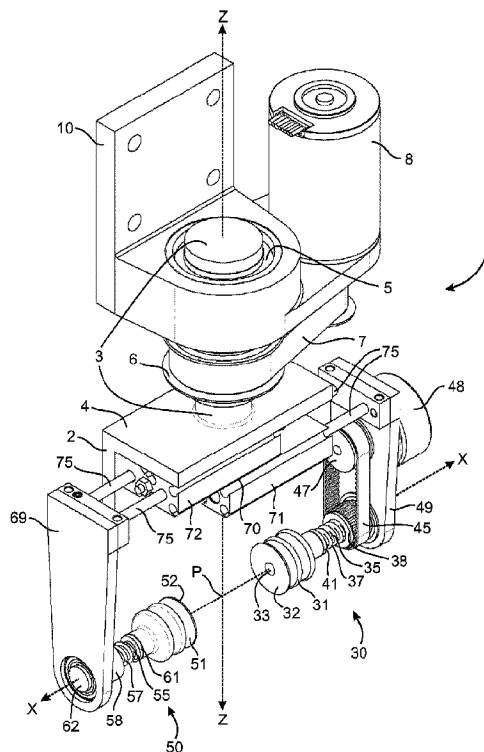




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 (54) Title: GRIPPER, SYSTEM AND PROCESS FOR GRIPPING, ORIENTING AND HANDLING A BIOLOGICAL HORTICULTURAL OBJECT



(57) **Abrégé/Abstract:**

A gripper has a mounting bracket, opposed rotatable gripper heads mounted on the bracket, a translation actuator configured to translate at least one of the gripper heads along a gripper head rotation axis to grip a horticultural object between the gripper

(57) **Abrégé(suite)/Abstract(continued):**

heads, a drive shaft configured to rotate the object, at least one rotation actuator configured to rotate at least one of the gripper heads to rotate the object between the gripper heads, and the at least one rotation actuator configured to rotate the drive shaft. The gripper heads are rotatable about a common gripper head rotation axis. The drive shaft is configured to rotate the object about a second rotation axis orthogonal to the gripper head rotation axis, the second rotation axis passing between the gripper heads. The gripper is useful in systems and processes for handling solid three-dimensional biological horticultural objects.

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(54) Title: GRIPPER, SYSTEM AND PROCESS FOR GRIPPING, ORIENTING AND HANDLING A BIOLOGICAL HORTICULTURAL OBJECT

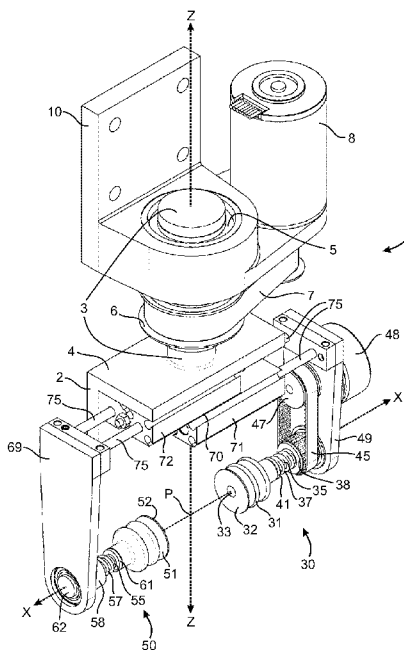


Fig. 1

(57) Abstract: A gripper has a mounting bracket, opposed rotatable gripper heads mounted on the bracket, a translation actuator configured to translate at least one of the gripper heads along a gripper head rotation axis to grip a horticultural object between the gripper heads, a drive shaft configured to rotate the object, at least one rotation actuator configured to rotate at least one of the gripper heads to rotate the object between the gripper heads, and the at least one rotation actuator configured to rotate the drive shaft. The gripper heads are rotatable about a common gripper head rotation axis. The drive shaft is configured to rotate the object about a second rotation axis orthogonal to the gripper head rotation axis, the second rotation axis passing between the gripper heads. The gripper is useful in systems and processes for handling solid three-dimensional biological horticultural objects.

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GRIPPER, SYSTEM AND PROCESS FOR GRIPPING, ORIENTING AND HANDLING A
BIOLOGICAL HORTICULTURAL OBJECT

Cross-reference to Related Applications

This application claims priority to United States Provisional Patent Application
5 USSN 62/501,000 filed May 3, 2017.

Field

This application relates to horticulture. In particular, this application relates to a gripper, system and process for gripping, orienting and handling a solid three-dimensional biological horticultural object.

10 Background

Greenhouses plant millions of bulbs each year to produce cut and potted flowers. During the planting process flower bulbs are dumped onto conveyors in bulk before workers pick, orient and place each one with its roots down in a growing medium. Bulbs used for flower production are typically grown in regular arrays (e.g. in rectangular plastic crates, in
15 hydroponic trays, on spikes, etc.) arranged neatly to maximize the usage of greenhouse space. Aligning each bulb properly promotes an even rate of growth and ensures that the resulting flowers are approximately equal in height at harvest time. The wholesale price of flowers is based on their length so consistent quality (i.e. height) is very important to growers.

20 The planting process is manually intensive; no automated solutions have been adopted by growers. Workers can plant approximately 3000 bulbs per hour per person. This high throughput is one of the primary challenges to automation. Another challenge is the large variation in size and shape of flower bulbs. These variations can be significant within the same species, let alone between different species, which makes handling and
25 alignment difficult. The bulbs are also very sensitive to shock and vibration once they start to grow, preventing the use of many mechanical orientation techniques, such as vibratory hoppers.

There remains a need for an automated handling system for solid three-dimensional biological horticultural objects, which automatically orients and places such objects in a
30 desired area, for example automatically orients and plants flower bulbs.

Summary

In one aspect, there is provided a gripper for gripping and re-orienting a solid three-dimensional biological horticultural object, the gripper comprising: a mounting bracket; opposed first and second rotatable gripper heads rotatably mounted on the mounting
5 bracket, the opposed first and second rotatable gripper heads rotatable about a common gripper head rotation axis; a translation actuator configured to translate at least one of the opposed rotatable gripper heads along the gripper head rotation axis to grip a solid three-dimensional biological horticultural object between the opposed first and second rotatable gripper heads; a drive shaft configured to rotate the object about a second rotation axis
10 substantially orthogonal to the gripper head rotation axis, the second rotation axis passing between the opposed first and second rotatable gripper heads; and, at least one rotation actuator, the at least one rotation actuator configured to rotate the drive shaft to thereby rotate the object, and the at least one rotation actuator configured to rotate at least one of the opposed rotatable gripper heads to thereby rotate the object gripped between the
15 opposed first and second rotatable gripper heads.

In another aspect, there is provided a gripper for gripping and re-orienting a solid three-dimensional biological horticultural object, the gripper comprising: a mounting bracket; opposed first and second rotatable gripper heads rotatably mounted on the mounting bracket, the opposed first and second rotatable gripper heads rotatable about a
20 common gripper head rotation axis; a translation actuator configured to translate at least one of the opposed rotatable gripper heads along the gripper head rotation axis to grip a solid three-dimensional biological horticultural object between the opposed first and second rotatable gripper heads; a drive shaft connected to the mounting bracket, the drive shaft configured to rotate the mounting bracket about a mounting bracket rotation axis, the
25 mounting bracket rotation axis substantially orthogonal to the gripper head rotation axis, the mounting bracket rotation axis passing between the opposed first and second rotatable gripper heads; and, at least one rotation actuator, the at least one rotation actuator configured to rotate at least one of the opposed rotatable gripper heads to thereby rotate the object gripped between the opposed first and second rotatable gripper heads, and the
30 at least one rotation actuator configured to rotate the drive shaft to thereby rotate the mounting bracket.

In one embodiment, the drive shaft may be mounted on a first side of the mounting bracket, the translation actuator may be mounted on a second side of the mounting bracket opposed to the first side along the mounting bracket rotation axis, and the opposed first
35 and second rotatable gripper heads may be rotatably mounted on first and second opposed

flanges, respectively, the first and second opposed flanges mounted on opposed translatable elements of the translation actuator, whereby movement of the opposed translatable elements causes the opposed flanges to move toward or away from each other thereby translating the opposed rotatable gripper heads along the gripper head rotation
5 axis.

In one embodiment, the drive shaft may be connected to a third gripper head and the drive shaft may be configured to rotate the third gripper head about the second rotation axis. The drive shaft may pass through the mounting bracket and may be rotatable without rotating the mounting bracket. The third gripper head may be translatable along the second
10 rotation axis, for example by translating the drive shaft along the second rotation axis. The third gripper head may be deployed to grip the object and then translate the object along the second rotation axis to be positioned on the gripper head rotation axis for gripping by the rotatable gripper heads or for releasing into a storage area. Translation of the third gripper head may be accomplished without moving the mounting bracket. Rotation of the
15 third gripper head about the second rotation axis may also orient the object into a desired orientation before being gripped by the rotatable gripper heads. The third gripper head may be a jamming gripper head, a suction cup, a pincer or the like. Jamming gripper heads are particularly useful for irregularly shaped objects.

In some embodiment, the second rotation axis and the gripper head rotation axis
20 are the only rotation axes on the gripper. The at least one rotation actuator may comprise a first rotation actuator configured to rotate the at least one of the opposed rotatable gripper heads, and a second rotation actuator configured to rotate the drive shaft. The rotation actuators may comprise motors, for example electric, hydraulic or pneumatic motors or the like. Belts, drive wheels, chains, sprockets, gears or other elements useful in connecting
25 the rotation actuators to the drive shaft and/or gripper heads may be employed.

In some embodiments, the mounting bracket may comprise a horizontally oriented plate. The drive shaft may extend substantially vertically upwardly from the horizontally oriented plate, for example from an upper surface of the horizontally oriented plate, and preferably from a center of the plate. In such a configuration, the second rotation axis may
30 be a vertical axis. In one embodiment, rotation of the drive shaft about the second rotation axis rotates the plate about the mounting bracket rotation axis (i.e. in a horizontal plane when the mounting bracket rotation axis is a vertical axis). In another embodiment, the drive shaft passes through the plate and rotation of the drive shaft does not rotate the plate.

The opposed first and second rotatable gripper heads rotatably mounted on the mounting bracket may be connected to and situated below the plate. The opposed gripper heads rotate about a common gripper head rotation axis substantially orthogonal to the second rotation axis. When the second rotation axis is a vertical axis, the gripper head rotation axis is a horizontal axis. The second rotation axis may or may not intersect the gripper head rotation axis. Preferably, the second rotation axis intersects the gripper head rotation axis. Preferably, the opposed gripper heads are mounted below the plate such that the second rotation axis and the gripper head rotation axis intersect at an intersection point below the plate. With the drive shaft centrally located on or through the upper surface of the plate, the opposed gripper heads are symmetrically disposed along the gripper head rotation axis on either side of the intersection point. When the two rotation axes intersect, calculation of the rotation between the initial random orientation of the object and the predetermined orientation is simplified. Additionally, physical size of the gripper is reduced.

At least one of the opposed gripper heads is translatable along the gripper head rotation axis to permit gripping of the object between the opposed gripper heads. Preferably, both of the opposed gripper heads are translatable, preferably translatable in concert. Each of the opposed gripper heads preferably translate toward the intersection point of the two rotational axes when being translated for gripping, and away from the intersection point when being translated for releasing the object. The opposed gripper heads may be mounted on at least one translation actuator, which is configured to translate the opposed gripper heads. The translation actuator preferably comprises a single actuator that can simultaneously translate both gripper heads along the gripper head rotation axis. The translation actuator may be pneumatic, hydraulic, electric or any other suitable type of actuator. The translation actuator may be mounted on to an underside or on top of the horizontally oriented plate. The opposed gripper heads may be mounted on movable elements of the translation actuator such that extension and retraction of the movable elements effect translation of the opposed gripper heads. Preferably, the opposed gripper heads are mounted on flanges, the flanges mounted on the moveable elements of the translation actuator. The flanges may extend away from the translation actuator parallel to the second rotation axis so that the opposed gripper heads are located below the horizontally oriented plate, and below the translation actuator, by a distance sufficient to accommodate a size of the object to be gripped between the opposed gripper heads.

The opposed gripper heads are both rotatable about the gripper head rotation axis and translatable along the gripper head rotation axis. Preferably, the opposed gripper heads comprise shafts through which the gripper head rotation axis passes. The shafts

may be mounted in bearings that permit rotation of the shafts within the bearings and translation of the shafts through the bearings. The shafts may be further housed in housings, whereby the shafts and housings are machined with matching features such as flat faces, keys or the like so that driving rotation of at least one of the housings causes
5 rotation of the shaft in the at least one housing while permitting sliding motion of the shaft in the housing while still transmitting torque and rotation. The housings around the shafts of both opposed gripper heads may be driven, or one of the housings may be idle, allowing rotational forces transmitted through a gripped object to the idle opposed gripper head to rotate the idle opposed gripper head.

10 The opposed gripper heads preferably possess a degree of compliancy along the gripper head rotation axis to provide an ability to handle objects with some size variation, and to reduce or eliminate damage to the object due to over-gripping. Compliancy in the opposed gripper heads permits the use of a less accurate, and therefore less expensive, translation actuator. Preferably, the opposed gripper heads comprise flexible fingertips,
15 springs or both flexible fingertips and springs to provide compliancy, although other ways of providing compliancy may be provided. Flexible fingertips may be made of a deformable material, for example an elastomer or a thermoplastic. The flexible fingertips may be compressible along the gripper head rotation axis. The fingertips may be mounted on spring-loaded shafts, springs on the spring-loaded shafts abutting stops to provide
20 resiliency along the gripper head rotation axis by biasing at least one of the opposed gripper heads along the gripper head rotation axis. Any type of springs may be employed (e.g. helical springs, leaf springs, and the like). The flexible fingertips may conform around a surface of the object, and the spring-loaded shafts may compress to further compensate for larger variations in object size and to prevent or minimize crushing the object when
25 gripped.

Advantageously, the gripper only requires two axes of rotation having full 360° ranges of motion to handle all random object orientations and properly re-orient the object around the object's own center of gravity (or approximate center of gravity) in two independent angular directions, which is simpler and less expensive to manufacture than
30 typical 6-axis robotic grippers. By rotating the gripper about the second rotation axis before gripping the object, then rotating the gripper heads about the gripper head rotation axis after the object has been gripped, and finally rotating the gripper once again about the second rotation axis before releasing the object, any object randomly oriented in three orthogonal directions may be re-oriented into any specified orientation, without relying on
35 any assumptions of the object's physical shape or dynamic behavior.

In embodiments utilizing the third gripper head, the object may be first gripped by the third gripper head and rotated without rotating the entire gripper before being gripped by the opposed gripper heads. Once gripped by the opposed gripper heads, the object may be rotated into the desired orientation. Again, any object randomly oriented in three
5 orthogonal directions may be re-oriented into any specified orientation, without relying on any assumptions of the object's physical shape or dynamic behavior. The use of the third gripper head permits reduction in the physical space occupied by the entire gripper, which facilitates placing objects closer together in the storage area when an array of grippers is being used. The ability to translate the third gripper head along the second rotation axis
10 also facilitates placing the objects directly in a tightly packed storage area without employing an intermediate staging area for the objects.

Further, the gripper is modular, therefore multiple instances of the gripper may be used in an array to handle multiple objects in parallel leading to greater throughput. Furthermore, the gripper is robust in handling non-uniform objects, i.e. objects that exhibit
15 relatively large and uncontrolled variations in size and shape. The simplicity, modularity, robustness and low cost lend to utilizing a plurality of the grippers in a process line to provide a handling process that is more efficient with higher throughputs than existing prior art processes for handling solid three-dimensional biological horticultural objects having uncontrolled variations in size and shape.

