing a driving apparatus for controlling the robotic linkage apparatus according to further embodiment of the present invention;

Fig.23

[0062] [Fig.23] is a perspective view showing a flexible cable of the driving apparatus shown in Fig. 22;

Fig.24

[0063] [Fig.24] is an exploded partial view of Fig. 22;

Fig.25

[0064] [Fig.25] is a perspective view showing driving cables attached to a robotic linkage apparatus of Fig. 2;

Fig.26

[0065] [Fig.26] is a perspective view showing a portion of the driving apparatus of Fig. 22 and a portion of the robotic linkage apparatus of Fig. 25.

Description of Embodiments

[0066] According to one embodiment, the present invention provides a robotic linkage apparatus for guiding positioning robots. The robotic linkage apparatus can be used, for example, in a medical guiding positioning robot, and in particular can be used in a robot for biopsy operation. The applications of robotic linkage apparatus for the guiding positioning robot is not limited to the medical field, but may be suitable for other suitable fields.

- [0067] As shown in Fig. 1 to Fig. 9, according to one embodiment, a robotic linkage apparatus 10 includes a base 1, an executing member 2 such as an operating arm, and at least two sets of movement units.
- [0068] In a preferred embodiment, the base 1 is a cylindrical shaped framework having at least two coaxially arranged annular seats 11 and 12 surrounding an opening 100 therethrough. The opening 100 is positioned in the center hollow portion of each annular seat 11, 12. Preferably, the opening 100 is arranged coaxially with respect to each annular seat 11, 12.
- [0069] In the embodiment as shown in Figs. 1 to 9, the first annular seat 11 has a first annular track 110 formed thereon, and the second annular seat 12 has a second annular track 120 formed thereon. The first annular seat 11 and the second annular seat 12 are coaxially arranged with respect to each other, and spaced apart from each other along a longitudinal axis 14 of the base 1. The longitudinal axis 14 passes through the geometric center of the cylindrical-shaped base 1, the first annular seat 11, the second annular seat 12, the first annular track 110 and the second annular track 120. The first annular seat 11 and the second annular seat 12 are fixedly connected to each other by one or more connection racks 13. The first annular seat 11 and the second annular seat 12 may have the same structure, and are fixed to each other by the connection racks 13 in a back-to-back manner. The connection racks 13 are shaped and structured to support the first annular seat 11 and the second annular seat 12, and to unblock the opening 100. Preferably, in the present embodiment, the connection racks 13 includes a plurality of rods arranged spaced apart from each other and disposed along the annular periphery of the first annular seat 11 and the second annular seat 12, with even or arbitrary angular intervals. Each rod has one end fixedly connected to the first annular seat 11 and the second annular seat 12. As such, the overall weight of the robotic linkage apparatus can be reduced while the structural strength and rigidity of the base 1 maintained. The base 1 can be in other configurations and structures in other embodiments.
- [0070] When used in a medical robot, the executing member 2 can be configured to be suitable for a surgical tool e.g. a biopsy needle, a biopsy gun or the like to be mounted thereon.
- [0071] As shown with further details in conjunction with Figs. 10A and 10B, the first annular track 110 and the second annular track 120 are structured to correspond to the two sets of movement units, respectively. One of the movement units includes a first connecting member such as a first rotating seat 31, a first guide rail 32, a first support member such as a first slider 33, a first sphere 34, a first driving device 70 and a first actuator 80 or 92. The other set of movement unit includes a second connecting member such as a second rotating seat 31', a second guide rail 32', a second support

member such as a second slider 33', a second sphere 34', a second driving device 70' and a second actuator 80' or 92.

[0072] The first rotating seat 31 is rotatably coupled to the first annular seat 11, and is rotatable along the first annular track 110. The second rotating seat 31' is rotatably coupled to the second annular seat 12, and is rotatable along the second annular track 120. The first guide rail 32 is fixed to the first rotating seat 31, and is rotatable following the rotation of the first rotating seat 11. The second guide rail 32' is fixed to the second rotating seat 31', and is rotatable following the rotation of the second rotating seat 12. The first guide rail 32 is oriented perpendicular to the longitudinal axis 14 of the first annular track 110. The second guide rail 32' is oriented perpendicular to the longitudinal axis 14 of the second annular track 120. The first slider 33 is linearly slidable along the first guide rail 32. The second slider 33' is linearly slidable along the second guide rail 32'. The first sphere 34 is positioned in and rotatably coupled to the first slider 33. The second sphere 34' is positioned in and rotatably coupled to the second slider 33'. The first sphere 34 has an assembling hole 340. The second sphere 34' has an assembling hole 340'. Structured in the above-illustrated manner, the first slider 33 is movable relative to the base 1 within a first plane 101, and the second slider 33' is movable relative to the base 1 within a second plane 102 positioned spaced apart from the first plane 101 (Fig. 1) with respect to the longitudinal axis 14 of the base 1. Preferably, the first plane 101 and the second plane 102 are parallel to each other.

[0073] The first driving device 70 and second driving device 70' are configured to rotate the first and second rotating seats 31, 31' relative to the first and second annular seats 11 and 12, respectively. The first actuator 80 and the second actuator 80' are configured to move the first and second sliders 33, 33' relative to the first and second rotating seats 31 and 31', respectively.

[0074] The first sphere 34 and the second sphere 34' are positioned spaced apart from each other along the longitudinal axis 14. The executing member 2 is coupled to the first slider 33 and the second slider 33', by being placed to pass through the opening 100, and passing through the assembling hole 340 of the first sphere 34 and the assembling hole 340' of the second sphere 34', such that the executing member 2 is connected to the base 1 in a parallel manner. Supported by the first slider 33 and the second slider 33', via the respective first sphere 34 and the second sphere 34', the executing member 2 becomes movable relative to the base 1, by following the movement of one or both of the first slider 33 and the second slider 33' relative to the base 1. Movement of the first slider 33 and/or the second slider 33' therefore varies the postural orientation of the executing member 2. The postural orientations may include, for example, one at which the executing member 2 is aligned coaxial with the longitudinal axis 14 of the

base 1, as shown in Fig. 11.

- [0075] Following the movement of one, several or all of the following: the first slider 33 relative to first annular seat 31, the first annular seat 31 relative to the base 1, the second slider 33' relative to the second annular seat 31' and the second annular seat 31' relative to the base 1, the executing member 2 may be positioned at various postural orientations relative to the base 1. For example, following the linear sliding movement 33'L of the second slider 33' relative to the second annular seat 31' in a direction away from the center longitudinal axis 14, the postural orientation of the executing member 2 can be varied from a position concentric with the longitudinal axis 14, shown in Fig. 11, to a position shown in Fig. 12, i.e. angled with respect to the longitudinal axis 14.
- [0076] Following an independent rotational movement 31'R of the second rotating seat 31' relative to the base 1 about the longitudinal axis 14, the postural orientation of the executing member 2 can be varied from that shown in Fig. 12, to that shown in Fig. 13 i.e. with the tip 2a of the executing member 2 pointing to a direction away from that as shown in Fig. 12.
- [0077] Independent from the movement of the second slider 33' relative to the second annular seat 31', the postural orientation of the executing member 2 can be varied from the position shown in Fig. 11 to that shown in Fig. 14, i.e. angled with respect to the longitudinal axis 14 by following the linear sliding movement 33L of first slider 33 relative to the first annular seat 31 away from the longitudinal axis 14.
- [0078] Further following an independent rotational movement 31R of the first rotating seat 31 relative to the base 1 about the longitudinal axis 14, the postural orientation of the executing member 2 can be varied from that shown in Fig. 14, to that shown in Fig. 17, i.e. with the tip 2a of the executing member 2 pointing to a direction away from that as shown in Fig. 14.
- [0079] In situations where the linear sliding movement 33L of the first slider 33 and the linear movement 33'L of the second slider 33' relative to the base 1 are made with respect to the base 1 along the same direction, as shown in Fig. 15, the postural orientation of the executing member 2 is varies from that shown in Fig. 11. i.e. shifted parallelly from the longitudinal axis 14. Alternatively, the linear sliding movement 33L of the first slider 33 and the linear movement 33'L of the second slider 33' relative to the base 1 may be made with respect to the base 1 along opposite directions, by which, the postural orientation of the executing member 2 is varied to an angled position crossing the longitudinal axis 14, as shown in Fig. 16,
- [0080] In situations where the linear sliding movement 33L of the first slider 33 relative to the first rotating seat 31, the rotational movement 31R of the first rotating seat 31 relative to the base 1, the linear sliding movement 33'L of the second slider 33'

relative to the second rotating seat 31' and the rotational movement 31'R of the second rotating seat 31' relative to the base all take place, one independent from another, the postural orientation of the executing member 2 can be varied with respect to the base 1 to any arbitrary position, as shown in Figs. 18 and 19 as two specific examples.

[0081] Following the movement of the first slider 33 and the second slider 33' relative to each other, the distance between the first sphere 34 and the second sphere 34' varies. To adapt to the variation of the distance between the first sphere 34 and the second sphere 34', the executing member 2 is fixed to one of the spheres and slidably coupled to the other one of the spheres. For example, the executing member 2 is fixed to the second sphere 34' distal from the front tip 2a of the executing member 2, and slidably coupled to the first sphere 34 proximate to the front tip 2a of the executing member 2, as shown in Fig. 4. Alternatively, the executing member 2 is slidably coupled to the second sphere 34, and fixed to the first sphere 34', as shown in Fig. 6. Structured in the above-illustrated manner, the executing member 2 is capable of adapting to the relative movements of the first sphere 34 and the second sphere 34; and positioning at various postural orientations with maximum possible inclination angle within a three-dimensional geometry space defined by the base 1.

[0082] In a robotic linkage apparatus according to the present embodiment, the executing member 2 has four degrees of movement freedom, including two degrees of rotational freedom and two degrees of linearly sliding freedom. Rotation of the first and second rotating seats 31, 31' relative to the base 1 and the linear sliding movement of the first slider 33 and the second slider 33' relative to the first and second rotating seats 31 and 31', respectively, and preferably driven by the respective independently operable driving device 70, 70' and the actuator 80 / 92, 80' / 92', variation of the postural orientation of the executing member 2 to any arbitrary position within the three-dimensional geometry space defined by the base 1, can be achieved. Medical robotics equipped with a robotic linkage apparatus according to the present invention can therefore be configured compact in size, convenient for carrying, and compatible with the operations of medical equipment such as nuclear magnetic resonance imaging (MRI) equipment or the like.

[0083] With a robotic linkage apparatus according to the present invention, an MRI equipment can automatically scan lesion locations in real time and optimizes the target position (focal position) through the controller.

[0084] Preferably, in the present embodiment, the first rotating seat 31 and the second rotating seat 31' are each of a full-circled ring shape, and are co-axially arranged with respect to the longitudinal axis 14. The driving device of each movement units include a first driving device 70 adapted to drive the first rotating seat 31, a second driving device 70' adapted to drive the second rotating seat 31', a first actuator 80 adapted to

drive the first slider 33, and a second actuator 80' adapted to drive the second slider 33'. The first driving device 70 adapted to drive the first rotating seat 31 may be implemented under various configurations. For example, the first driving device 70 may be a geared rotational driving mechanism or a worm gear rotational driving mechanism. Examples of the above-illustrated rotational driving mechanism are illustrated below with respect to one of the movements units.