In another aspect, there is provided a gripping system for gripping and re-orienting a solid three-dimensional biological horticultural object, the gripping system comprising: at least one gripper as defined above; a visioning device configured to capture information about a randomly-oriented solid three-dimensional biological horticultural object to be gripped and re-oriented; and, a controller operably linked to the gripper and the visioning
20 device, the controller programmed to position and orient the gripper in a first configuration suitable for gripping the randomly-oriented object based on the information about the object captured by the visioning system, operate the gripper to grip the randomly-oriented object between the opposed first and second gripper heads of the gripper, and operate the gripper to rotate the gripped object from the random orientation into a predetermined orientation,
25 the predetermined orientation based on predetermined parameters for suitably orienting the object for further processing.

The system may comprise a variety of components including, for example, one or more grippers, one or more visioning devices (e.g. cameras or line scanners), a controller operatively linked to the one or more grippers and the one or more grippers. The controller
35 may be configured to operate the one or more grippers to grip and rotate randomly-oriented

objects based on information collected by the one or more visioning devices. One or more sensors (e.g. laser sensors) in electronic communication with the controller may be used to assist in locating the objects.

The system may further comprise one or more of a user interface for the controller,
5 an electrical supply, a conveyor configured to receive and singulate a plurality of the randomly-oriented objects, a holding area for re-oriented objects and at least one automated device (e.g. a robotic arm, a linear actuator or a Cartesian gantry mechanism) for translating the one or more grippers through space to be able to deposit the re-oriented objects in the holding area. Objects singulated on the conveyor at a constant spacing may
10 pass through a field of view of the visioning device. The one or more grippers may comprise a plurality of grippers longitudinally separated along the conveyor by the constant spacing, each of the plurality of grippers operated by the controller to grip a corresponding singulated object on the conveyor.

Control software for controlling aspects of the system may be embodied in the
15 controller. Electronic communication may be provided through wires or wirelessly. The controller may comprise, for example, a computer, an output device and an input device, the computer comprising a microprocessor for controlling operations and a non-transient electronic storage medium for storing information about the objects, the conveyor and the one or more grippers, and/or for storing computer executable code for carrying out
20 instructions for implementing the process. The computer may further comprise a transient memory (e.g. random access memory (RAM)) accessible to the microprocessor while executing the code. The computer may be conveniently mounted in an electrical panel for the system. A plurality of computer-based apparatuses may be connected to one another over a computer network system and geographically distributed. One or more of the
25 computer-based apparatuses in the computer network system may comprise a microprocessor for controlling operations and a non-transient electronic storage medium for storing information about the objects, the conveyor and the one or more grippers, and/or for storing computer executable code for carrying out instructions for implementing the process, and the computer-based apparatuses in the network may interact so that the
30 handling operation may be carried out automatically from remote locations. The output device may be a monitor, a printer, a device that interfaces with a remote output device or the like. The input device may be a keyboard, a mouse, a microphone, a device that interfaces with a remote input device or the like. With a computer, data may be a graphically displayed in the output device.

The control software may be configured to manage a variety of functions in the system. The control software may comprise, for example: vision application software configured to process digital data received from the one or more visioning devices into orientation of the objects on the conveyor; orientation control software that calculates
5 rotation angles required; gripper movement software to provide a sequence of movements that the gripper makes for each object; operator interface software to run the user interface; and software for other functions such as turning the conveyor and other equipment on and off, counting objects going into the holding area, etc. For example, the control software may calculate an initial orientation of the randomly-oriented object, calculate rotation angles
10 necessary to rotate the randomly-oriented object into the predetermined orientation and operate the gripper to rotate the gripped object based on the initial orientation and the calculated rotation angles.

In another aspect, there is provided a process for handling solid three-dimensional biological horticultural objects, the process comprising: singulating a solid three-
15 dimensional biological horticultural object from a plurality of solid three-dimensional biological horticultural object, the singulated object randomly oriented with respect to first and second orthogonal axes; determining the orientation of the randomly-oriented singulated object with a visioning system and comparing the orientation of the randomly-oriented singulated object to a predetermined orientation suitable for further processing;
20 deploying a gripper to the singulated randomly-oriented object, moving the gripper based on the comparison to suitably orient the gripper with respect to the randomly-oriented object; gripping the randomly-oriented object with the gripper and rotating the gripper about the first and second orthogonal axes to rotate the object from the random orientation into the predetermined orientation; and, deploying the gripper to place the object in the
25 predetermined orientation into a position for further processing.

The singulated randomly-oriented object may comprise a plurality of singulated randomly-oriented objects spaced apart at predetermined locations with respect to the visioning system. The predetermined locations may be separated by the constant spacing. The gripper may comprise a plurality of grippers operating to substantially simultaneously
30 re-orient the plurality of singulated randomly-oriented objects into the predetermined orientation.

Once the object has been re-oriented into the predetermined orientation, the object may be placed in a position for further processing. The position for further processing may depend on the purpose of the process. In one embodiment, the position for further
35 processing may be a storage area. The storage area may be, for example, a crate, box,

carton, tray or the like. The storage area may be temporary, for example an accumulator to temporarily hold the object before being placed in a more permanent storage area. The storage area may be configured for a desired purpose, for example the storage area may be configured as a planter, a container for commercial sale, a shipping container, a long-term storage container or the like.

The solid three-dimensional biological horticultural object may be, for example, a solid three-dimensional plant-based object intended for planting and/or shipping. Some examples of solid three-dimensional biological horticultural objects are plant bulbs (e.g. flower bulbs) and produce (e.g. fruits and vegetables). Some specific non-limiting examples include tulip bulbs, daffodil bulbs, lily bulbs, hyacinth bulbs, onions, tomatoes, bell peppers, peaches, pears, apples and oranges.

The gripper, system and process advantageously: allow handling objects gently using light pressure to prevent damage; incorporate some degree of mechanical compliancy so that objects of different shapes and sizes may be handled correctly; plants or packages objects in parallel (i.e. multiple objects at the same time) to increase throughput rate; plants or packages objects in a consistent alignment; and/or, are cost effective, for example by avoiding the use of multiple 6-axis industrial robotic manipulators.

Further features will be described or will become apparent in the course of the following detailed description. It should be understood that each feature described herein may be utilized in any combination with any one or more of the other described features, and that each feature does not necessarily rely on the presence of another feature except where evident to one of skill in the art.

Brief Description of the Drawings

For clearer understanding, preferred embodiments will now be described in detail by way of example, with reference to the accompanying drawings, in which:

Fig. 1 is an isometric view of a gripper;

Fig. 2 is a dimetric view of the gripper of Fig. 1;

Fig. 3 is an isometric view of the gripper of Fig. 1 without a vertical axis motor;

Fig. 4A is perspective view of the gripper of Fig. 3 in a vicinity of a randomly-oriented object;

Fig. 4B depicts the gripper of Fig. 4A having been rotated about a vertical axis to align gripper heads to grip the object at a desired location on the object;

Fig. 4C depicts the gripper of Fig. 4B having gripped the object between the gripper heads;

5 Fig. 4D depicts the gripper of Fig. 4C having rotated the object to upwardly orient a tip of the object;

Fig. 4E is a front cross-sectional view of a lower portion of the gripper of Fig. 4D;

Fig. 5 depicts a flow chart illustrating a process for planting tulip bulbs in a growing crate;

10 Fig. 6 depicts a system for handling tulip bulbs in the process of Fig. 5;

Fig. 7 depicts a growing crate in which the tulip bulbs from the system of Fig. 6 are planted;

Fig. 8A is an isometric view of another embodiment of a gripper;

15 Fig. 8B is a cross-sectional side view of the gripper of Fig. 8A with a piston rod extended;

Fig. 9A depicts the gripper of Fig. 8A with a jamming gripper head lowered to engage an object;

Fig. 9B is a bottom perspective view of Fig. 9A;

20 Fig. 10 depicts the gripper of Fig. 9A with the jamming gripper head raised with the object held therein;

Fig. 11 depicts the gripper of Fig. 10 having rotated the object about a vertical axis to align gripper heads to grip the object at a desired location on the object;

Fig. 12 depicts the gripper of Fig. 11 having gripped the object between the gripper heads;

25 Fig. 13 depicts the gripper of Fig. 12 having rotated the object about a horizontal axis to upwardly orient a tip of the object;

Fig. 14 depicts the gripper of Fig. 13 with the object re-gripped by the jamming gripper head; and,

Fig. 15 depicts the gripper of Fig. 14 with the object lowered to a storage area.

Detailed Description

5 With reference to Fig. 1, Fig. 2, Fig. 3, Fig. 4A, Fig. 4B, Fig. 4C, Fig. 4D and Fig. 4E, a mechanical gripper **1** is shown configured for simultaneous orientation of a randomly oriented solid three-dimensional biological horticultural object **20**. The gripper **1** comprises a mounting bracket **2** having a horizontally oriented plate **4** on which an upwardly extending vertically oriented drive shaft **3** is fixedly mounted. The drive shaft **3** is rotatable about a vertical rotation axis **Z**, where rotation of the drive shaft **3** results in rotation of the mounting bracket **2** about the vertical rotation axis **Z**, i.e. rotation of the mounting bracket **2** in a horizontal plane. The drive shaft **3** is rotatably mounted in a bearing **5** in an assembly mount **10**. The drive shaft **3** has a first drive pulley **6** mounted concentrically thereon, the first drive pulley **6** rotatable by a first drive belt **7** driven by a first motor **8** mounted on the assembly mount **10**. The first motor **8** is preferably an electric motor, although other motors may be used, for example hydraulic motors, pneumatic motors and the like. The assembly mount **10** is configured to be securely mounted on a support arm (not shown). The support arm may be moveable to permit translation of the entire gripper **1** through space.

20 The gripper **1** further comprises a first gripper head **30** and a second gripper head **50** opposed to the first gripper head **30**. The opposed gripper heads **30**, **50** are rotatably and translatably mounted below the mounting bracket **2**. The opposed gripper heads **30**, **50** are rotatable around and translatable along a horizontal axis **X**, the horizontal axis **X** substantially orthogonal to the vertical rotation axis **Z** and substantially parallel to the horizontally oriented plate **4**. Preferably, the drive shaft **3** is mounted at a center point of the mounting bracket **2** so that the vertical rotation axis **Z** intersects the horizontal axis **X** at a point **P** between and equidistant from the two gripper heads **30**, **50**. The point **P** is preferably at or proximate a center of gravity of the object **20** when the gripper **1** grips the object **20**.

30 As best seen in Fig. 4E, the first gripper head **30** comprises a flexible first fingertip **31**. The first fingertip **31** is made from a flexible material, for example an elastomer, a thermoplastic or the like, which permits compression and expansion of the first fingertip **31** along the horizontal axis **X**. The second gripper head **50** likewise comprises a flexible second fingertip **51**. The object **20** is gripped between the two fingertips **31**, **51** in contact

with front faces **32**, **52**, respectively, of the first and second fingertips **31**, **51**. The flexible fingertips **31**, **51** provide compliancy for properly gripping and orienting objects of different shapes and sizes. Further, damage to the object **20** due to over-gripping by the gripper heads **30**, **50** is at least partially mitigated by compression of the flexible first and second
5 fingertips **31**, **51**. The first and second fingertips **31**, **51** may be constructed as bellows, where the first fingertip **31** comprises a first hollow interior **34** open to the atmosphere through a first aperture **33** and the second fingertip **51** comprises a second hollow interior **54** open to the atmosphere through a second aperture **53**. Air escapes from the hollow interiors **34**, **54** during compression of the first and second fingertips **31**, **51** to offer less
10 resistance to compression and greater compliance for gripping the object **20**.

The first gripper head **30** further comprises a horizontally oriented first spring-loaded shaft **35** on a distal end of which is mounted the first fingertip **31**. The horizontal axis **X** passes longitudinally through the first spring-loaded shaft **35**. The distal end of the first spring-loaded shaft **35** comprises an outwardly extending first annular protrusion **36** that
15 secures the first fingertip **31** on the first spring-loaded shaft **35**. The first spring-loaded shaft **35** is loaded in a first helical spring **37** within a driven hollow first hub **38**, the first hub **38** mounted in a bearing **36**, the bearing **36** mounted in a vertically oriented first head supporting flange **49**. The first hub **38** is rotatable in the bearing **36** about the horizontal axis **X**, thereby rotating the first spring-loaded shaft **35**, which is keyed to the first hub **38**
20 at first mated flat portions **39** of the first hub **38** and the first spring-loaded shaft **35**. The first helical spring **37** is contained within a cavity **40** of the first hub **38** through which the first spring-loaded shaft **35** passes. As the gripper heads **30**, **50** grip the object **20**, the first spring-loaded shaft **35** translates outwardly along the horizontal axis **X** and the first helical spring **37** is compressed to provide compliancy for properly gripping and orienting objects
25 of different sizes, and to mitigate damage to the object **20** that could have arisen through over-gripping. A first distal stop **41** of the first spring-loaded shaft **35** contains the first helical spring **37** in the cavity **40** at a distal end of the first hub **38**, the distal stop **41** abutting against a distal outer surface of the first hub **38** to limit compression of the first helical spring **37**. As the object **20** is released by the gripper heads **30**, **50**, the first helical spring **37**
30 expands thereby translating the first spring-loaded shaft **35** inwardly until a proximal stop **42** abuts an outer surface of the bearing **36** to limit further inward translation of the first spring-loaded shaft **35**.

To rotate the first spring-loaded shaft **35** about the horizontal axis **X**, and therefore to rotate the first fingertip **31** about the horizontal axis **X**, the first hub **38** is drivingly
35 connected to a second motor **48** mounted on the first head supporting flange **49**. The

second motor is preferably an electric motor, although other types of motors (e.g. hydraulic motors or pneumatic motors) may be used, A drive belt **45** is looped around the first hub **38** and a drive wheel **47** mounted on a drive shaft of the second motor **48**. Instead of wheels and belts, chains and sprockets may be used to drive the first hub, which may be configured
5 to receive either a belt or chain. Operating the second motor **48** drives drive wheel **47**, which drives the belt **45** thereby rotating the first hub **38** about the horizontal axis **X**. Although the first spring-loaded shaft **35** is translatable within the first hub **38** along the horizontal axis **X**, the first spring-loaded shaft **35** and the first hub **38** are keyed together at the mated flat portions **39** thereof to permit the first hub **38** to also rotate the first spring-
10 loaded shaft **35** about the horizontal axis **X**.

The second gripper head **50** is constructed in a similar manner as the first gripper head **30**. Thus, the second gripper head **50** further comprises a horizontally oriented second spring-loaded shaft **55**, an outwardly extending second annular protrusion **56**, a second helical spring **57**, a hollow second hub **58**, a bearing **56** mounted in a vertically
15 oriented second head supporting flange **69**, second mated flat portions **59**, a cavity **60** of the second hub **58**, a distal stop **61** and a proximal stop **62**. The second gripper head **50** differs from the first gripper head **30** in that the hollow second hub **58** is not driven by a separate motor. Rather the hollow second hub **58** is rotatable in the bearing **56** but only rotates when the object **20** is being gripped between the gripper heads **30**, **50** and the first
20 hub **38** is being driven by the second motor **48**. Thus, if an object **20** has been gripped, rotation from the motor-driven fingertip **31** will be transmitted to the object **20** and the freely rotating fingertip **51** will follow the rotation and support the gripped object **20**.

As best seen in Fig. 1, Fig. 2 and Fig. 3, the gripper **1** further comprises an actuator **70**. While a pneumatic actuator is depicted, any other suitable actuator may be used, for
25 example a hydraulic actuator or an electric actuator. The actuator **70** is mounted on an underside of the horizontally oriented plate **4**. The first and second head supporting flanges **49**, **69** are mounted on or proximate opposite ends of the actuator **70** so that the first and second fingertips **31**, **51** oppose each other and are symmetrically disposed on either side of the point **P** on the horizontal axis **X** of the rotatable gripper heads **30**, **50**. The actuator
30 **70** comprises a first arm **71** on which the first head supporting flange **49** is mounted, and a second arm **72** on which the second head supporting flange **69** is mounted. The actuator **70** comprises rods **75**, whereby operation of the actuator **70** causes rods **75** to retract or extend, which causes the first and second head supporting flanges **49**, **69** to translate relative to each other in a direction parallel to the horizontal axis **X** of the opposed gripper
35 heads **30**, **50**. Retraction of the rods **75** causes the supporting flanges **49**, **69** to translate

toward each other, thereby causing the opposed gripper heads **30**, **50** to translate toward each other. Extension of the rods **75** causes the supporting flanges **49**, **69** to translate away from each other, thereby causing the opposed gripper heads **30**, **50** to translate away from each other. Operation of the actuator **70** therefore permits gripping and releasing of the
5 object **20**.

With reference to Fig. 4A, Fig. 4B, Fig. 4C, Fig. 4D and Fig. 4E, a process of re-orienting an object using the gripper **1** is illustrated. As shown in Fig. 4A, to properly grip the randomly oriented object **20**, the gripper **1** is moved to a vicinity of the object **20** (or the object **20** is moved to a vicinity of the gripper **1**) and the gripper **1** is centered over the object
10 **20**. As shown in Fig. 4B, the entire gripper **1** is rotated about the vertical rotation axis **Z** until the horizontal axis **X** of the opposed gripper heads **30**, **50** is parallel to a transverse axis **T** through a center of gravity **C** of the object **20**, the transverse axis **T** typically passing through a widest section of the object **20**. The transverse axis **T** is substantially orthogonal to a main axis **M** of the object **20** passing through a tip **21** of the object **20**. The gripper **1** is rotated
15 about the vertical rotation axis **Z** by operating the first motor **8** (see Fig. 1) to rotate the vertically oriented drive shaft **3**.

As shown in Fig. 4C, the gripper **1** is then moved (e.g. lowered) so that the object **20** is between the opposed gripper heads **30**, **50** with the center of gravity **C** of the object **20** substantially co-located in space with the point **P** on the horizontal axis **X** of the opposed
20 gripper heads **30**, **50**. The gripper head supporting flanges **49**, **69** are translated inwardly by action of the actuator **70** to grip the object **20** between the first and second fingertips **31**, **51** of the first and second gripper heads **30**, **50**, respectively. Absolutely precise movement of the actuator **70** is not required because the compliance in the first and second gripper heads **30**, **50** due to compression of the first and second fingertips **31**, **51** and compression
25 of the first and second helical springs **37**, **57** permits gripping the object **20** without damage even when the actuator **70** translates the gripper head supporting flanges **49**, **69** further inward toward point **P** than would be absolutely required, as seen in Fig. 4C.

As shown in Fig. 4D, with the object **20** gripped between the first and second fingertips **31**, **51**, the object **20** may be rotated about the horizontal axis **X** so that the tip **21**
30 and therefore the main axis **M** of the object **20** are vertically oriented. Rotation of the object **20** gripped between the first and second gripper heads **30**, **50** is effected by operation of the second motor **48** as described previously. When the object **20** is a tulip bulb, Fig. 4D shows the desired orientation for planting the tulip bulb where the tip **21** is pointing upwardly (i.e. roots are down). If the tulip bulb is to be packaged instead of planted, the tulip bulb

may be rotated about the horizontal axis **X** so that the tip **21** points downwardly instead of upwardly.

Fig. 5 depicts a flow chart illustrating a process **100** for planting tulip bulbs in growing crates. The process **100** is illustrated as three connected sub-processes, which
5 are: growing crate handling **110**; bulb handling **120**; and, computer visioning **150**.

The crate handling **110** sub-process comprises providing growing crates pre-filled with soil **111** and transferring the pre-filled growing crates to an indexed conveyor **112**. Each crate is advanced in an indexed manner to a next row of bulbs **113** being handled by the bulb handling sub-process **120**, where the crate waits for a row of bulbs to be planted
10 therein **114** by the bulb handling sub-process **120**. When a row of bulbs is planted in the crate, a determination is made as to whether the crate is now full **115**. If the determination is 'No' and the crate is not yet full, the crate remains in position to wait further **113** for a next row of bulbs to be planted therein **114**. If the determination is 'Yes' and the crate is full, the full crate is advanced to an unloading station **116** where the crate is unloaded from the
15 conveyor as a growing crate filled with tulip bulbs **117**. A plurality of growing crates is processed in this manner until there are no more tulip bulbs to be planted. The unloaded crates are then transported to a storage facility.

The bulb handling sub-process **120** comprises providing bulk tulip bulbs **121** and dumping the tulip bulbs into a hopper **122**. The bulbs from the hopper are singulated **123**
20 and released intermittently on to a conveyor at a constant spacing and in a random orientation **124**. The bulbs singulated on the conveyor pass within a Field of View of a visioning system **125**, where the computer visioning sub-process **150** obtains information (e.g. digital images or point cloud data) about each bulb **151** (e.g. with a 3D camera or a line scan), calculates orientation of each bulb **152** (e.g. with a programmed computer) and
25 calculates required rotation angles for each bulb **153** (e.g. with the programmed computer). The conveyor is stopped when a predetermined number (**N**) of the bulbs are in picking positions **126**. A number **N** of grippers simultaneously pick and orient the **N** bulbs **127** based on the rotation angles calculated by the computer visioning sub-process **150** for each bulb.

Prior to gripping the bulb, and based on the calculated rotation angles for a given
30 bulb, the corresponding gripper is first rotated about the mounting bracket rotation axis by an amount sufficient to orient the gripper head rotation axis substantially orthogonally with the main axis of the bulb, the main axis being an axis passing through the tip and a centroid (i.e. the center of gravity) of the bulb. After the bulb is gripped, the bulb is rotated about the gripper head rotation axis to vertically orient the main axis of the bulb. Once the main axis

is re-oriented to the vertical and before releasing the bulb, the gripper is again rotated about the mounting bracket rotation axis to bring the bulb into a final orientation for transfer into an accumulator. Thus, although the randomly oriented bulbs have three possible rotational degrees of freedom, and therefore need up to three rotation angles to fully re-define their orientations, the gripper only has and only requires two degrees of freedom to complete
5 the three rotations to properly re-orient the bulbs based on the calculated rotation angles. In this manner, any randomly oriented bulb can be rotated into any specified orientation.

The N bulbs are transferred into the accumulator 128 by the grippers, and a determination is made as to whether the accumulator is now full 129. If the determination
10 is 'No' and the accumulator is not yet full, the accumulator remains in position for a next predetermined number (N) of the bulbs to be transferred into the accumulator 128. If the determination is 'Yes' and the accumulator is full, spacing between the bulbs in the accumulator is reduced 130, and the bulbs in the accumulator are transferred into the growing crate 131, which is waiting for a row of bulbs to be planted therein 114 in the
15 growing crate handling sub-process 110. Transferring the bulbs from the accumulator to the growing crate can be accomplished by a robot.

With reference to Fig. 6 and Fig. 7, a system 200 is depicted for handling tulip bulbs 220 (only one labeled). The system 200 comprises a conveyor belt 205 on to which the tulip bulbs 220 are singulated at a constant spacing d and in a random orientation by
20 passing a plurality of the tulip bulbs 220 on a feed chute 201 through a singulating gate 202. The bulbs 220 pass through a field of vision of a digital camera 210, which acquires digital images of the bulbs 220 on the conveyor belt 205 as the bulbs 220 pass through the field of vision. Image data is transmitted to a computer (not shown) programmed to calculate the orientation of each randomly oriented bulb 220 and then calculate required
25 rotation angles to bring each of the bulbs 220 into a predetermined orientation for placement into an accumulator 225 (e.g. an egg crate foam holder) proximate the conveyor belt 205.

When enough of the bulbs 220 reach a picking station comprising a plurality of grippers 1 (three shown and labeled) as described in connection with Fig. 1, the conveyor
30 belt 205 stops. In the illustrated embodiment, the grippers 1 are spaced apart longitudinally over the conveyor belt 205 by a distance equal to the constant spacing d between the tulip bulbs 220. Thus, when the conveyor 205 stops, each of the grippers 1 has a randomly oriented tulip bulb 220 directly below the point P (see Fig. 1) of each of the grippers 1. Each of the grippers 1 is independently rotated about respective vertical axes by rotating the
35 drive shafts 3 of each of the grippers 1 through angles calculated by the computer for the

individual tulip bulbs **220**. The grippers **1** are under the control of the computer and are rotated automatically rotated by the computer based on the angles calculated by the computer. Each of the grippers **1** is shown in Fig. 6 having been first rotated about their respective vertical axes by an angle suitable for gripping the respective randomly oriented tulip bulbs **220** along the bulb's transverse axis through the center gravity of the bulb, as
5 described above.

After the grippers **1** grip the tulip bulbs **220**, the grippers **1** then rotate the gripped bulbs **220** about the respective horizontal gripper head rotation axes to orient the bulbs with tips pointing upward. A final rotation of the grippers **1**, about the respective vertical axes
10 brings the bulbs into a final orientation before depositing the bulbs in the accumulator **225**. The grippers **1** may be mounted on one or more, preferably one, translatable arm (not shown), which is configured to translate the grippers **1** transversely with respect to the conveyor belt **205** to position the grippers **1** over the accumulator **225**. Once over the accumulator **225**, the grippers **1** may release the bulbs **220** into individual cells of the
15 accumulator **225**. Either the accumulator **225** or the grippers **1** may be translatable longitudinally with respect to the conveyor belt **205** so that the grippers **1** are able to fill the cells of the accumulator **225**. Preferably, the translatable arm is configured to translate the grippers **1** both transversely and longitudinally. Once the grippers **1** have deposited the bulbs **220** in the accumulator **225**, the conveyor belt **205** is switched on under the control
20 of the computer to bring the next batch of bulbs **220** into position to be gripper by the grippers **1**.

The bulbs **220** in the accumulator are transferred to a crate **230** (see Fig. 7), for example by another robot or workers. If the crate **230** is a growing crate as illustrated in Fig. 7, the bulbs **220** are placed in the crate **230** with roots down (tips up). If the bulbs **220**
25 are being packaged for a storage, a crate with a plurality of pins protruding from a floor of the crate may be lowered over the accumulator so that the pins pierce the tip of the bulbs and the bulbs are stored in the crate with roots up (tips down).

With reference to Fig. 8A, Fig. 8B, Fig. 9A, Fig. 9B, Fig. 10, Fig. 11, Fig. 12, Fig. 13, Fig. 14 and Fig. 15, another embodiment of a mechanical gripper **300** is shown configured
30 for simultaneous orientation of a randomly oriented solid three-dimensional biological horticultural object **320**.

The gripper **300** comprises an upwardly extending vertically oriented housing **380** on which a mounting bracket **302** having a horizontally oriented plate **304** is fixedly mounted. The housing **380** comprises a top mounting flange **389** through which the gripper

300 may be connected to external hardware. The housing 380 contains a linear actuator 381 having a piston rod 303 that is rotatable about a vertical rotation axis N and translatable along the vertical rotation axis N. An end of the piston rod 303 is equipped with a jamming gripper head 385, although another device such as a suction cup or pincer can be used, which is connected to the piston rod 303 by a collar 387. Rotation of the linear actuator 381 rotates the piston rod 303 resulting in rotation of the jamming gripper head 385 about the vertical rotation axis N. The piston rod 303 in this embodiment acts as a drive shaft for the jamming gripper head 385. The linear actuator 381 is rotatably mounted on bearings 305 situated in the housing 380. The linear actuator 381 is operatively coupled to a motor 308, operation of the motor 308, causing the linear actuator 381, and therefore the jamming gripper head 385, to rotate about the vertical rotation axis N. The motor 308 is preferably an electric motor, although other motors may be used, for example hydraulic motors, pneumatic motors and the like. Instead of a linear actuator, other types of actuators may be employed, for example hydraulic or pneumatic cylinders, provided the actuator is capable of translating the jamming gripper head 385 along the vertical rotation axis N.

The jamming gripper head 385 comprises a flexible membranous sac filled with a flowable granular material (e.g. sand, coffee grounds, plastic beads or the like). The sac is connected to a source of inflation fluid (e.g. air) and a source of vacuum through ports 386 on the jamming gripper head 385. When inflated, the jamming gripper head 385 is deformable and may be pushed on to the object 320, the membranous sac conforming to a surface of the object 320. When a vacuum is applied, the jamming gripper head 385 deflates, the fluid between granules of the granular material is removed and the granules 'jam' thereby locking in place. The jamming gripper head 385 holds the deflated shape thereby gripping the object 320.

The gripper 300 further comprises a first rotatable gripper head 330 and a second rotatable gripper head 350 opposed to the first gripper head 330. The opposed gripper heads 330, 350 are rotatably and translatably mounted below the mounting bracket 302. The opposed gripper heads 330, 350 are rotatable around and translatable along a horizontal axis M, the horizontal axis M substantially orthogonal to the vertical rotation axis N and substantially parallel to the horizontally oriented plate 304. The piston rod 303 of the linear actuator 381 extends through an aperture in the plate 304 so that the jamming gripper head 385 is below the plate 304. Preferably, the piston rod 303 is situated to extend through at a center point of the mounting bracket 302 so that the vertical rotation axis N intersects the horizontal axis M at a point Q between and equidistant from the two opposed gripper heads 330, 350. The point Q is preferably at or proximate a center of gravity of the object

320 when the gripper 300 grips the object 320. The opposed gripper heads 330, 350 may be the same as those previously described in connection with the gripper 1. The opposed gripper heads 330, 350 are mounted on opposed supporting flanges 349, 369, respectively, which are slidingly mounted on and depend vertically downward from the mounting bracket
5 302. The opposed gripper heads 330, 350 are rotated about the horizontal axis M by a motor 348 mounted on the supporting flange 349 and operatively coupled through bevel gears 345 to the gripper head 330. The gripper head 350 is an idler and is rotated along with gripper head 330 when the object 320 is gripper between the opposed gripper heads 330, 350.

10 The gripper 300 further comprises an actuator 370, for example a motor, mounted on a topside of the horizontally oriented plate 304 and operatively coupled to the supporting flanges 349, 369. The supporting flanges 349, 369 comprise sliders 376, 377, respectively, slidingly mounted on a slide rail 375, the slide rail 375 mounted on an underside of the mounting bracket 302, as best seen in Fig. 9B and Fig. 10 Operation of the actuator 370
15 causes sliders 376, 377 and therefore the supporting flanges 349, 369 to translate horizontally on the slide rail 375 along the underside of the mounting bracket 302, thereby causing the opposed gripper heads 330, 350 to translate toward or away from each other along the horizontal axis M. Operation of the actuator 370 therefore permits gripping and releasing of the object 320 from the opposed gripper heads 330, 350.