[0085] As shown in Fig. 10A, a first geared rotational driving mechanism 70 includes a first motor 72, a first driving gear 74 and a first follower gear 76. The first motor 72 is fixedly mounted to the base 1. The first driving gear 72 is fixedly mounted to the output shaft of the first motor 72. The first follower gear 76 is mounted to or formed on the external periphery of the first rotating seat 31, and is meshed to the first driving gear 74. Rotation of the first motor 72 can therefore drive the rotational motion of the first rotating seat 31 relative to the base 1 accordingly. The first driving gear 74 and the first follower gear 76 may be directly meshed to each other, or meshed via an intermediate gear.

[0086] A worm gear rotating mechanism includes a rod motor, a worm rod and a worm gear. The rod motor is fixed to the base 1. The worm rod is coupled to the output shaft of the rod motor. The worm gear is mounted to an outer periphery of the first rotating seat 31. Rotation of the rod motor, forwardly or reversely, is transferred via the coupling of the worm rod and the worm gear to rotate the first rotating seat 31 accordingly.

[0087] To make the rotational motion between the rotating seats and the annular tracks smoother and low resistant, rotating bearings may be provided between the first rotating seat 31 and the first annular track 110, and between the second rotating seat 31' and the second rotating annular track 120.

[0088] In the present embodiment, sliding guides 32 and 32' are preferably linear guide rails. In addition, during movement of the first slider 33 and the second slider 33' along the respective guide rails 32, 32' from one end towards the other end, the first sphere 34 and the second sphere 34' pass through the longitudinal axis 14 of the first annular track 110 and the second annular track 120. Another words, the reciprocal movement of the first sphere 34 and the second sphere 34' along the respective guide rail 32 and 32' is along an radial direction of the respective first and second tracks 110 and 120, such that, the executing member 2 can pass through the rotation center of the first annular track 110 and the second annular track 120. As such, the executing member 2 can be positioned with any arbitrary postural orientation to better adapt to various requirements of surgical operations.

[0089] Linear guide rails 32 and 32' are preferably mounted with the two ends to the respective first and second rotating seats 31 and 31', such that the first and second rotating seats 31 and 31' are firmly supported. Preferably, the two ends of the first

guide rail 32 are connected to the inner periphery wall of the first rotating seat 31, and the two ends of the second guide rail 32' are connected to the inner periphery wall of the second rotating seat 31'. As such, the axial dimension of the robotic linkage apparatus can be reduced for space saving.

[0090] For linear guide rails, the first and second actuators 80, 80' may have various implementation solutions e.g. in the form of a pneumatic cylinder or a lead screw.

[0091] In detail, as illustrated below by taking one of the movement units as an example and in conjunction with Fig. 10A, first actuator 80 includes a pneumatic cylinder 82 with one end pivotally connected to the first rotating seat 31, and another end connected to the first slider 33. Extension and the retraction of the cylinder can therefore drive the linear sliding movement 33L of the first slider 33 along the first guide rail 32 to move the first sphere 34, to vary the postural orientation of the executing member 2.

[0092] In embodiments where the first and/or second actuator takes the form of a lead screw mechanism, with the above-illustrated movement unit as an example and in conjunction with Fig. 10B, the lead screw mechanism includes a first screw motor 92 and a first lead screw 4 connected to the output shaft of the first screw motor 92. The first screw motor 92 is fixed to the first rotating seat 31. The linear guide rail 32 is configured in the shape of a guide rod, arranged parallel to the lead screw 4, and positioned within or parallel to the first plane 101. The lead screw 4 is preferably rotatably supported by the rotating seat 31. The first slider 33 has a threaded hole that is threadedly engaged with the lead screw 4, and a guide hole slidably engaged with the first guide rail 32. As the first slider 33 is restricted by the first guide rail 32 from rotating together with the first lead screw 4, the forward and reverse rotation of the screw motor will cause the forward and reverse rotation of the lead screw 4 which is converted to reciprocating linear sliding movement 33L of the first slider 33 along the lead screw 4 and the first guide rail 32.

[0093] Also shown in Fig. 10B is a second lead screw 4' and a second guide rail 32' positioned within or parallel to the second plane 102, and coupled to the second slider 33', with the structure and operation the same as the first lead screw 4 and first guide rail 32 illustrate above. A second screw motor 92' is fixed to the second rotating seat 31' and with the output shaft of the second screw motor 92 connected to the second lead screw 4' to drive the rotation of the second lead screw 4' which in turn cause the linear sliding movement of the second slider 33'.

[0094] The executing member 2 is movably coupled to the first slider 33 and the second slider 33', and positioned between the first guide rail 32 and the first lead screw 4, and positioned between the second guide rail and the second lead screw, as shown in Fig. 10B.

[0095] It will be understood that the above description is for a preferred embodiment of the

invention. In other alternative embodiments, a robotic linkage apparatus provided by the embodiment of the present invention may adopt at least one modification as described hereinafter:

- [0096] In a first alternative embodiment, the annular sliding groove can be configured in more than two planes. Accordingly, the movement unit can also be configured in more than two sets. This configuration is preferred in situations where the length between the spheres near the ends of the executing member 2 is relatively long, hence one or more additional sets of movement units is advantageous in providing stronger support to the executing member 2.
- [0097] In a second alternative embodiment, each rotating seat can be a partial annular ring. For example, the rotating seat may have an arc-shaped structure. Under this configuration, the driving device for driving the rotation of the rotating seat can take different forms for different rotating seat configurations.
- [0098] In a third alternative embodiment, the annular tracks and the rotating seats of the corresponding set of movement unit is arranged on the same plane, so that the guide rails of each set of movement unit (for example, the linear guide rail which is perpendicular to the longitudinal axis of the annular sliding grooves) is respectively connected to corresponding rotating seats through the base, such that the spheres of the respective set of movement unit are separately positioned apart from each other along the longitudinal axis of the base.
- [0099] In a fourth alternative embodiment, the form of the first driving mechanism and the second driving mechanism may be, for example, an electrical motor, a motor-driven roller, a motor-driven belt transmission, a motor-driven gear transmission, a nickel-titanium alloy wire drive, a flexible shaft drive consisting of steel wire shaft, pneumatic drive, or any combinations of the above.
- [0100] According to another embodiment, as shown in Fig. 20 and Fig. 21, used in a robotic linkage apparatus as illustrated hereinabove, a sphere 34 has a threaded hole 342 formed there on at a position e.g. along a direction 341 perpendicular to the assembling hole 340. A fastening member e.g. a locking screw 346 is couplable to the sphere 34 through the threaded hole 342 which, upon being tightened through an operation hole 332 formed on the slider 33, fixes the sphere 34 to the executing member 2. When the locking screw 346 is loosened, the executing member 2 becomes slidable relative to the sphere 33, along upward direction 202 or downward direction 204, to enable positional adjustment of the executing member 2 relative to the sphere 33, e.g. the distance between the end tip 26 to the executing member 2 relative to the base 1, from the original position 21A to upward position 21B or downward position 21C.
- [0101] According to a further embodiment, as shown in Figs. 22 to 26, a robotic linkage apparatus 50 includes a driving apparatus 60 for manipulating the operation of the

robotic linkage apparatus 50. Driving apparatus 60 includes a first outer pulley 620 and a first inner pulley 630 coupled to a first housing 610, and a second outer pulley and a second inner pulley coupled to a second housing 650. Flexible cable segments 722 and 732 wrap around the first outer pulley 620 and the first rotating seat 531. Flexible cable segments 724 and 734 wrap around the first inner pulley 630 and connected to the opposite ends of the first slider 533, respectively.

- [0102] Rotation of the first outer pulley 620 and the first inner pulley 630 are effected by motors via respective driving gears 622 and 632. Each cable segment is formed by a cable with a sleeve 74 and a core 72 slidably disposed in the sleeve. Taking the cable segments 722, 732, 724 and 734 as an example for illustration, as shown in Fig. 22, each cable segment is attached to the driving apparatus 60 with the sleeve 74 fixed to the first housing 610, and the core 72 engaged to the first outer pulley 620 and the first inner pulley 630, respectively.
- [0103] As shown in Fig. 25, the other end portion of the cable segments 722 and 732 wrap around the first rotating seat 531, with the sleeve 74 fixed to the base 51 and the core engaged to the rotating seat 531. The core 72 of the other end segments 724 and 734 are connected to the opposite ends of first slider 533, and with the sleeve 74 fixed to the first rotating seat 531.
- [0104] Configures in the above-illustrated manner, rotation of the first outer pulley 620 will move the core 72 of the cable segments 722 and 732 relative to the sleeve 74. Movement of the core 72 is therefore conveyed to the other end of the cable segment, and rotate the first rotating seat 531. Independent from the first outer pulley 620, rotation of the first inner pulley 630 moves the core 72 of the cable segments 724 and 734, to cause the linear movement of the first slider 533 relative to the first rotating seat 531. Likewise, connected by the cable segments 762, 764, 772 and 774, movement of the second rotating seat 531' and the second slider 533' can be driven by the driving apparatus 60 in a similar manner.
- [0105] The above embodiments are merely illustrative of several embodiments of the present invention, and are not to be construed as limiting the scope of the invention. It should be noted that a number of variations and modifications may be made by those skilled in the art without departing from the spirit and scope of the invention. Therefore, the scope of the invention should be determined by the claims appended hereto.

Claims

- [Claim 1] A robotic linkage apparatus comprising: a base; a first connecting member movably coupled to the base; a first support member movably coupled to the first connecting member; a second connecting member movably coupled to the base; a second support member movably coupled to the second connecting member; an executing member movably coupled to the first support member and the second support member; wherein movement of at least one of the first support member and the second support member relative to the base varies a postural orientation of the executing member relative to the base.
- [Claim 2] The apparatus as recited in claim 1, wherein the first support member is movable relative to the base within a first plane, and the second support member is movable relative to the base within a second plane spaced apart from the first plane.
- [Claim 3] The apparatus as recited in claim 2, wherein the first plane and the second plane are parallel to each other.
- [Claim 4] The apparatus as recited in claim 1, wherein the first connecting member is positioned between the base and the first support member.
- [Claim 5] The apparatus as recited in claim 4, wherein the first connecting member is a first rotating seat coupled to the base, and is rotatable relative to the base about a longitudinal axis of the base.
- [Claim 6] The apparatus as recited in claim 5, further comprising a first driving device coupled to the base and the first rotating seat to rotate the first rotating seat relative to the base.
- [Claim 7] The apparatus as recited in claim 6, wherein the first driving device comprises a first motor mounted to the base, a first driving gear coupled to an output shaft of the first motor and a first follower gear coupled to the first rotating seat and meshed to the first driving gear.
- [Claim 8] The apparatus as recite in claim 6, wherein the first driving device comprises a flexible cable having a sleeve and a core movably disposed in the sleeve, the sleeve being fixed to the base and a housing of a driving apparatus, the core being engaged to the first rotating seat and a first outer pulley coupled to the housing of the driving apparatus, wherein rotation of the first outer pulley moves the core relative to the sleeve to rotate the first rotating seat relative to the base.
- [Claim 9] The apparatus as recited in claim 5, further comprising a first guide rail fixed to the first rotating seat, wherein the first support member is a