20 With reference to Fig. 8A, Fig. 9A, Fig. 10, Fig. 11, Fig. 12, Fig. 13, Fig. 14 and Fig. 15, a process of re-orienting the object 320 using the gripper 300 is illustrated. As shown in Fig. 8A, the gripper 300 is first positioned over the randomly oriented object 320 so that the object 320 is substantially directly below the jamming gripper head 385. As shown in Fig. 9A, the piston rod 303 is extended to lower the jamming gripper head 385 to engage the
25 object 320, the jamming gripper head 385 operated to then grip the object 320. As shown in Fig. 10, the piston rod 303 is then retracted to raise the jamming gripper head 385 with the object 320 gripped therein to a point where the center of gravity of the object 320 is at the point Q. As shown in Fig. 11, the motor 308 is used to rotate the linear actuator 381 about the vertical rotation axis N thereby rotating the jamming gripper head 385 and the
30 object 320 gripped therein so that a transverse axis through the center of gravity of the object 320 is oriented substantially parallel to the horizontal axis M of the opposed gripper heads 330, 350. As shown in Fig. 12, the gripper head supporting flanges 349, 369 are then translated inwardly by action of the actuator 370 to grip the object 320 between the opposed gripper heads 330, 350. As shown in Fig. 13, the jamming gripper head 385 is
35 then operated to release the object 320, and the piston rod 303 is further retracted to raise

the jamming gripper head **385** out of the way of the object **320**. With the jamming gripper head **385** moved out of the way, the opposed gripper heads **330**, **350** may be rotated by operation of the motor **348** to rotate the object **320** about the horizontal axis **M** to vertically orient a tip **321** of the object **320**. As shown in Fig. 14, with the tip **321** of the object **320** vertically oriented, the piston rod **303** is extended to lower the jamming gripper head **385** to engage the object **320**, where the jamming gripper head **385** is again operated to grip the object **320**. As shown in Fig. 15, the piston rod **303** is further extended to lower the jamming gripper head **385** with the object **320** gripped therein to place the object in a storage area where the jamming gripper head **385** is operated to release the object **320**. In this manner, the object **320** may be placed in a storage area without the need to first place the object **320** in an intermediate area and without the need for a further gripper to transfer the object **320** to the storage area.

The novel features will become apparent to those of skill in the art upon examination of the description. It should be understood, however, that the scope of the claims should not be limited by the embodiments but should be given the broadest interpretation consistent with the wording of the claims and the specification as a whole.

Claims:

1. A gripper for gripping and re-orienting a solid three-dimensional biological horticultural object, the gripper comprising:

a mounting bracket;

5 opposed first and second rotatable gripper heads rotatably mounted on the mounting bracket, the opposed first and second rotatable gripper heads rotatable about a common gripper head rotation axis;

10 a translation actuator configured to translate at least one of the opposed rotatable gripper heads along the gripper head rotation axis to grip a solid three-dimensional biological horticultural object between the opposed first and second rotatable gripper heads;

a third gripper head for gripping the object independently of the opposed first and second rotatable gripper heads;

15 a drive shaft connected to the third gripper head, the drive shaft configured to rotate the third gripper head and the object about a second rotation axis substantially orthogonal to the gripper head rotation axis, the second rotation axis passing between the opposed first and second rotatable gripper heads; and,

20 at least one rotation actuator, the at least one rotation actuator configured to rotate the drive shaft to thereby rotate the object, and the at least one rotation actuator configured to rotate at least one of the opposed rotatable gripper heads to thereby rotate the object gripped between the opposed first and second rotatable gripper heads.

2. The gripper of claim 1, wherein the drive shaft is connected to the mounting bracket and the drive shaft is configured to rotate the mounting bracket about the second rotation axis.

25 3. The gripper of claim 2, wherein

the drive shaft is mounted on a first side of the mounting bracket,

the translation actuator is mounted on a second side of the mounting bracket opposed to the first side along the second rotation axis, and

the opposed first and second rotatable gripper heads are rotatably mounted on first and second opposed flanges, respectively, the first and second opposed flanges mounted on opposed translatable elements of the translation actuator, whereby movement of the opposed translatable elements causes the opposed flanges to move toward or away from each other thereby translating the opposed rotatable gripper heads along the gripper head rotation axis.

4. The gripper of any one of claims 1 to 3, wherein the third gripper head is translatable along the second rotation axis.
5. The gripper of any one of claims 1 to 4, wherein the third gripper head comprises a jamming gripper head.
6. The gripper of any one of claims 1 to 5, wherein the second rotation axis and the gripper head rotation axis are the only rotation axes on the gripper.
7. The gripper of any one of claims 1 to 6, wherein the at least one rotation actuator comprises a first rotation actuator configured to rotate the at least one of the rotatable gripper heads, and a second rotation actuator configured to rotate the drive shaft.
8. The gripper of any one of claims 1 to 7, wherein the second rotation axis intersects the gripper head rotation axis.
9. The gripper of any one of claims 1 to 8, wherein the first gripper head, the second gripper head or both the first and second gripper heads are compliant.
10. The gripper of claim 9, wherein at least one of the gripper heads comprises a flexible fingertip compressible along the gripper head rotation axis.
11. The gripper of claim 9 or 10, wherein at least one of the gripper heads comprises a spring that biases the at least one of the gripper heads along the gripper head rotation axis.
12. A gripping system for gripping and re-orienting a solid three-dimensional biological horticultural object, the gripping system comprising:

at least one gripper as defined in any one of claims 1 to 11;

a visioning device configured to capture information about a randomly-oriented solid three-dimensional biological horticultural object to be gripped and re-oriented; and,

a controller operably linked to the gripper and the visioning device, the controller programmed to

5 position and orient the gripper in a first configuration suitable for gripping the randomly-oriented object based on the information about the object captured by the visioning system,

operate the gripper to grip the randomly-oriented object between the first and second gripper heads of the gripper, and

10 operate the gripper to rotate the gripped object from the random orientation into a predetermined orientation, the predetermined orientation based on predetermined parameters for suitably orienting the object for further processing.

13. The system according to claim 12, wherein the controller calculates an initial orientation of the randomly-oriented object, calculates rotation angles necessary to rotate the randomly-oriented object into the predetermined orientation and operates the gripper to rotate the gripped object based on the initial orientation and the calculated rotation angles.

14. The system of claim 12 or 13, further comprising a conveyor on which a plurality of the randomly-oriented objects are singulated at a constant spacing to pass through a field of view of the visioning device.

15. The system of claim 14, wherein the gripper comprises a plurality of grippers longitudinally separated along the conveyor by the constant spacing, each of the plurality of grippers operated by the controller to grip a corresponding singulated object on the conveyor.

16. The system of any one of claims 12 to 15, wherein the object is a tulip bulb.

17. A process for handling solid three-dimensional biological horticultural objects, the process comprising:

25 singulating a solid three-dimensional biological horticultural object from a plurality of solid three-dimensional biological horticultural object, the singulated object randomly oriented with respect to first and second orthogonal axes;

determining the orientation of the randomly-oriented singulated object with a visioning system and comparing the orientation of the randomly-oriented singulated object to a predetermined orientation suitable for further processing;

5 deploying a gripper as defined in any one of claims 1 to 11 to the singulated randomly-oriented object, moving the gripper based on the comparison to suitably orient the gripper with respect to the randomly-oriented object;

gripping the randomly-oriented object with the gripper and rotating the gripper about the first and second orthogonal axes to rotate the object from the random orientation into the predetermined orientation; and,

10 deploying the gripper to place the object in the predetermined orientation into a position for further processing.

18. The process of claim 17, wherein: the singulated randomly-oriented object comprises a plurality of singulated randomly-oriented objects spaced apart at predetermined locations with respect to the visioning system; the gripper comprises a
15 plurality of grippers, the plurality of grippers operating to substantially simultaneously re-orient the plurality of singulated randomly-oriented objects into the predetermined orientation; and, the plurality of objects in the predetermined orientation are placed into a position for further processing.

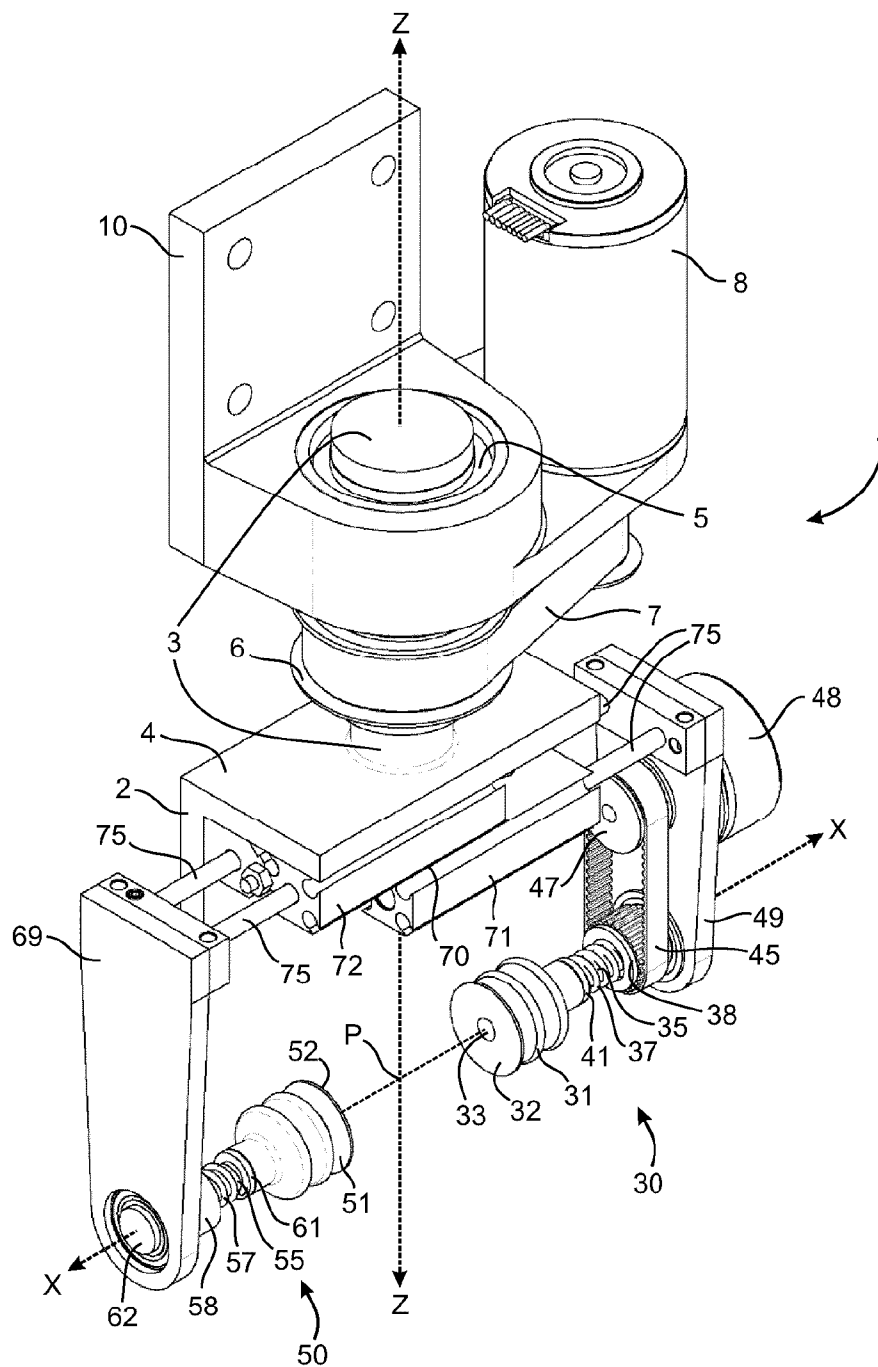


Fig. 1

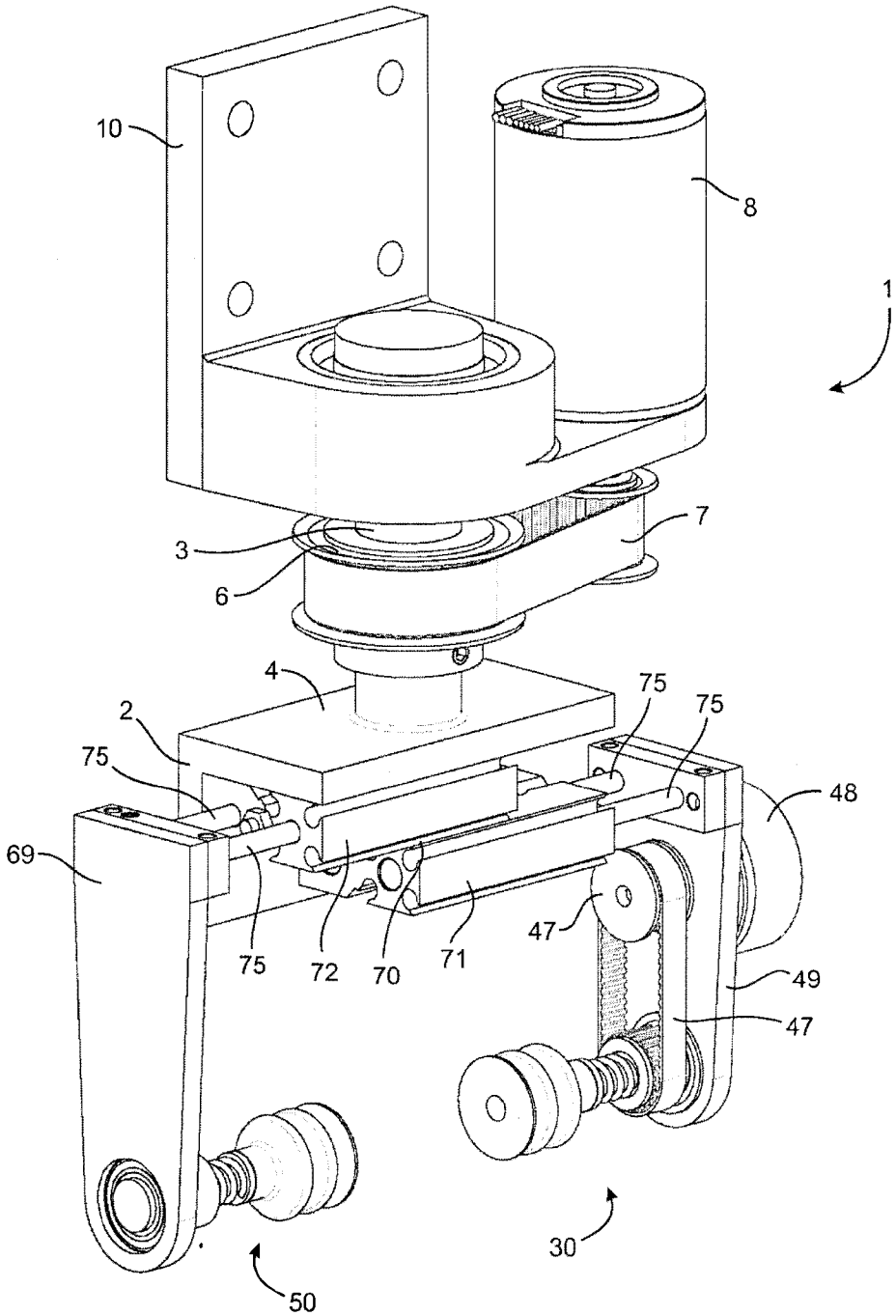


Fig. 2

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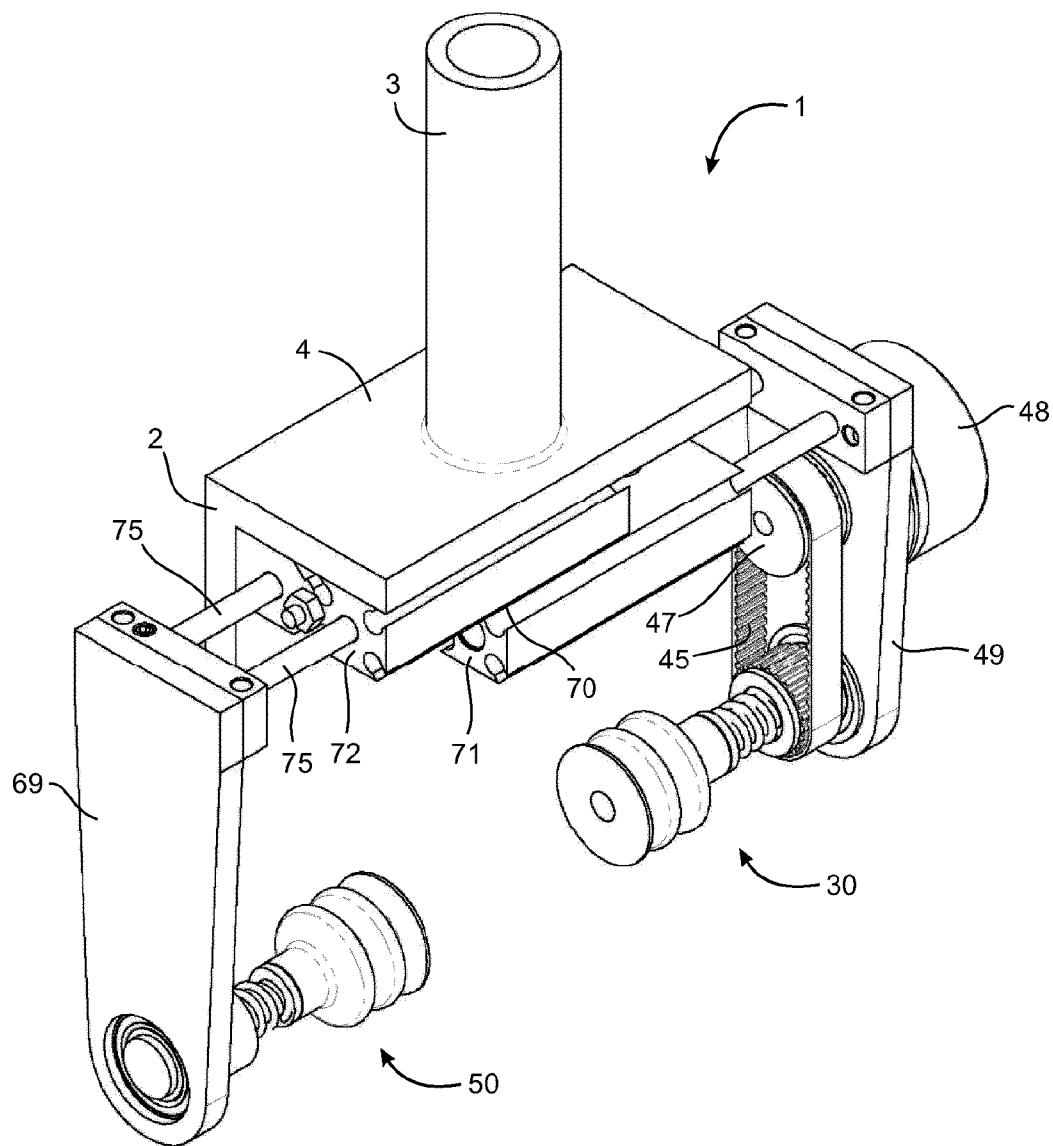


Fig. 3

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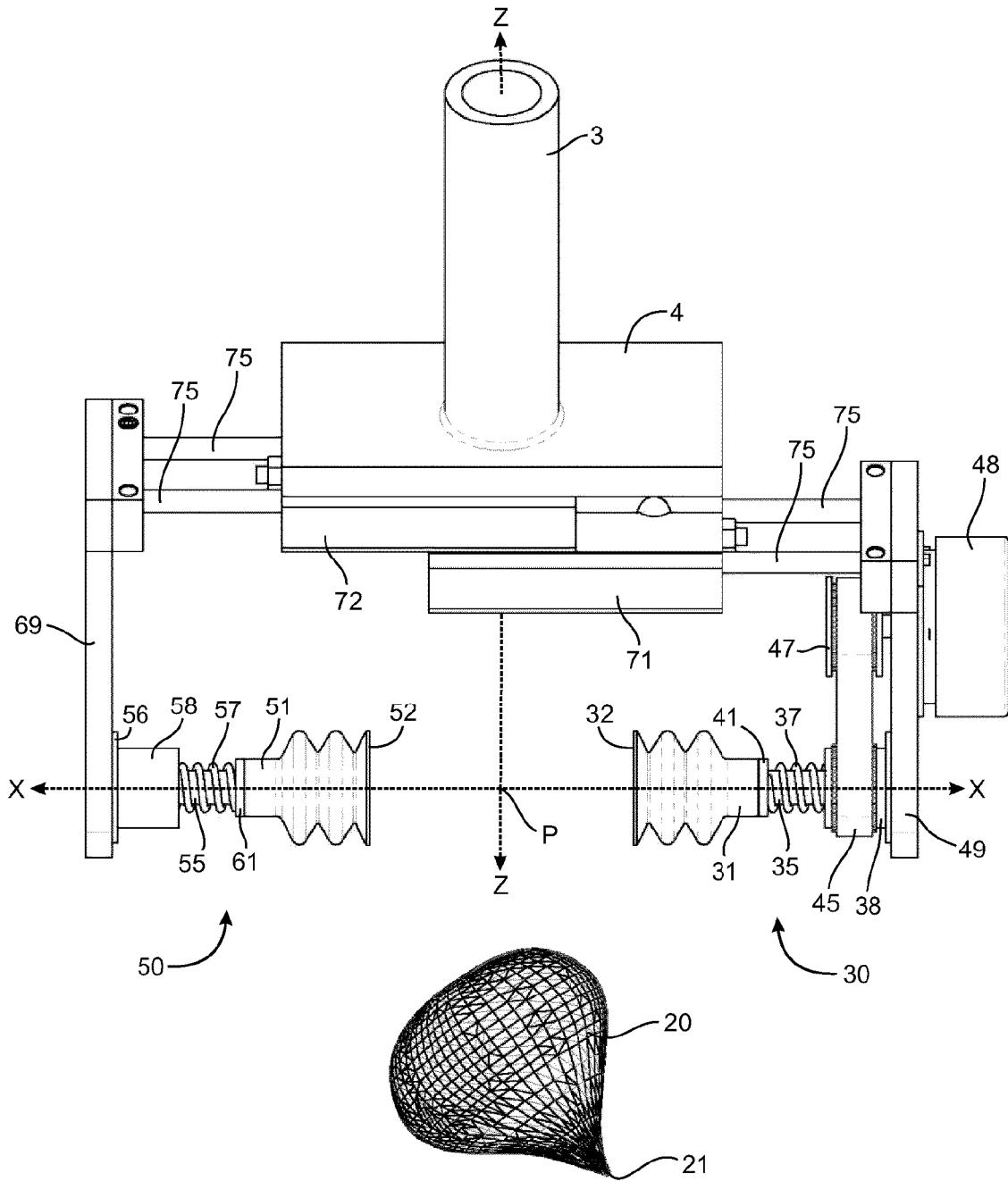


Fig. 4A

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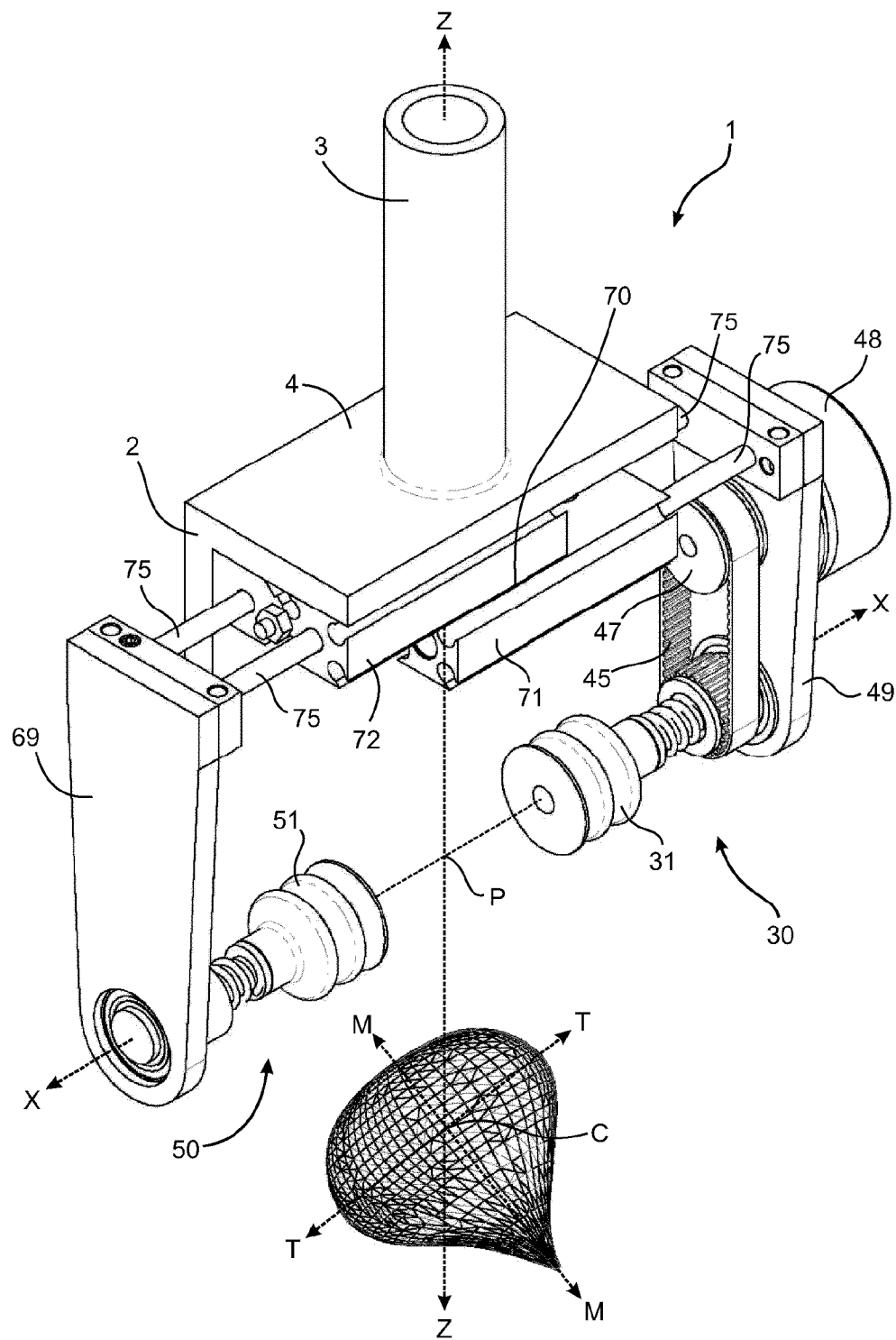


Fig. 4B

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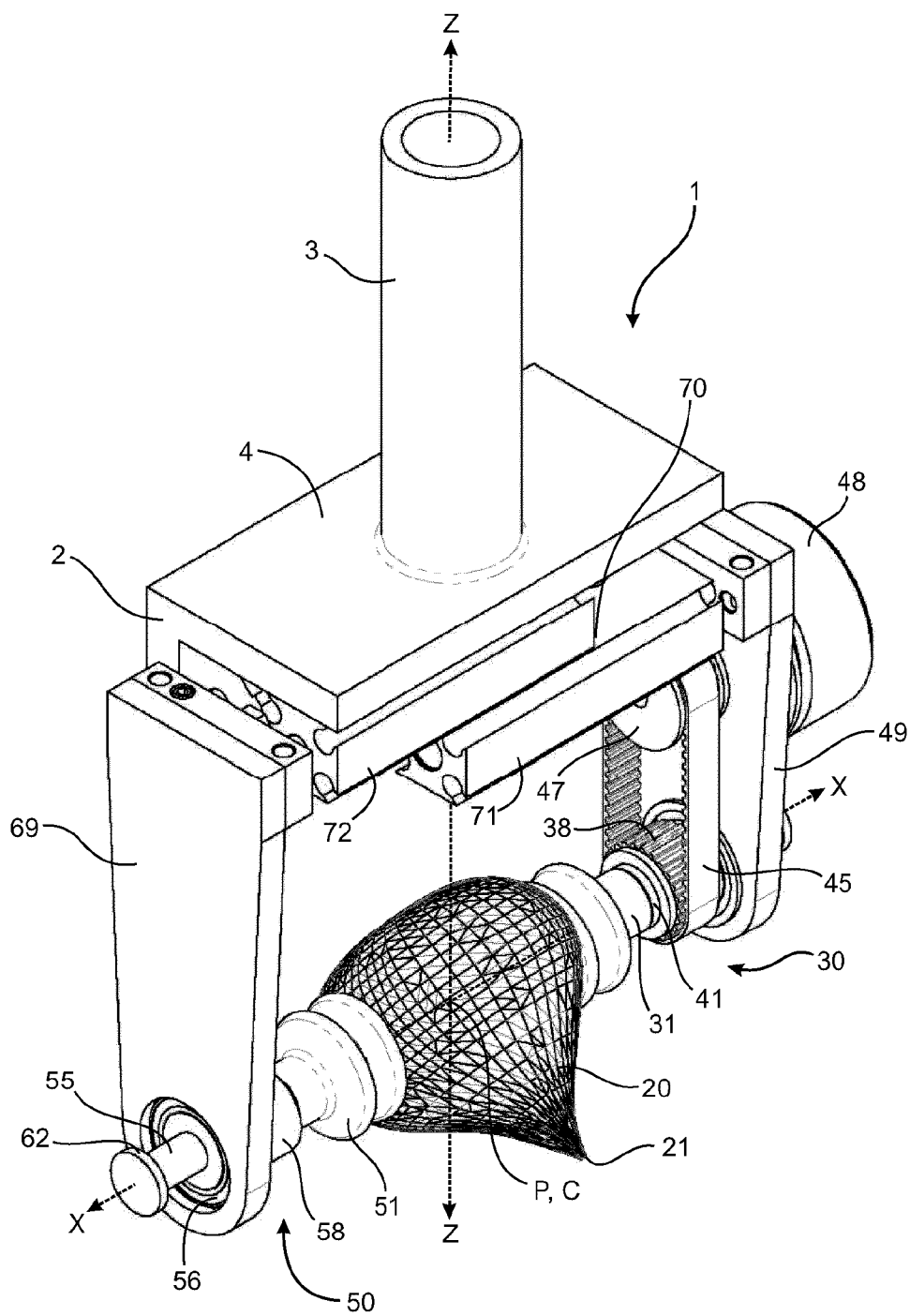