- first slider coupled to the first guide rail and linearly slidable along the first guide rail relative to the first rotating seat.
- [Claim 10] The apparatus as recited in claim 9, wherein the first guide rail is oriented along a direction orthogonal to the longitudinal axis.
- [Claim 11] The apparatus as recited in claim 9, further comprising a first actuator coupled to the first slider and the first rotating seat to move the first slider relative to the first rotating seat.
- [Claim 12] The apparatus as recited in claim 11, wherein the first actuator includes a first lead screw movably coupled to the first rotating seat and the first slider.
- [Claim 13] The apparatus as recited in claim 12, wherein the first lead screw is positioned to pass through the first slider and parallel to the first guide rail.
- [Claim 14] The apparatus as recited in claim 13, wherein the executing member is movably coupled to the first support member and positioned between the first guide rail and the first lead screw.
- [Claim 15] The apparatus as recited in claim 11, wherein the first actuator comprises a flexible cable having a sleeve and a core movably disposed in the sleeve, the sleeve being fixed to the first rotating seat and a housing of a driving apparatus, the core being connected to the first slider and a first inner pulley coupled to the housing of the driving apparatus, wherein rotation of the first inner pulley moves the core relative to the sleeve to cause a linear sliding movement of the first slider relative to the first rotating seat.
- [Claim 16] The apparatus as recited in claim 1, wherein the second connecting member is positioned between the base and the second supporting member.
- [Claim 17] The apparatus as recited in claim 16, wherein the second connecting member is a second rotating seat coupled to the base, and is rotatable relative to the base about a longitudinal axis of the base.
- [Claim 18] The apparatus as recited in claim 17, further comprising a second driving device coupled to the base and the second rotating seat to rotate the second rotating seat relative to the base.
- [Claim 19] The apparatus as recited in claim 18, wherein the second driving device comprises a second motor mounted to the base, a second driving gear coupled to an output shaft of the second motor and a second follower gear coupled to the second rotating seat and meshed to the second driving gear.

- [Claim 20] The apparatus as recited in claim 18, wherein the second driving device comprises a flexible cable having a sleeve and a core movably disposed in the sleeve, the sleeve being fixed to the base and a housing of a driving apparatus, the core being engaged to the second rotating seat and a second outer pulley coupled to the housing of the driving apparatus, wherein rotation of the second outer pulley moves the core relative to the sleeve to rotate the second rotating seat relative to the base.
- [Claim 21] The apparatus as recited in claim 17, further comprising a second guide rail fixed to the second rotating seat, wherein the second support member is a second slider coupled to the second guide rail and linearly slidable along the second guide rail relative to the second rotating seat.
- [Claim 22] The apparatus as recited in claim 21, wherein the second guide rail is oriented along a direction orthogonal to the longitudinal axis.
- [Claim 23] The apparatus as recited in claim 22, further comprising a second actuator coupled to the second slider and the second rotating seat to move the second slider relative to the second rotating seat.
- [Claim 24] The apparatus as recited in claim 23, wherein the second actuator includes a second lead screw movably coupled to the second rotating seat and the first slider.
- [Claim 25] The apparatus as recited in claim 24, wherein the second lead screw is positioned to pass through the second slider and parallel to the second guide rail.
- [Claim 26] The apparatus as recited in claim 25, wherein the executing member is movably coupled to the second support member and positioned between the second guide rail and the second lead screw.
- [Claim 27] The apparatus as recite in claim 23, wherein the second actuator comprises a flexible cable having a sleeve and a core movably disposed in the sleeve, the sleeve being fixed to the second rotating seat and a housing of a driving apparatus, the core being connected to the second slider and a second inner pulley coupled to the housing of the driving apparatus, wherein rotation of the second inner pulley moves the core relative to the sleeve to cause a linear sliding movement of the second slider relative to the second rotating seat.
- [Claim 28] The apparatus as recited in claim 1, wherein the first connecting member is movable relative to the base with a first degree of freedom, the first support member is movable relative to the first connecting member with a second degree of freedom; the second connecting

member is movable relative to the base with a third degree of freedom; the second support member is movable relative to the second connecting member with a fourth degree of freedom.

[Claim 29] The apparatus as recited in any one of the preceding claims, further comprising a first sphere and a second sphere, the first sphere being enclosed by and rotatably coupled to the first support member, the second sphere being enclosed by and rotatably coupled to the second support member, wherein the executing member is movably coupled to the first support member via the first sphere, and movably coupled to the second support member via the second sphere.

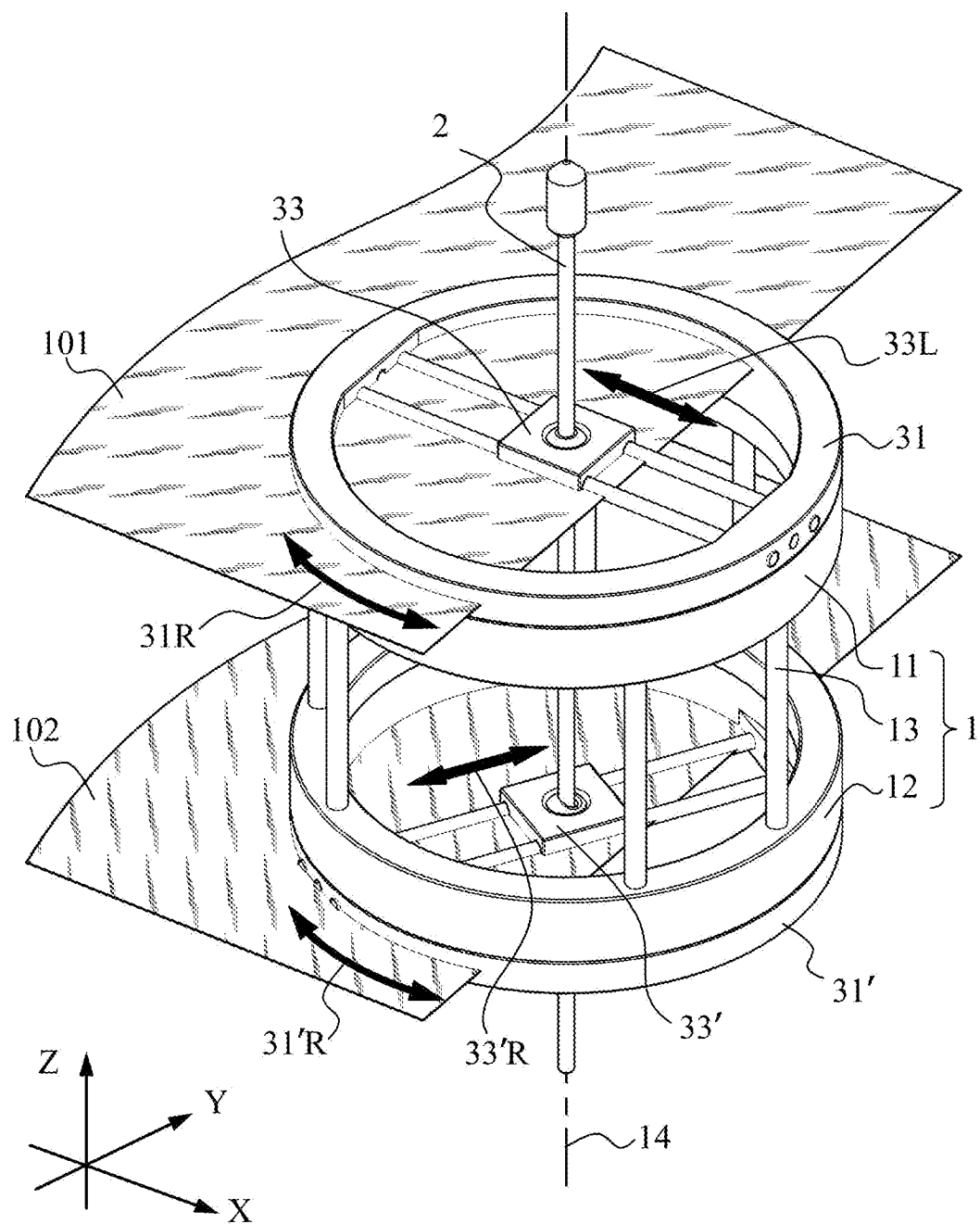
[Claim 30] The apparatus as recited in claim 29, wherein the executing member is fixed to the first sphere and passing through the first support member, and the executing member is slidably coupled to the second sphere and passing through the second support member.

[Claim 31] The apparatus as recited in claim 30, wherein the first sphere having a threaded hole formed thereon, the apparatus further comprising a fastening member movably coupled to the first sphere via the threaded hole to lock the executing member to the first sphere and to unlock the executing member from the first sphere.

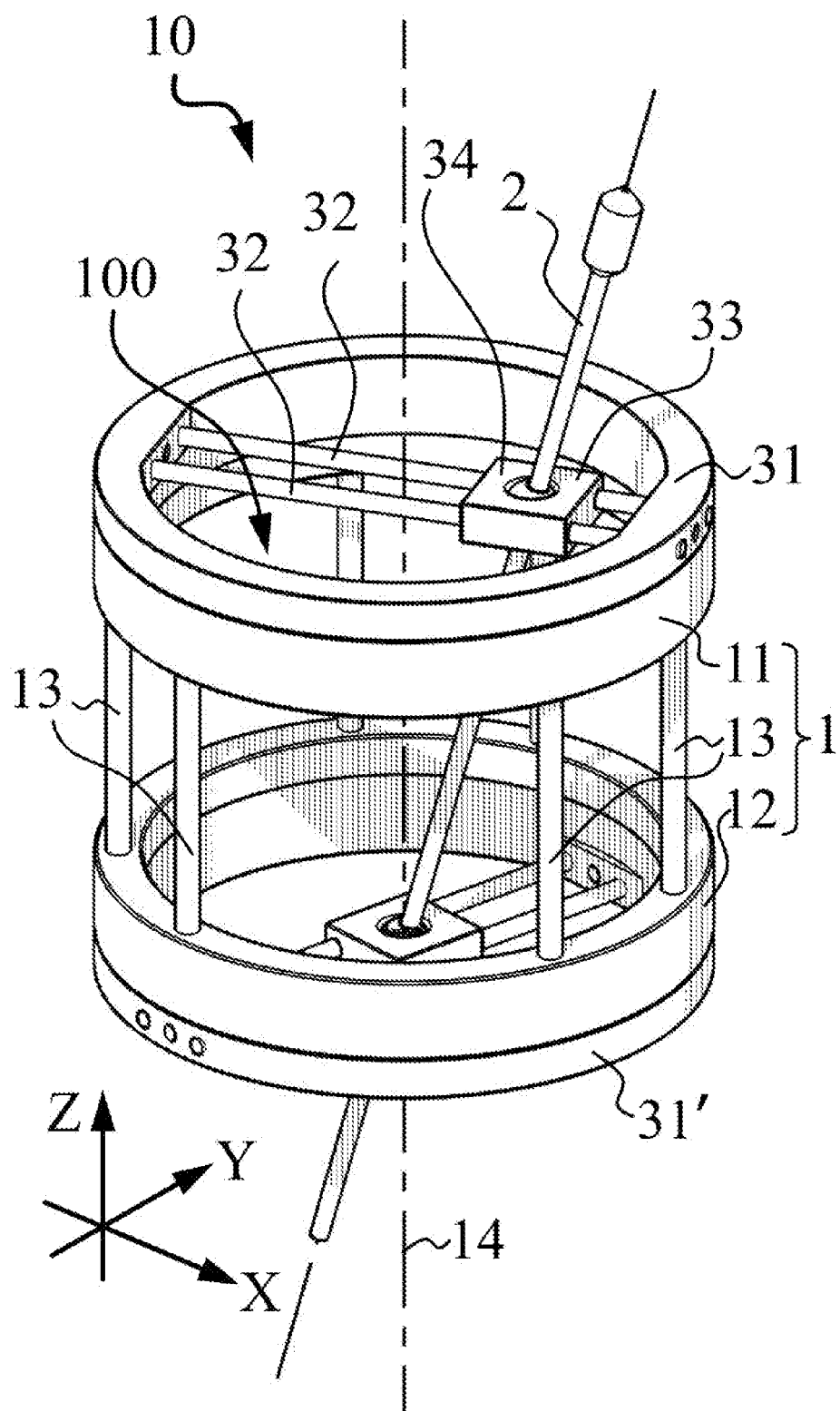
[Claim 32] The apparatus as recited in claim 29, wherein the executing member is slidably coupled to the first sphere and passing through the first support member, and the executing member is fixed to the second sphere and passing through the second support member.