Fig. 4C

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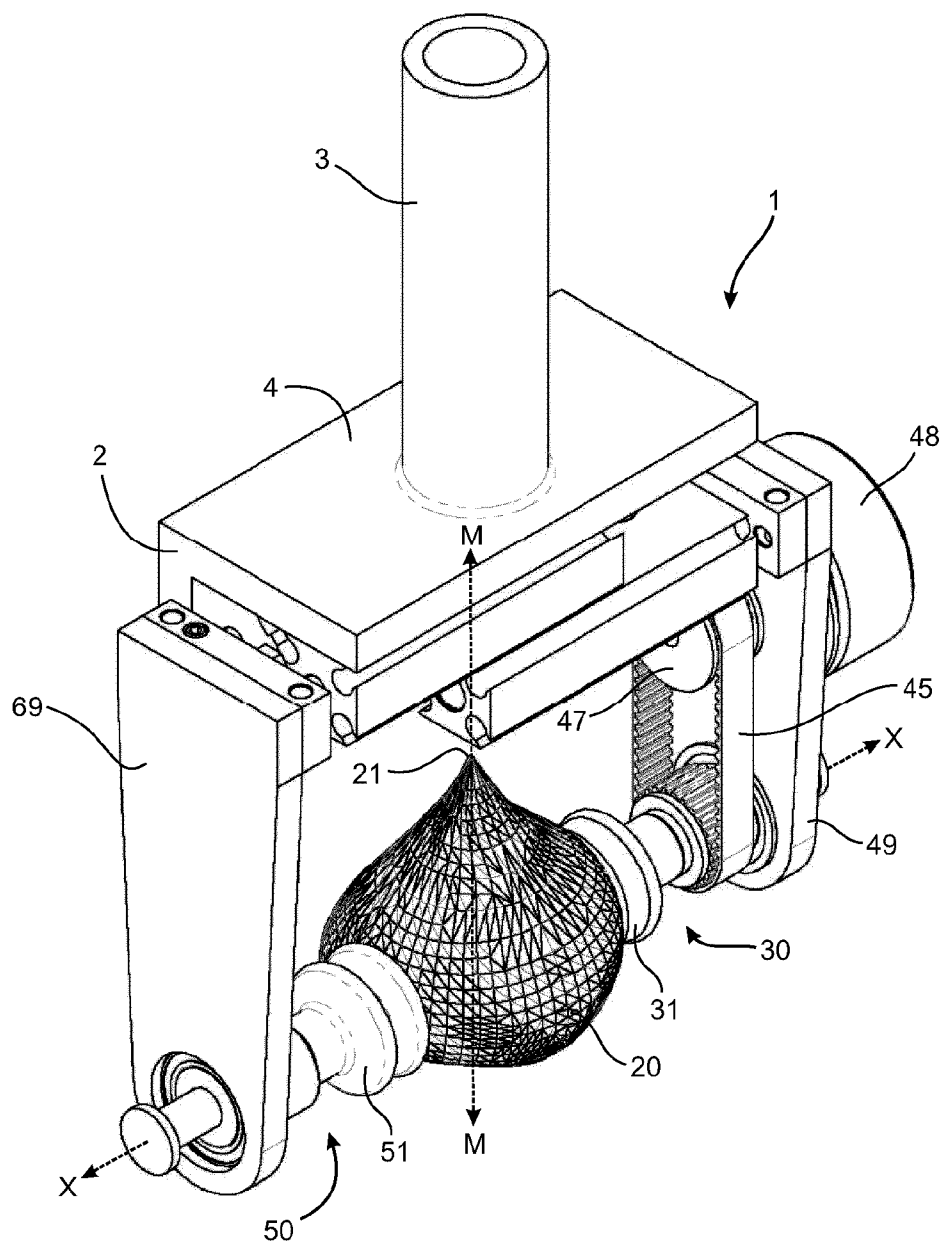


Fig. 4D

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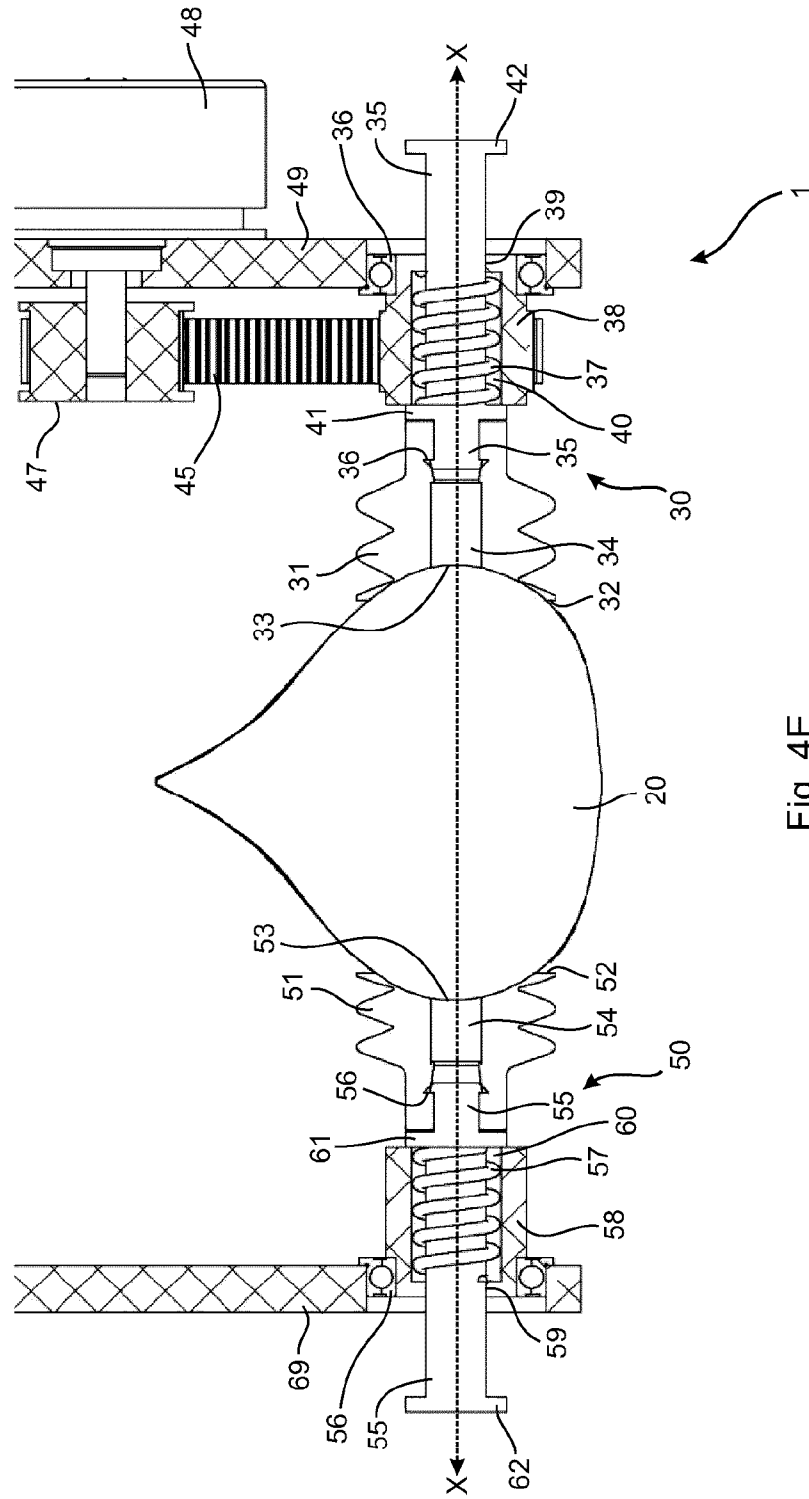


Fig. 4E

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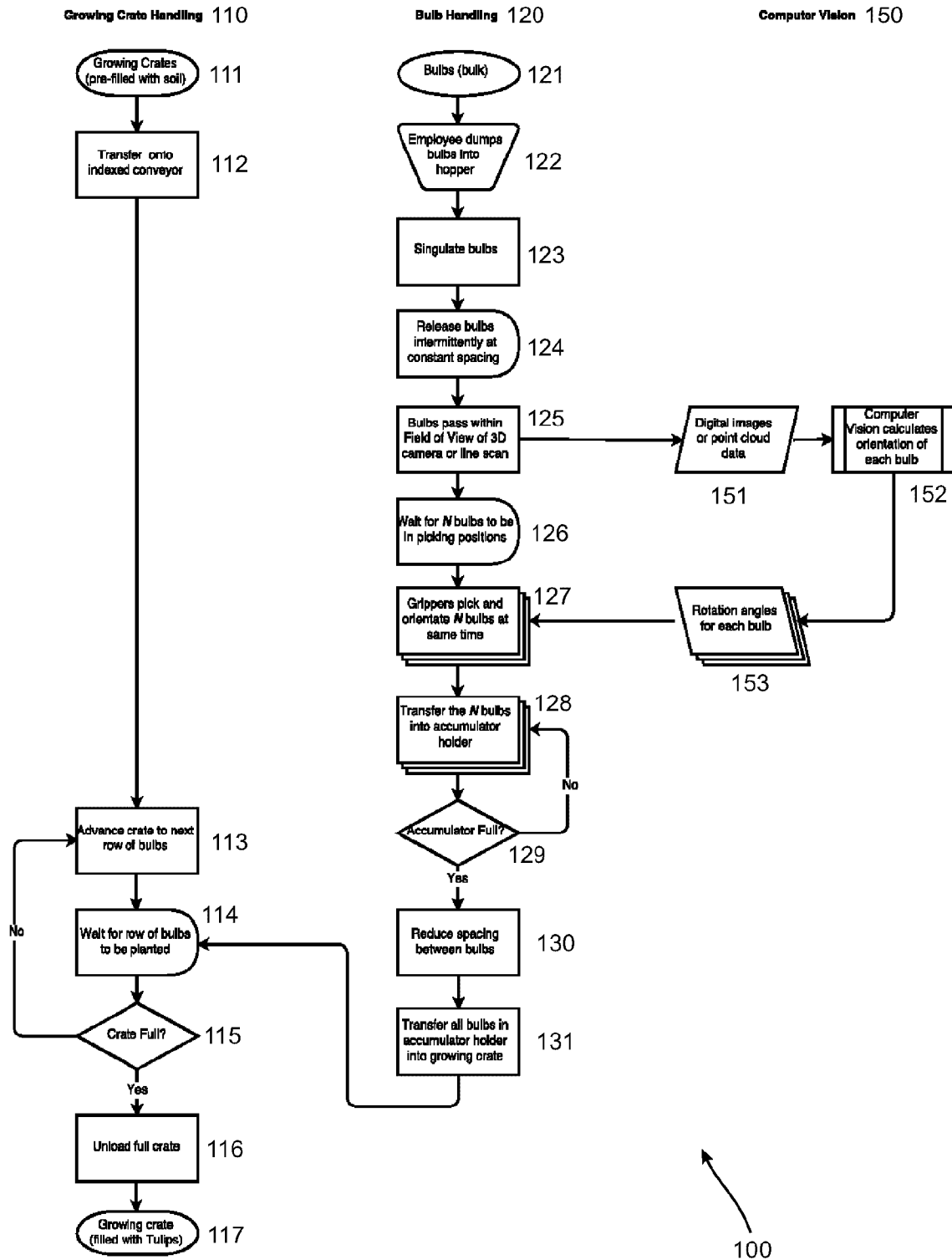


Fig. 5

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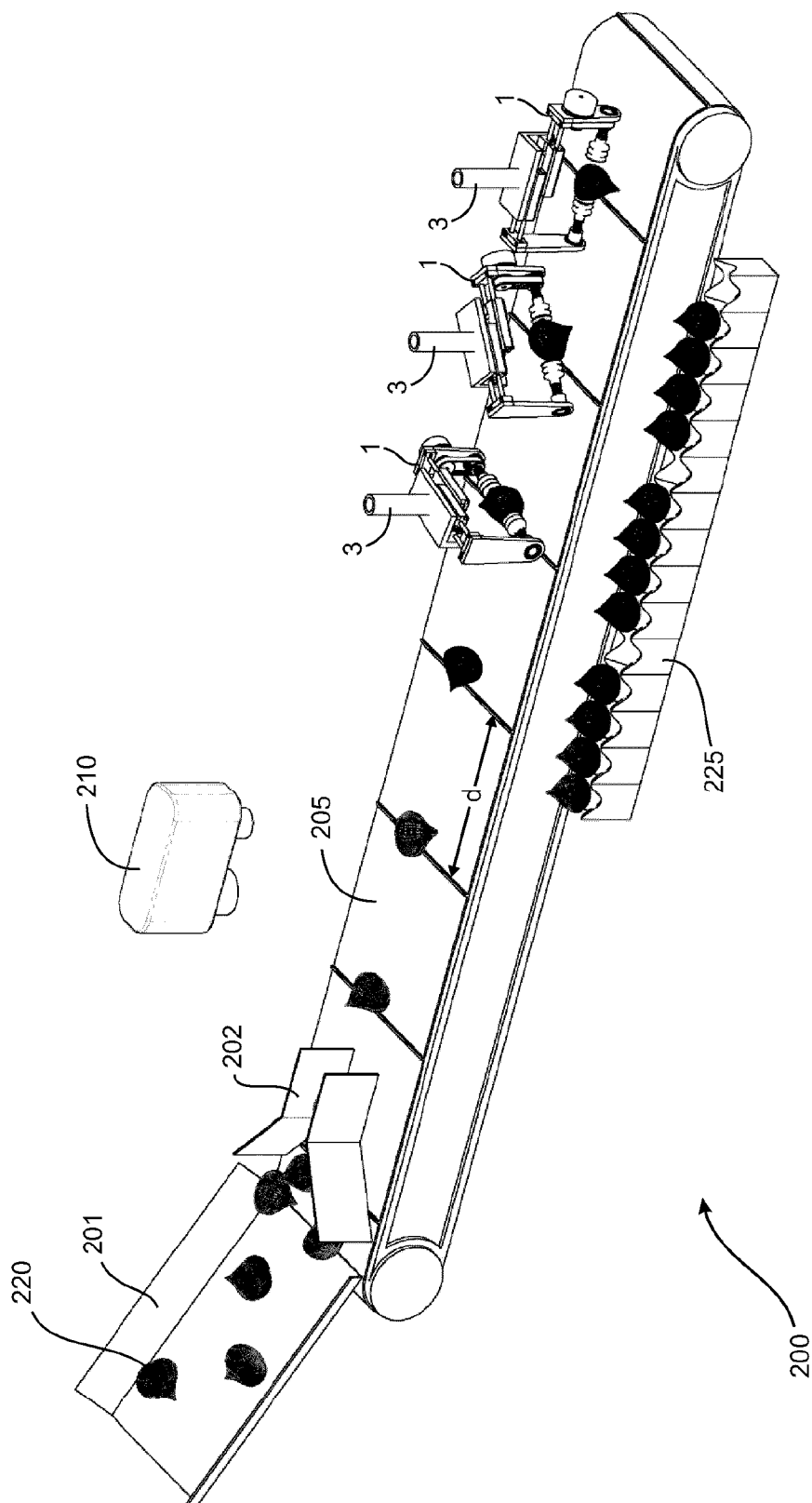


Fig. 6

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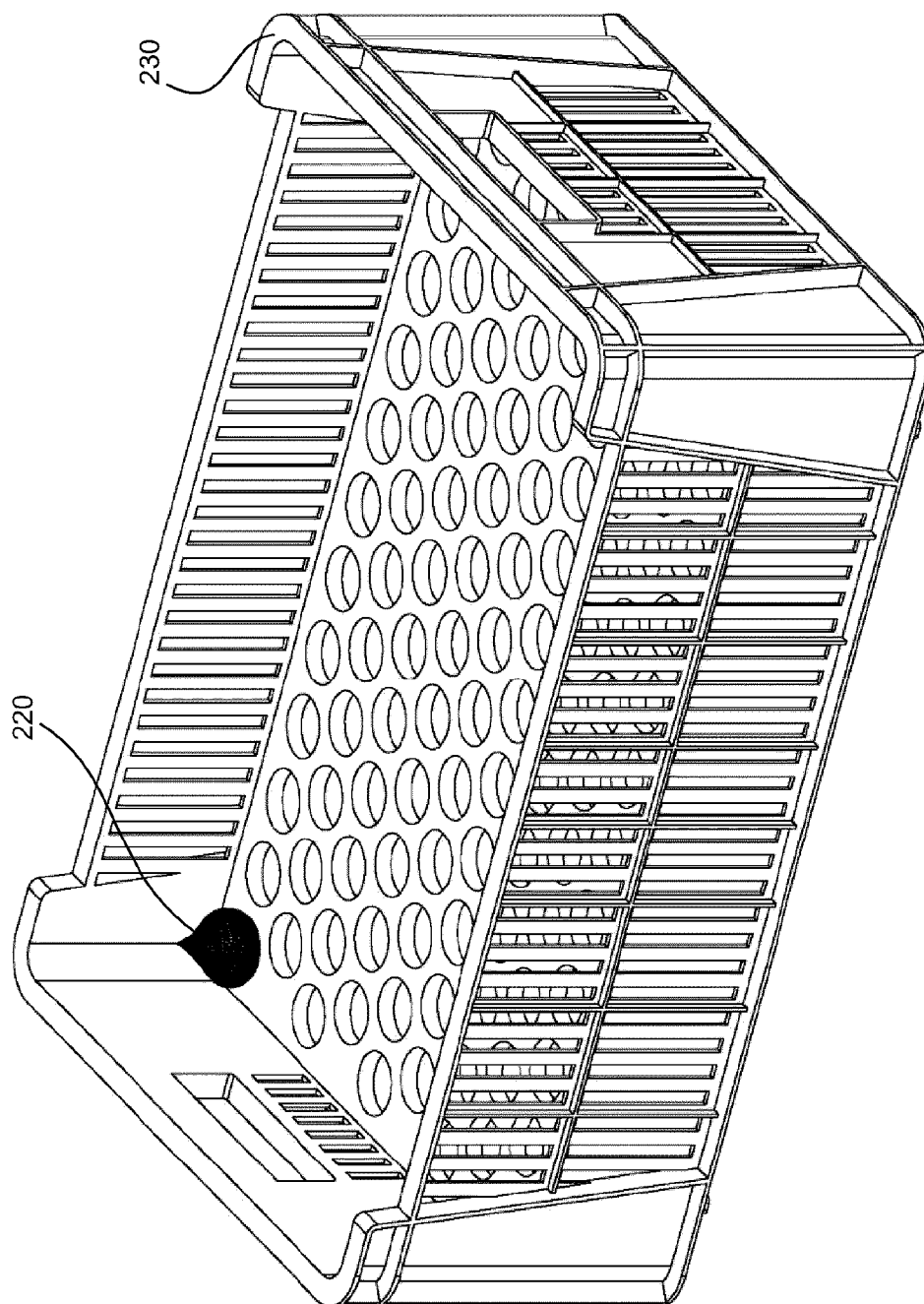


Fig. 7

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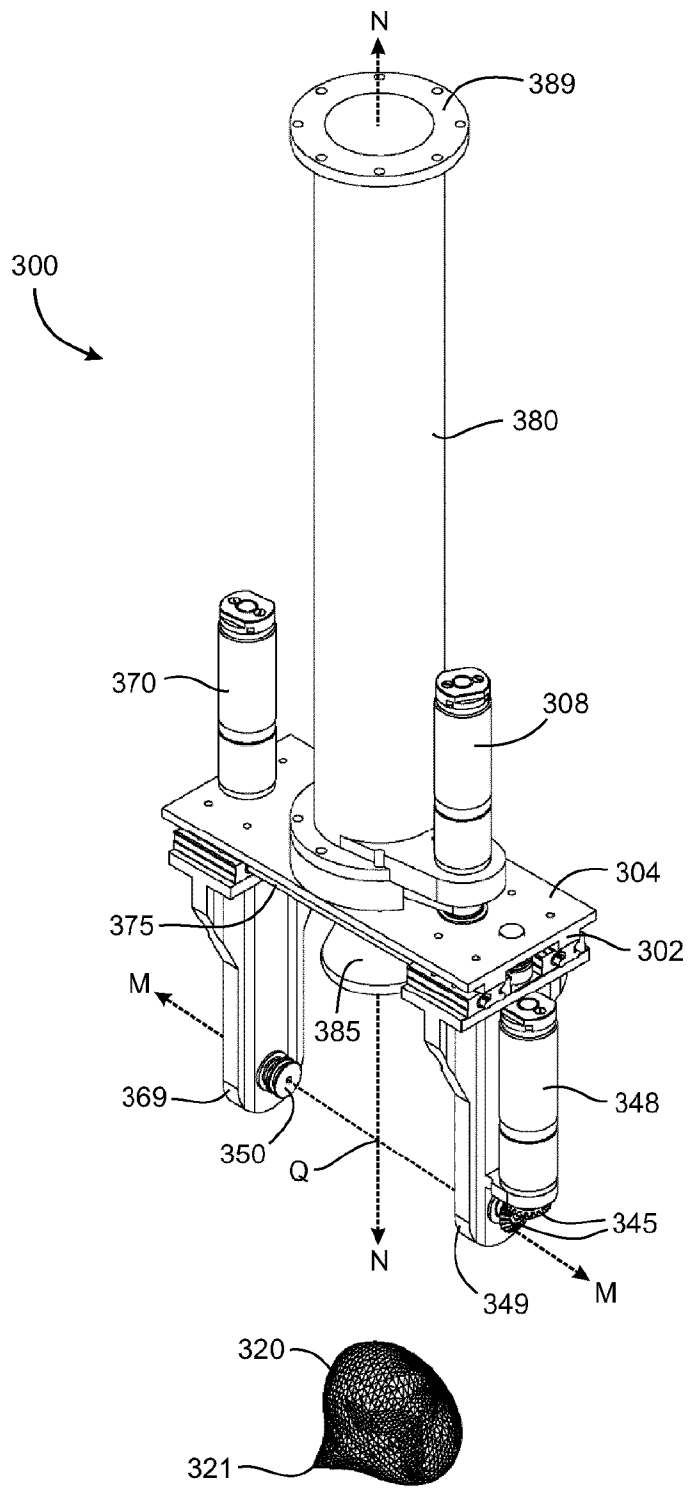


Fig. 8A

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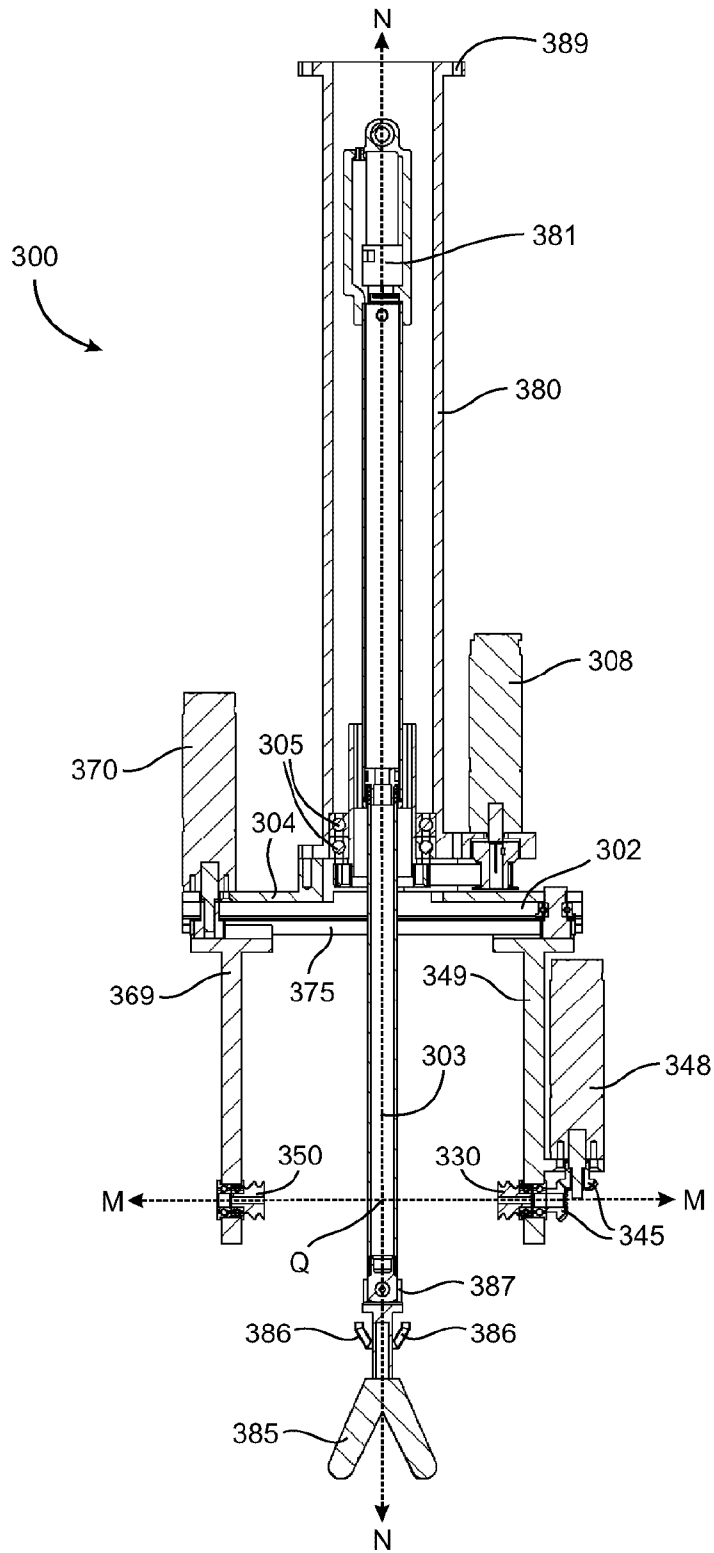


Fig. 8B

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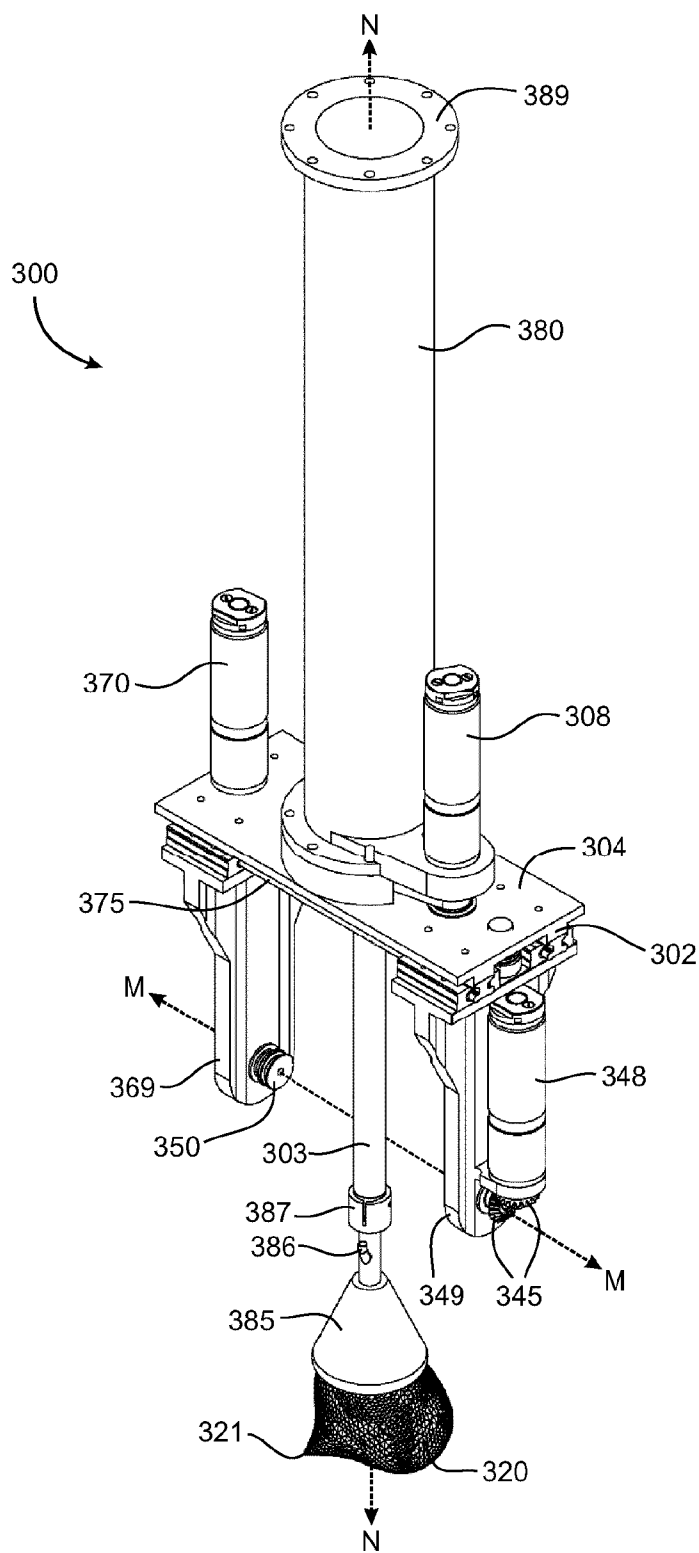