[Claim 33] The apparatus as recited in claim 32, wherein the second sphere having a threaded hole formed thereon, the apparatus further comprising a fastening member movably coupled to the second sphere via the threaded hole to lock the executing member to the second sphere and to unlock the executing member from the second sphere.

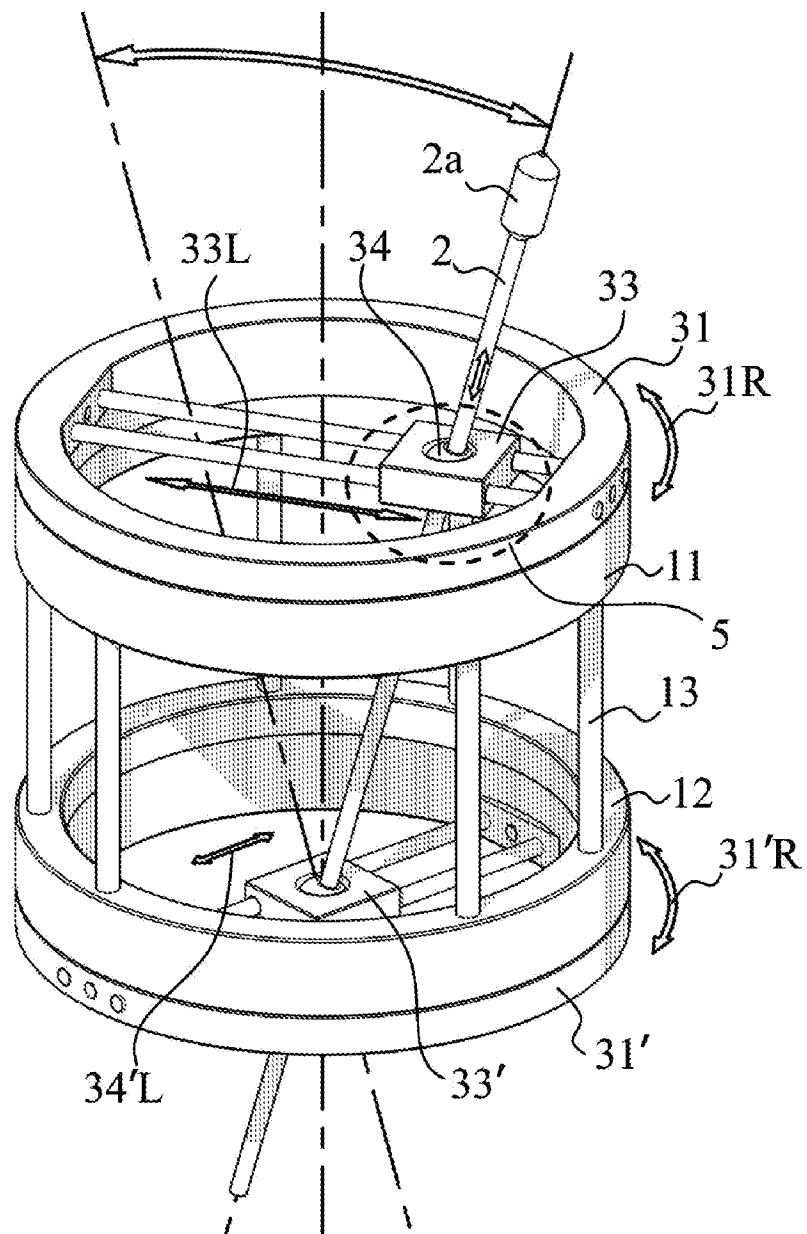
[Fig. 1]



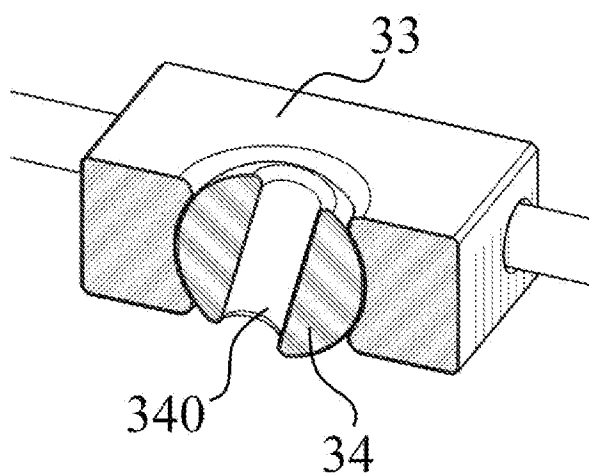
[Fig. 2]



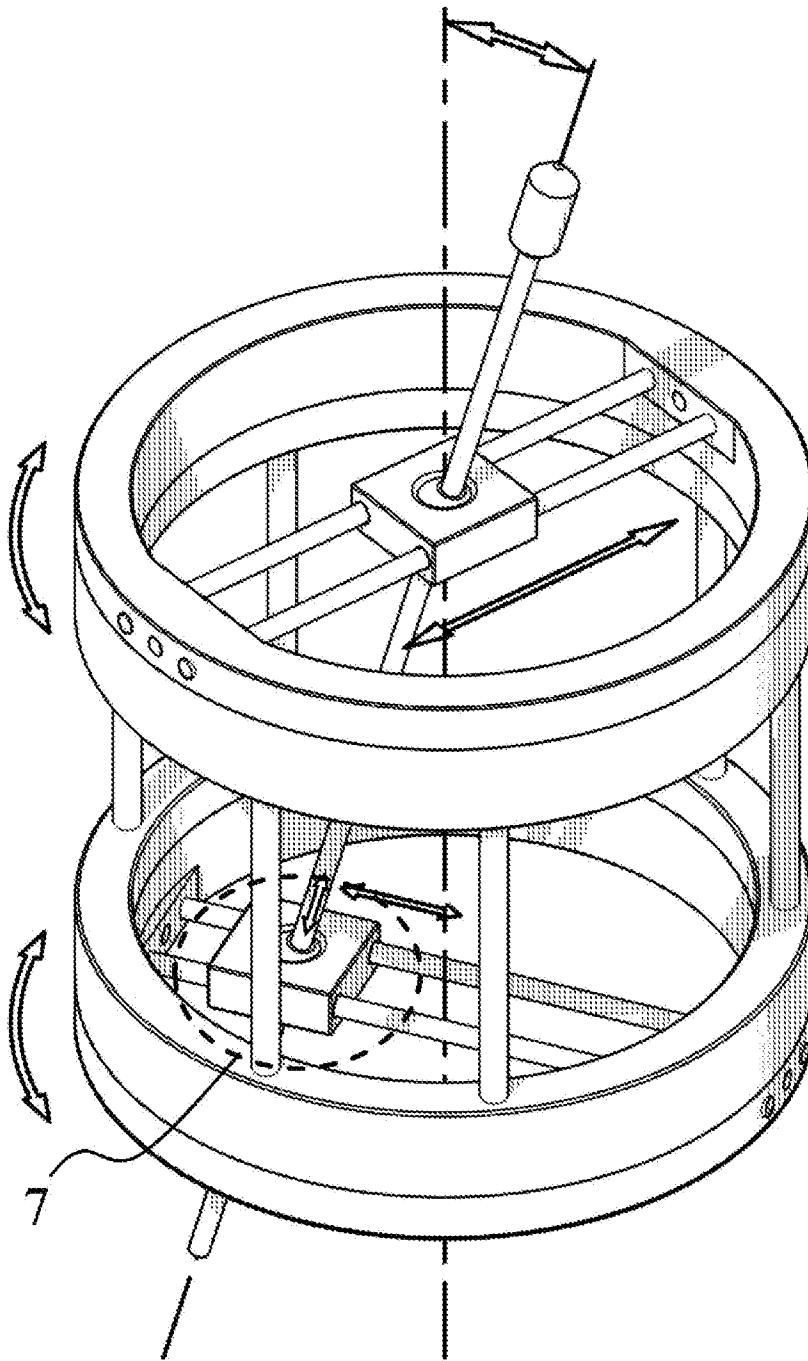
[Fig. 4]



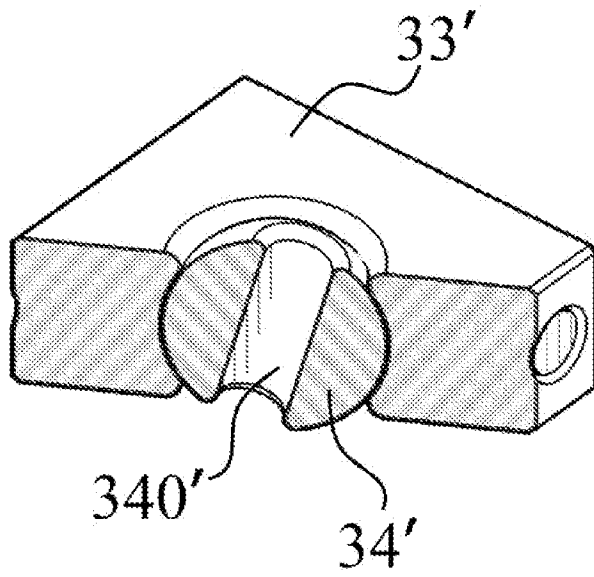
[Fig. 5]



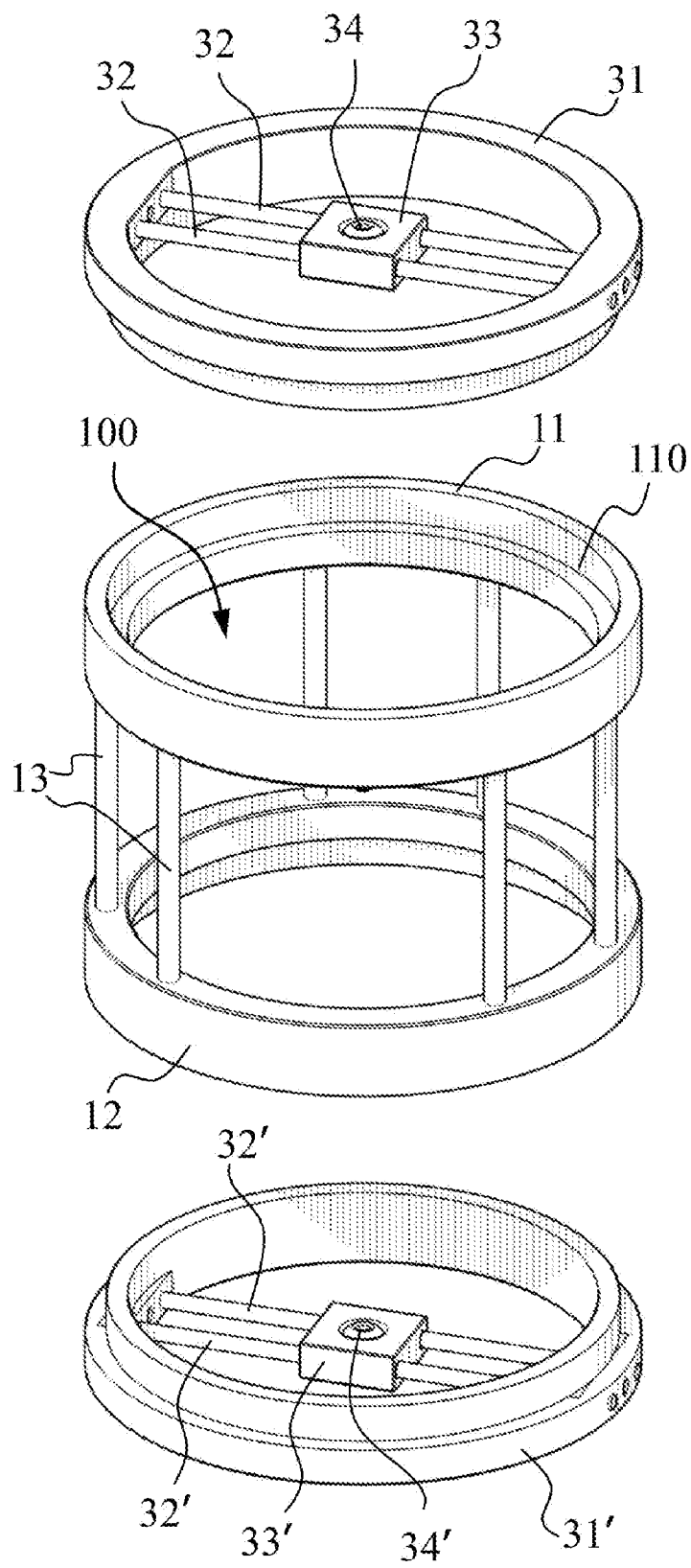
[Fig. 6]



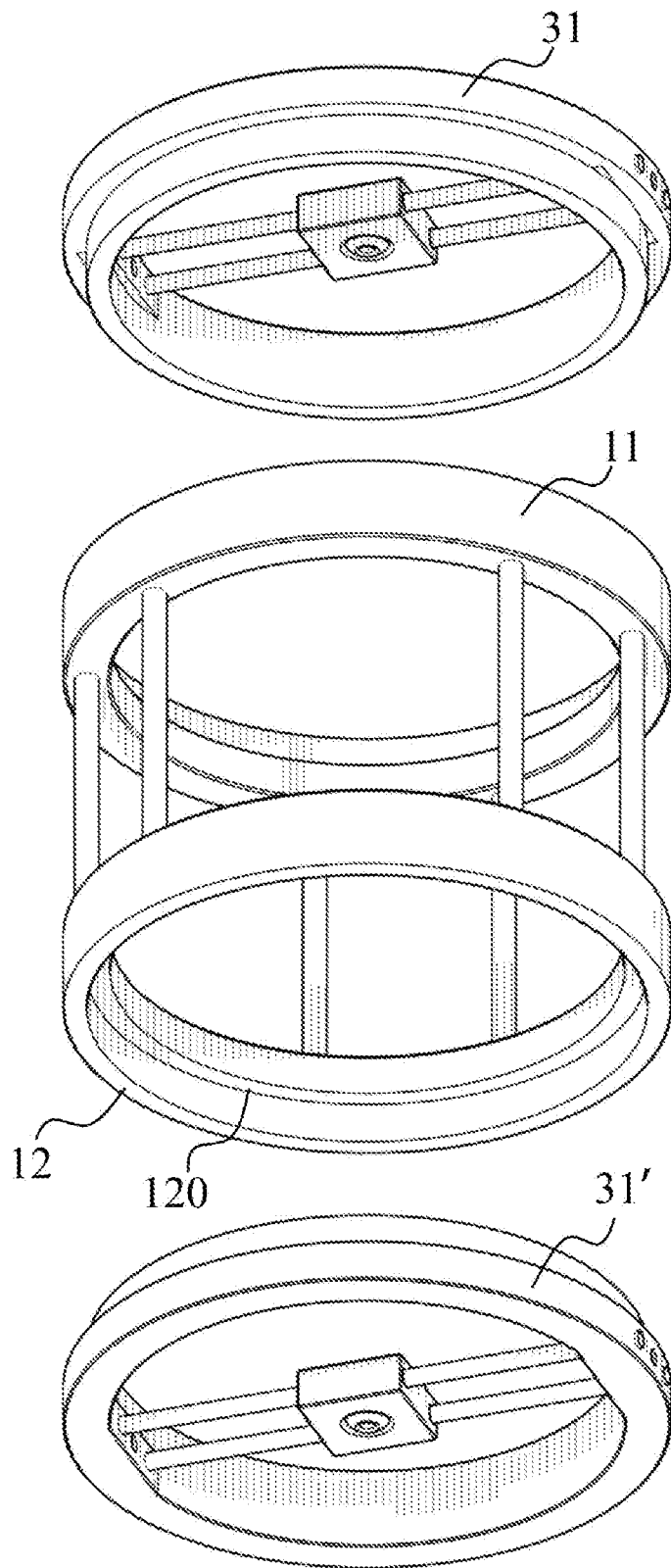
[Fig. 7]



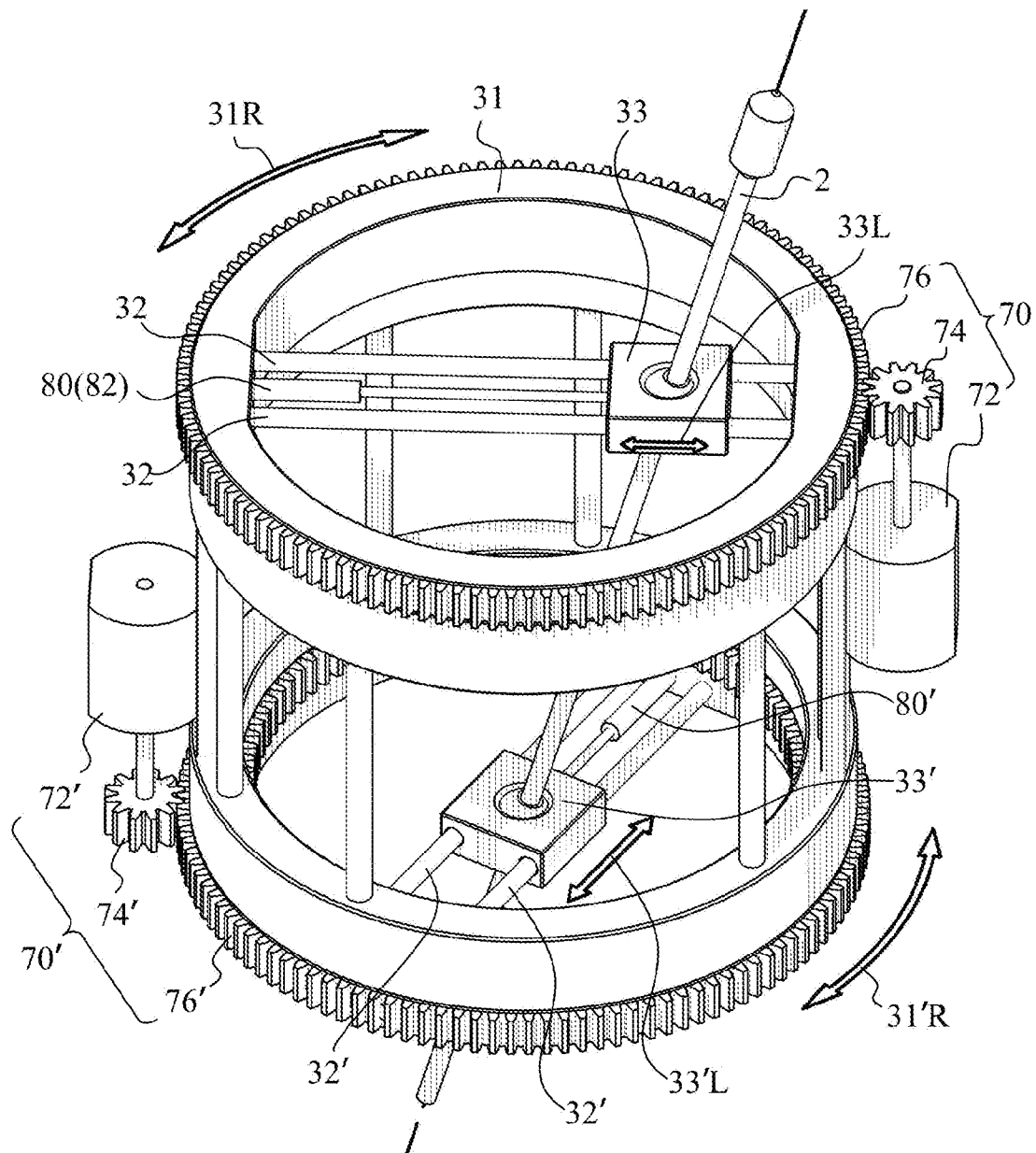
[Fig. 8]



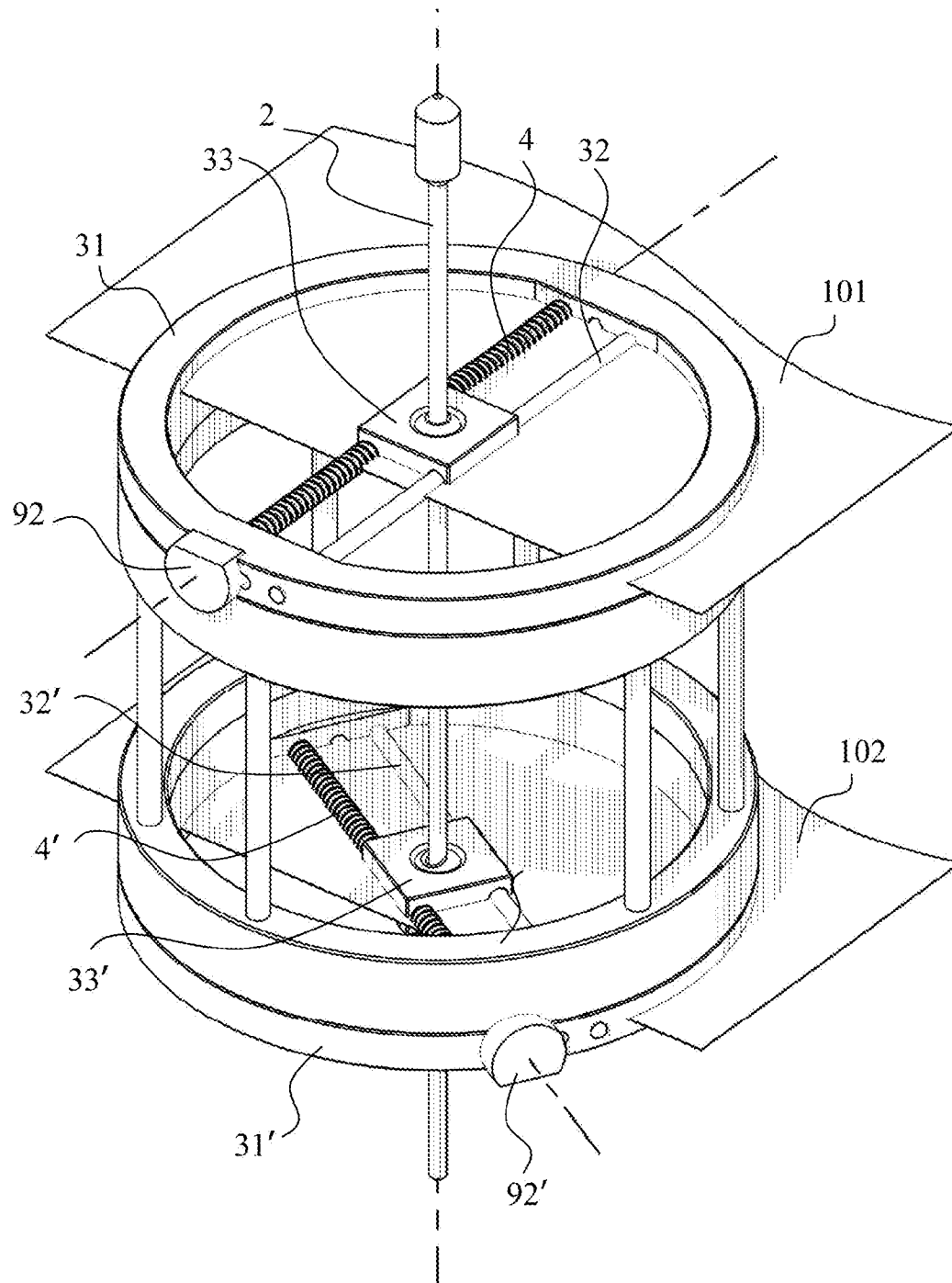
[Fig. 9]



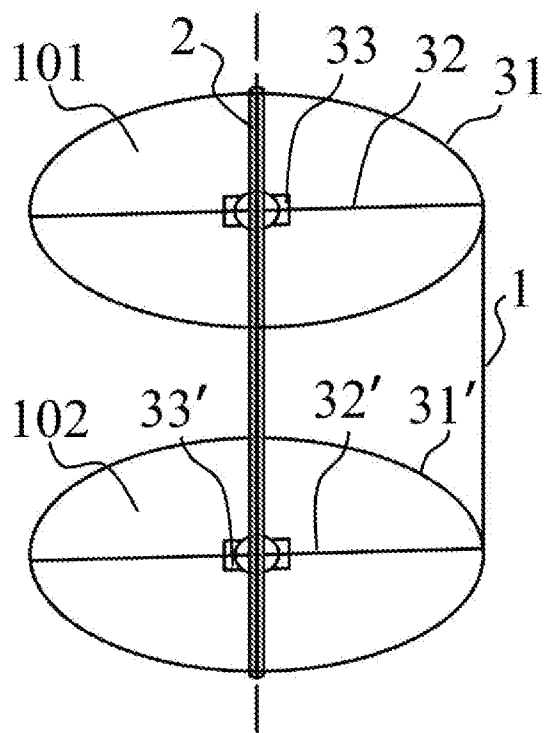
[Fig. 10A]



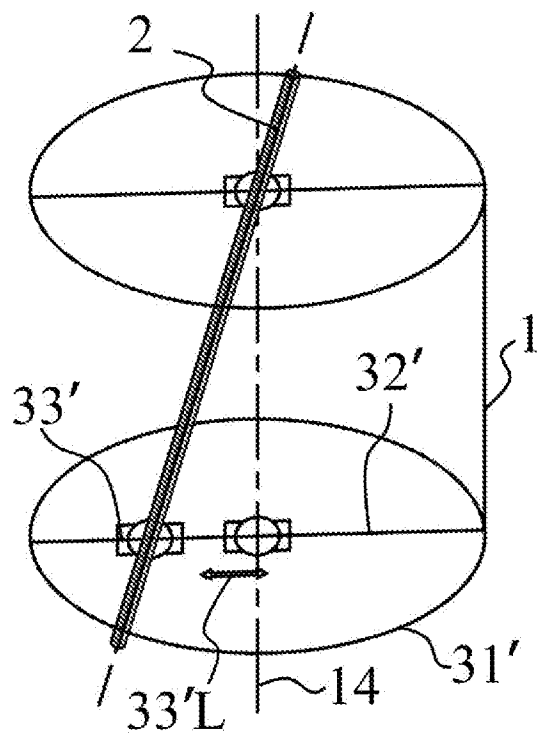
[Fig. 10B]



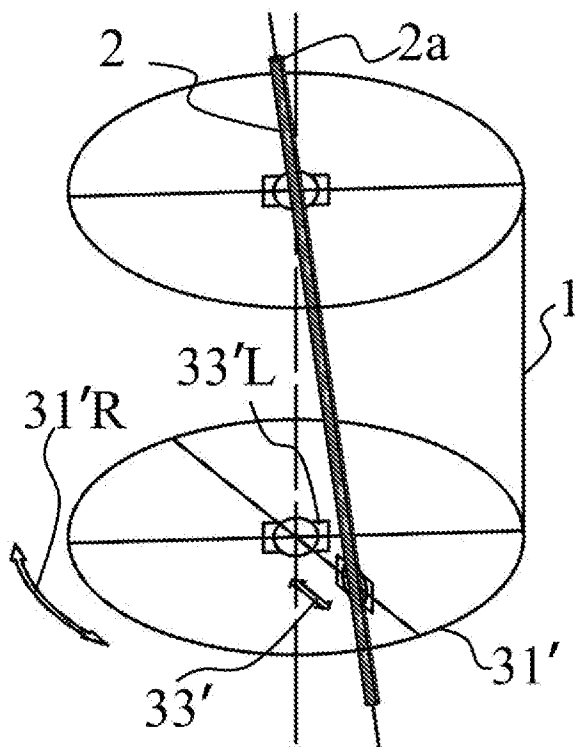
[Fig. 11]



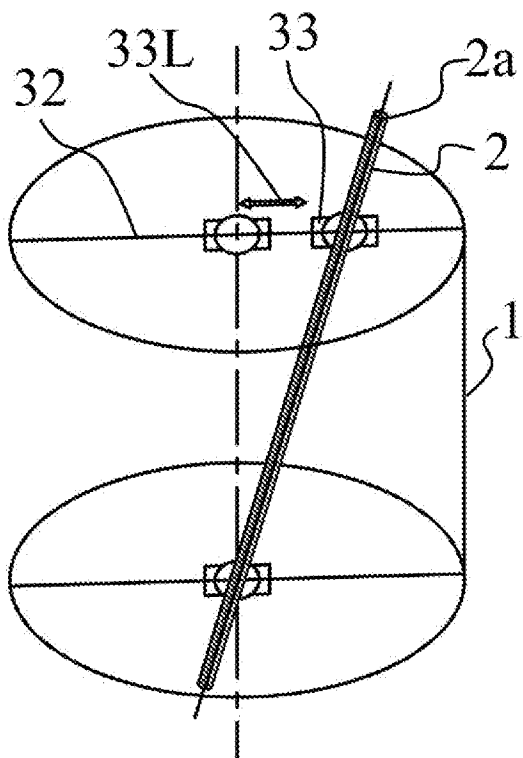
[Fig. 12]



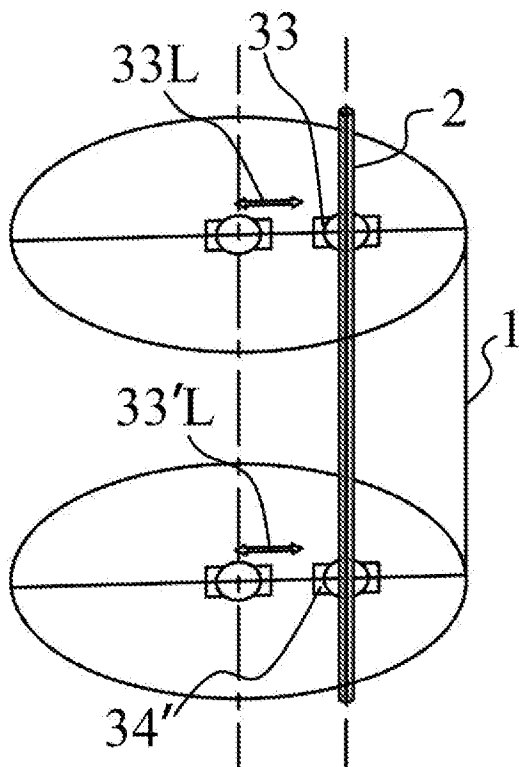
[Fig. 13]



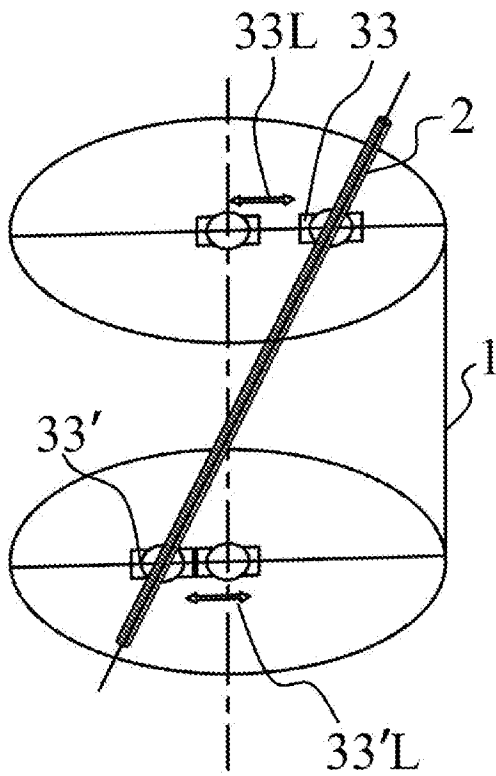
[Fig. 14]



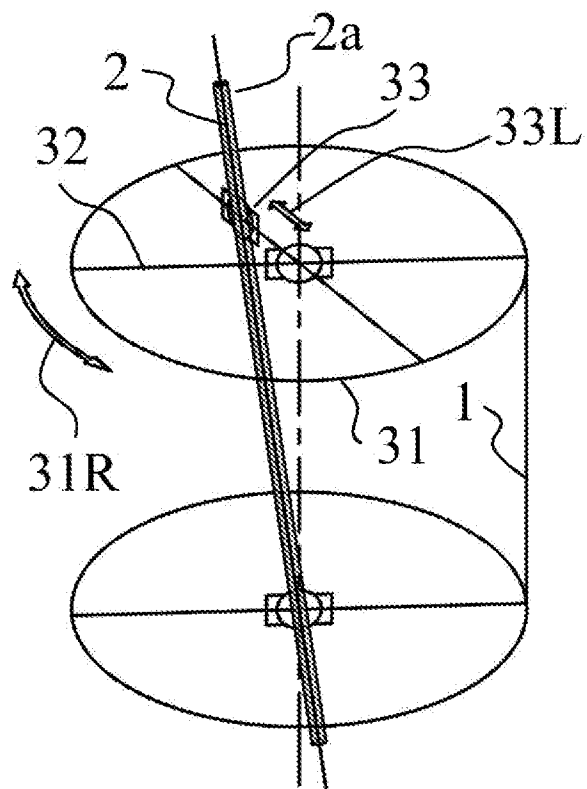
[Fig. 15]



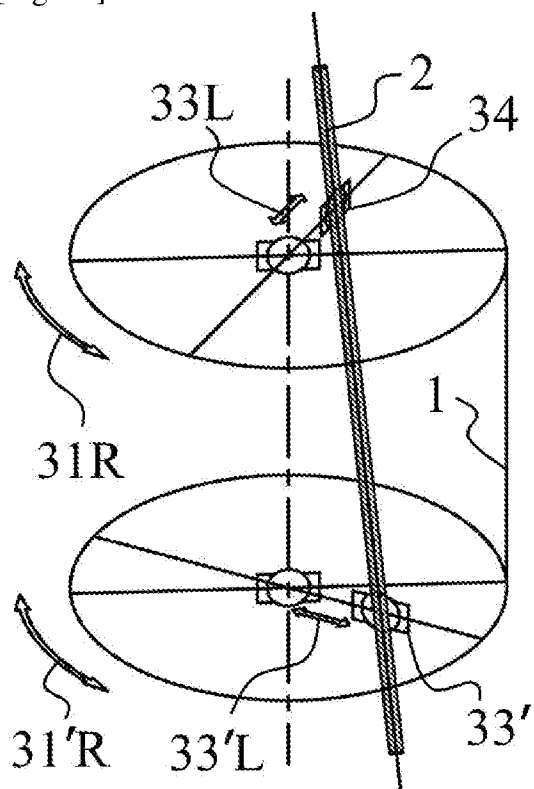
[Fig. 16]



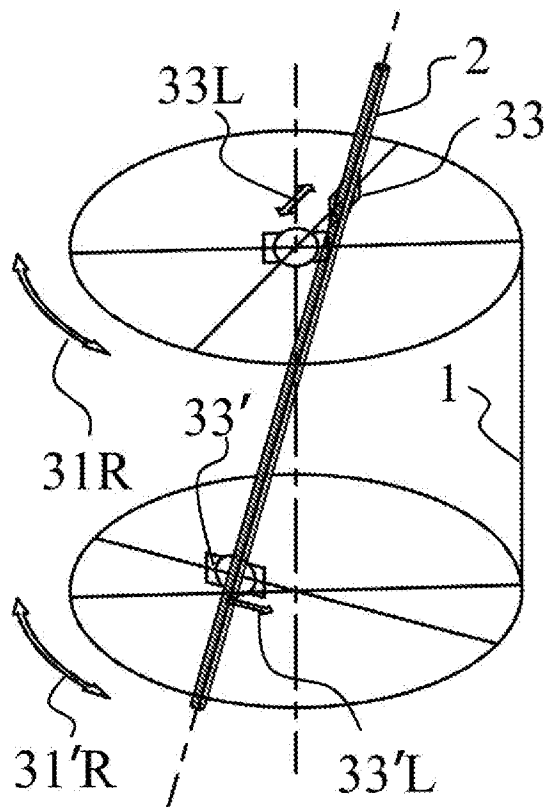
[Fig. 17]



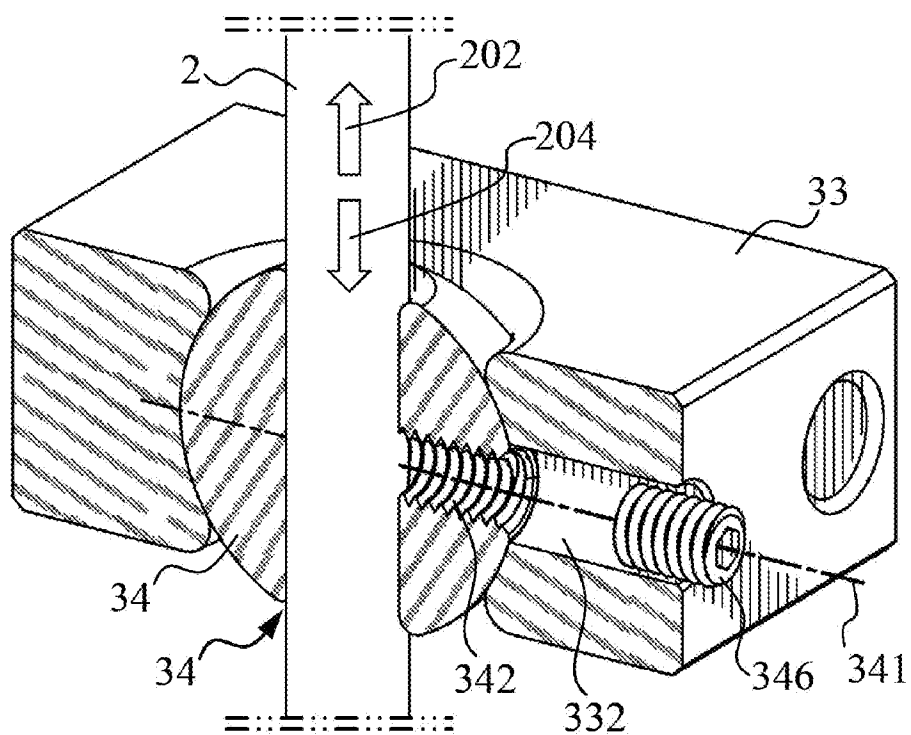
[Fig. 18]



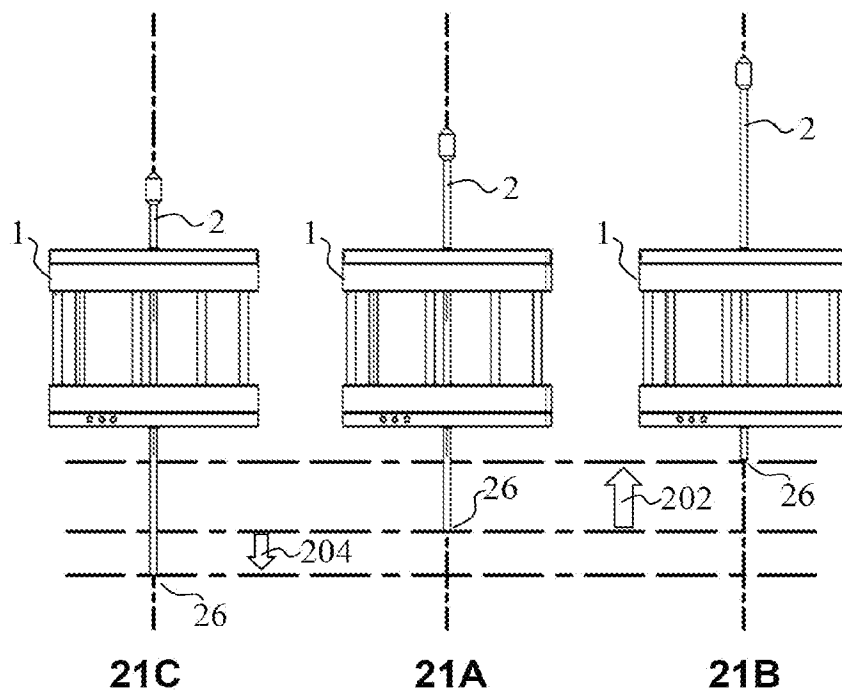
[Fig. 19]



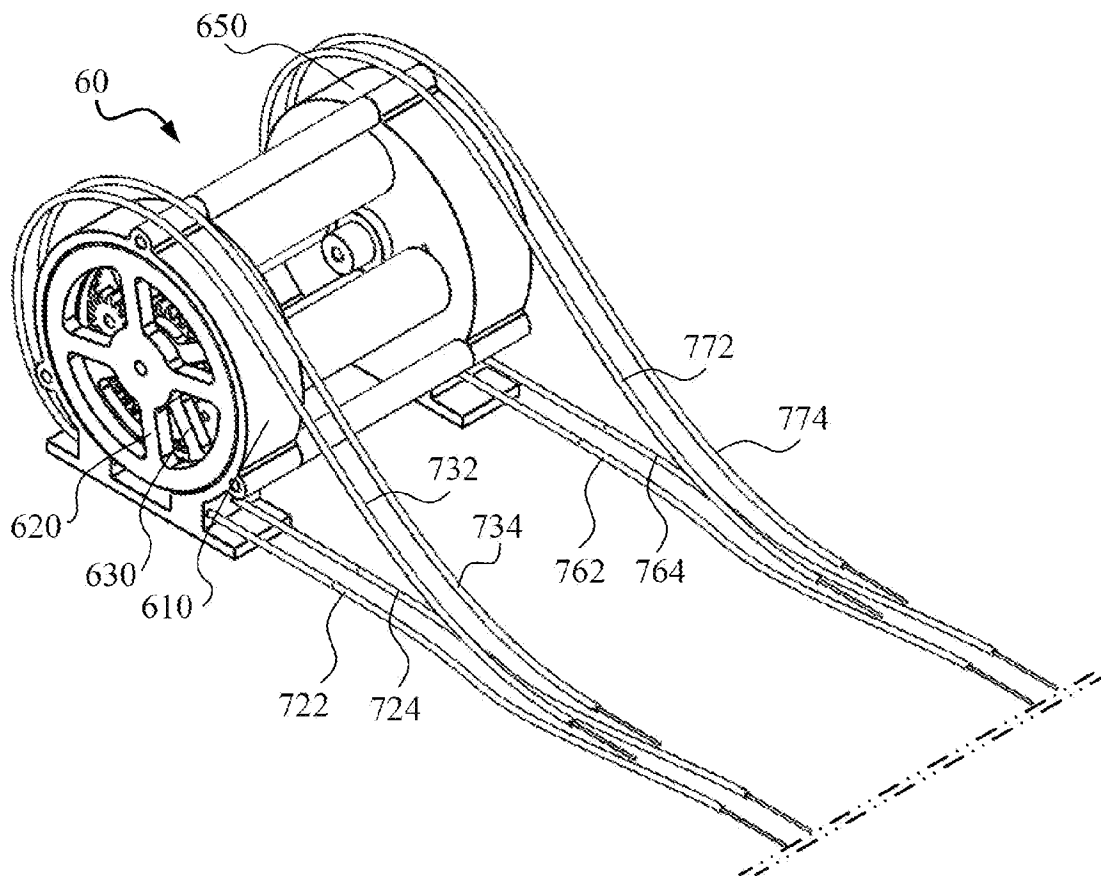
[Fig. 20]



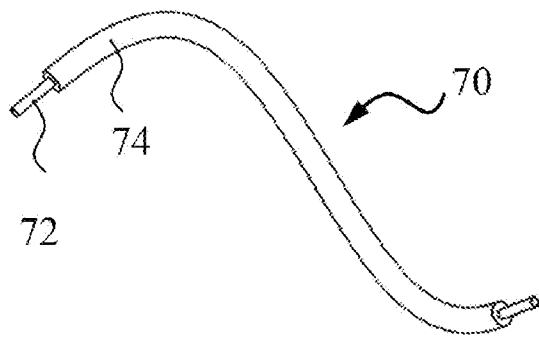
[Fig. 21]



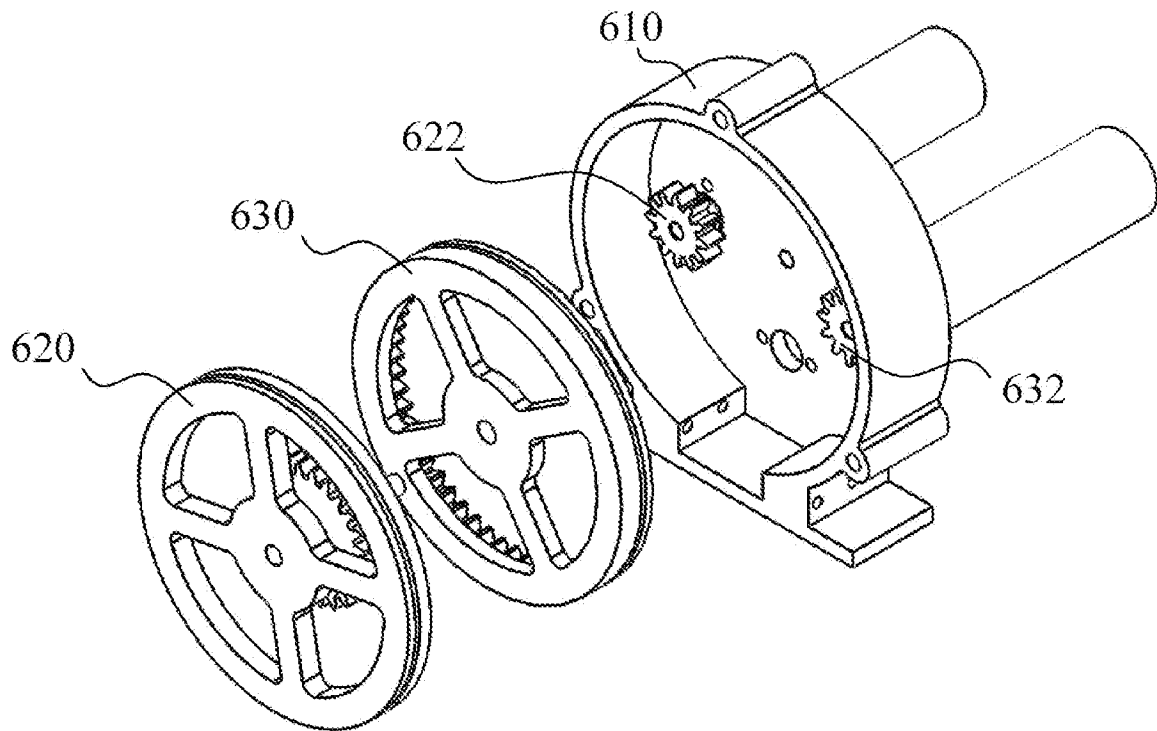
[Fig. 22]



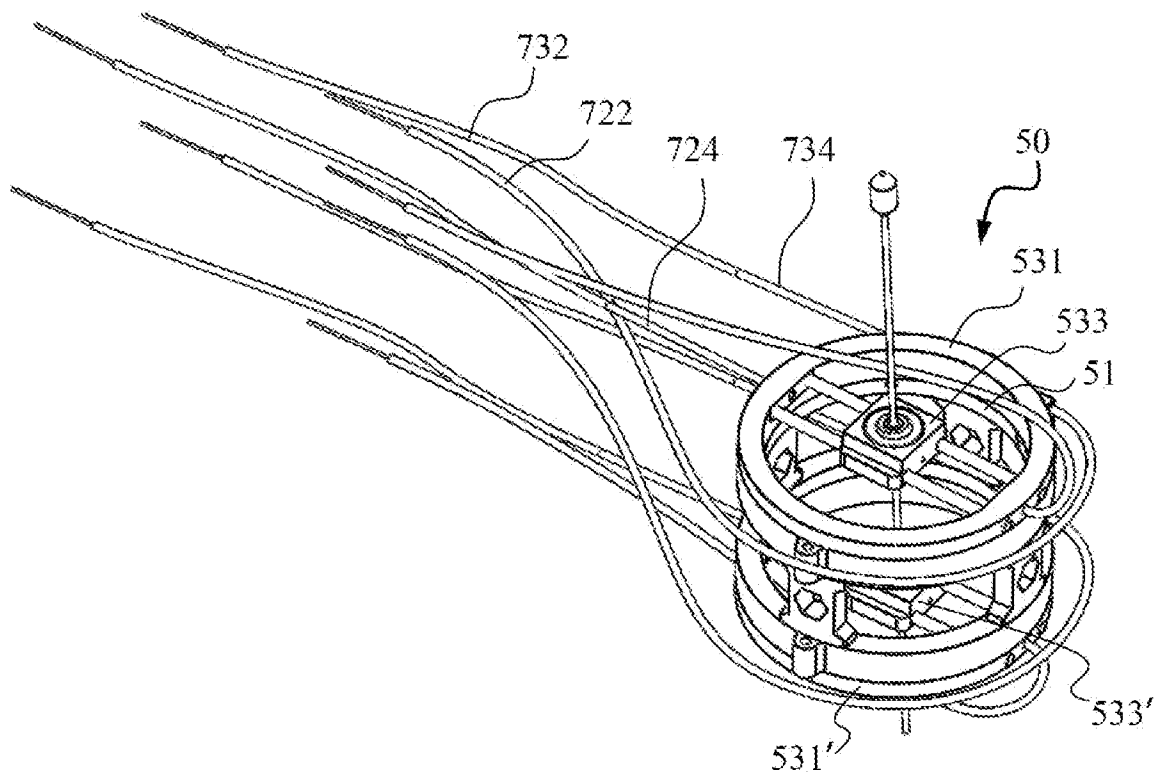
[Fig. 23]



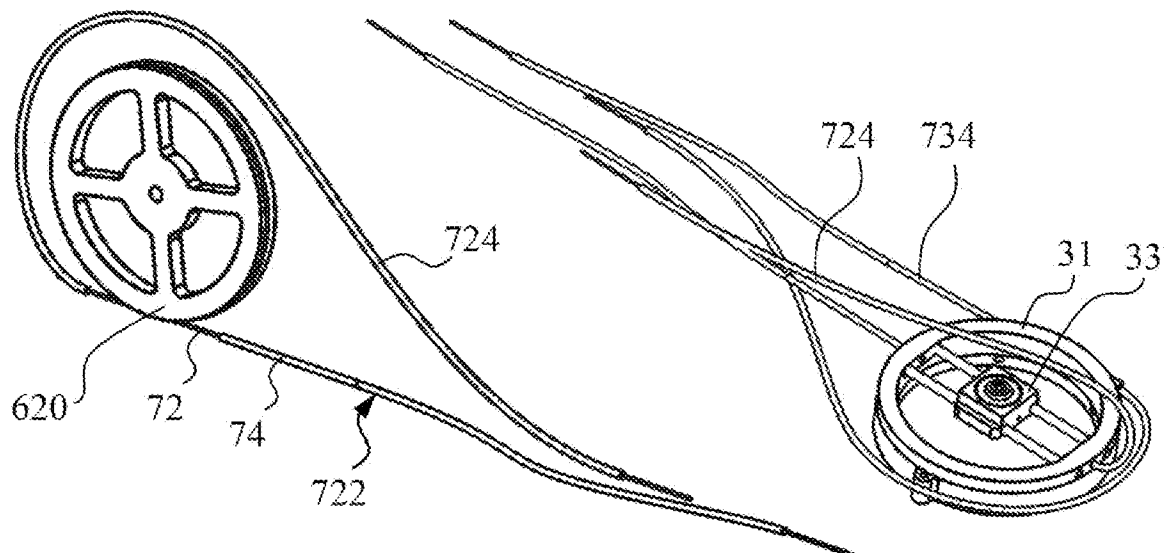
[Fig. 24]



[Fig. 25]



[Fig. 26]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2019/050325

A. CLASSIFICATION OF SUBJECT MATTER**A61B 34/30 (2016.01)** A61B 10/02 (2006.01) B25J 9/10 (2006.01)

According to International Patent Classification (IPC)

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A61B; B25J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

FAMPAT: robot, rotary, slide, posture, orientation, biopsy, 机械手, 圆周, 滑, 姿态, 方向, 穿刺 and similar terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	CN 101933842 A (KUNSHAN INDUSTRIAL TECHNOLOGY RESEARCH INSTITUTE) 5 January 2011 Whole document, especially figs. 1-3, para. [0045]-[0055] of the original non-English language document (a machine translation is enclosed only for your reference)	1-5, 9, 16-17, 21, 28 29-33 6-8, 10-15, 18-20, 22-27
X	CN 106965178 A (ZHEJIANG INSTITUTE OF MECHANICAL & ELECTRICAL ENGINEERING) 21 July 2017 Whole document, especially figs. 1-4, para. [0026]-[0033] of the original non-English language document (a machine translation is enclosed only for your reference)	1-4, 16, 28
Y	US 2017/0014193 A1 (NG K. W. ET AL.) 19 January 2017 Whole document, especially figs. 2A and 2B, para. [0052]	29-33

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Date of the actual completion of the international search

27/09/2019

(day/month/year)

Date of mailing of the international search report

08/10/2019

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IP OS Intellectual Property Office of Singapore
1 Paya Lebar Link, #11-03
PLQ 1, Paya Lebar Quarter
Singapore 408533

Email: pct@ipos.gov.sg

Authorized officer

Chen Jiahe (Dr)

IPOS Customer Service Tel. No.: (+65) 6339 8616

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2019/050325**C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 103786151 A (TIANJIN UNIVERSITY OF TECHNOLOGY) 14 May 2014 Whole document of the original non-English language document (a machine translation is enclosed only for your reference)	
A	US 2015/0051619 A1 (COOPER T. G. ET AL.) 19 February 2015 Whole document	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SG2019/050325

Note: This Annex lists known patent family members relating to the patent documents cited in this International Search Report. This Authority is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 101933842 A	05/01/2011	NONE	
CN 106965178 A	21/07/2017	NONE	
US 2017/0014193 A1	19/01/2017	SG 10201505560Y	27/02/2017
CN 103786151 A	14/05/2014	NONE	
US 2015/0051619 A1	19/02/2015	NONE	