Fig. 9A

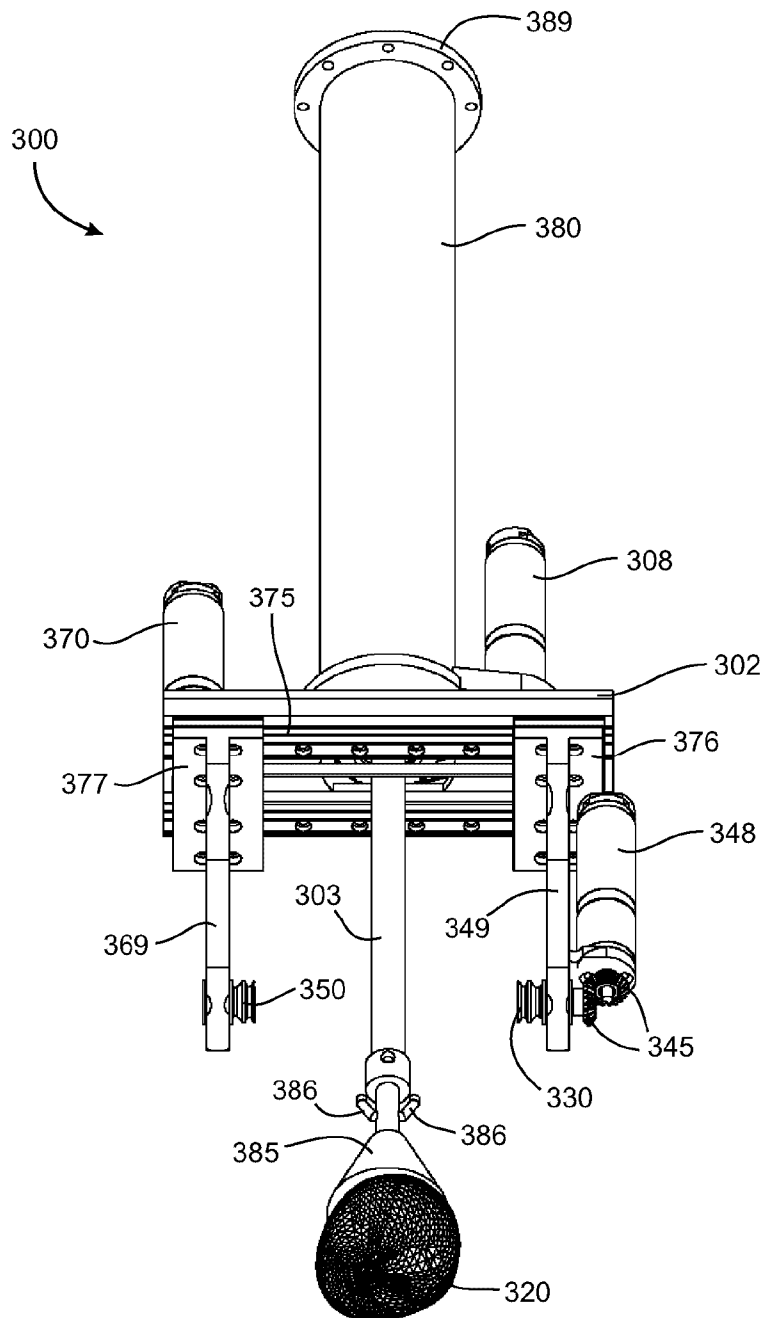


Fig. 9B

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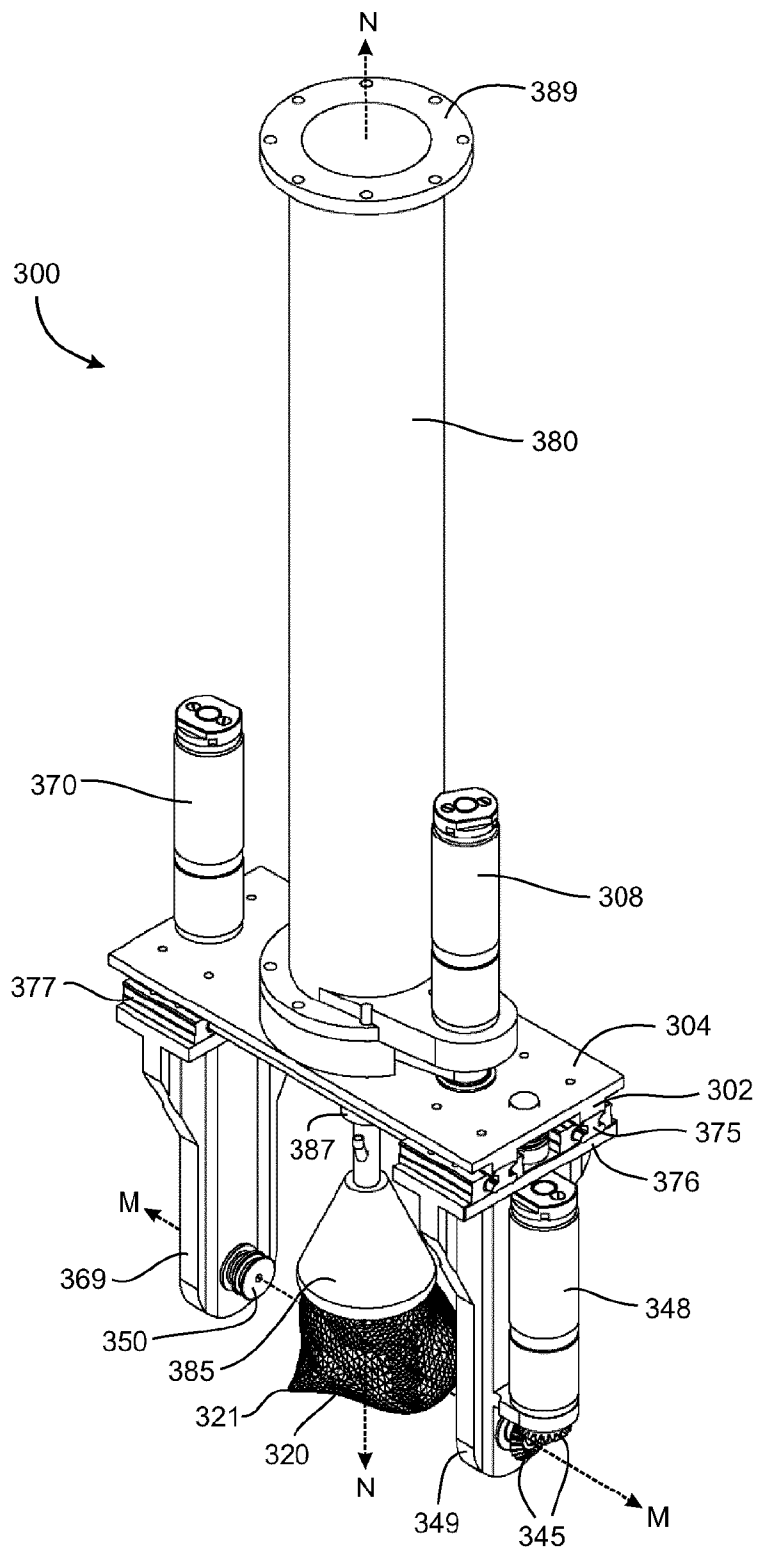


Fig. 10

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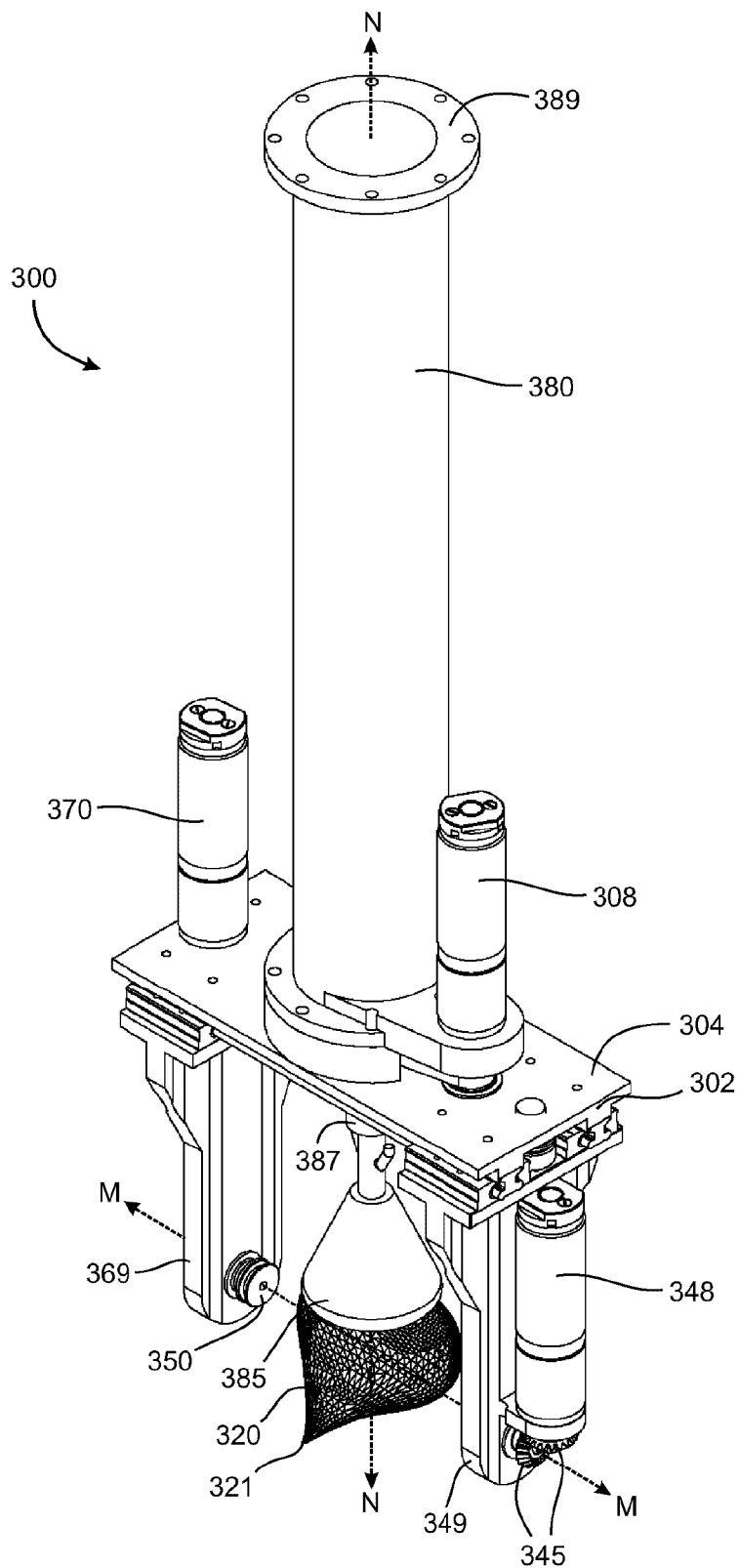


Fig. 11

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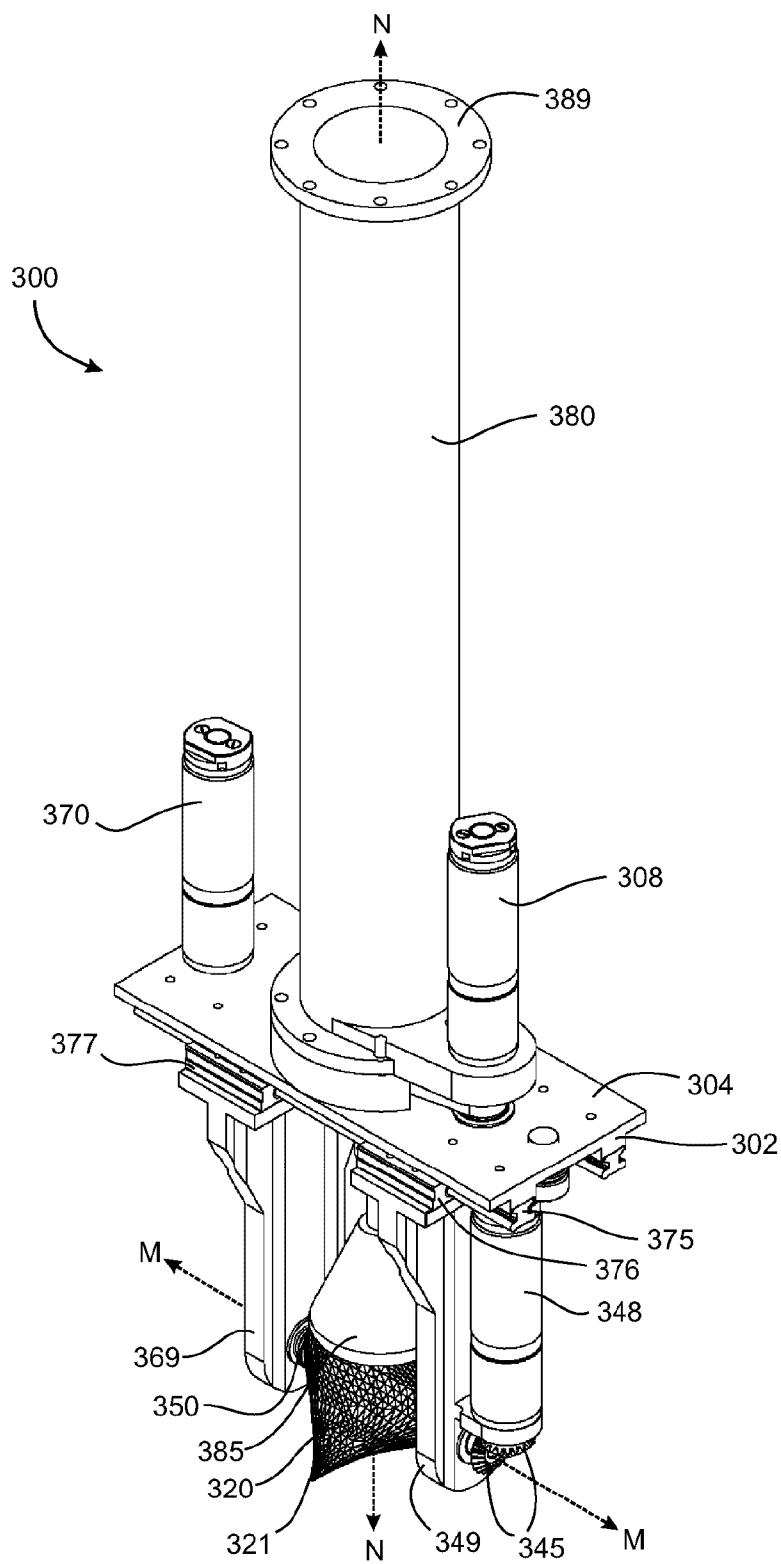


Fig. 12

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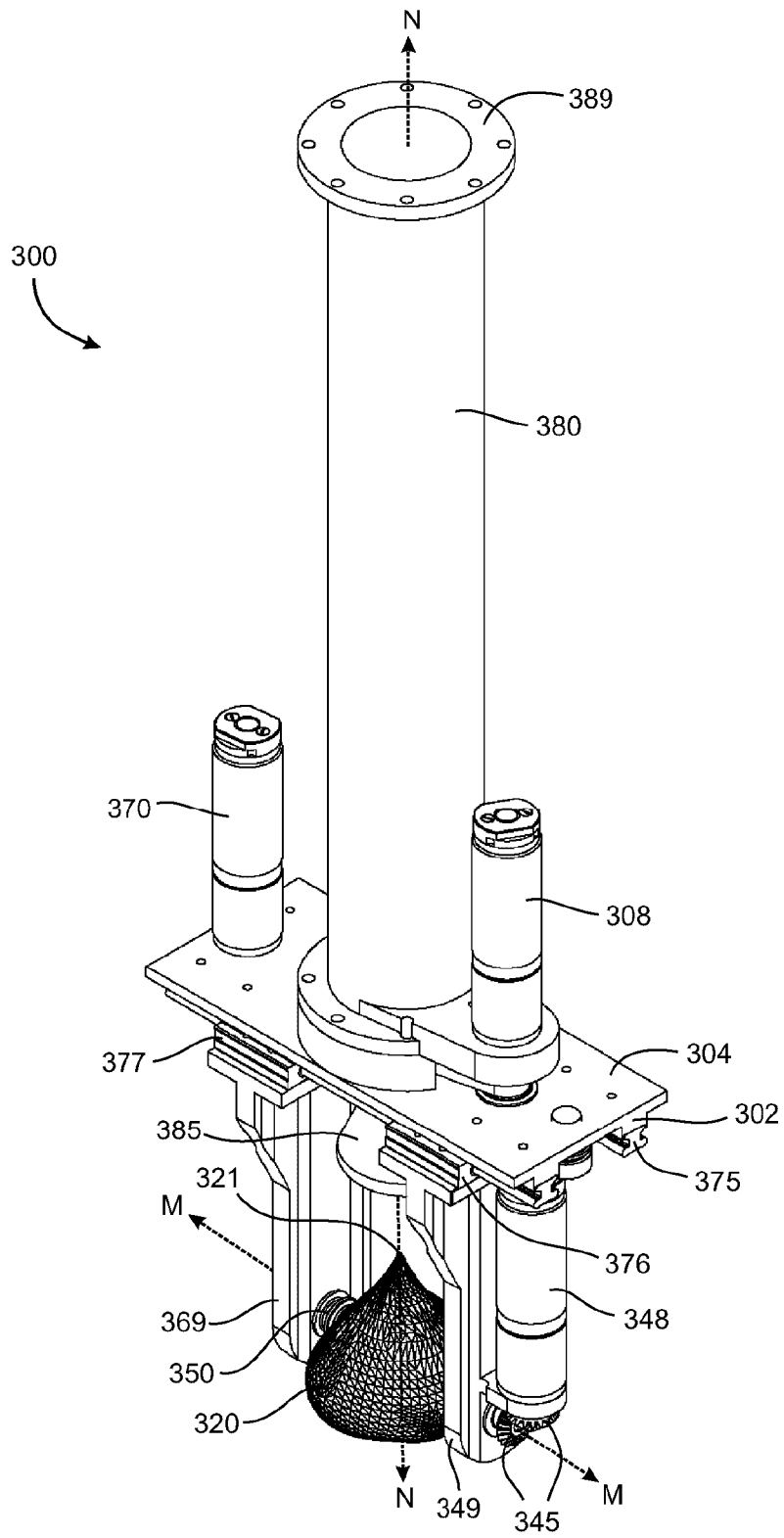


Fig. 13

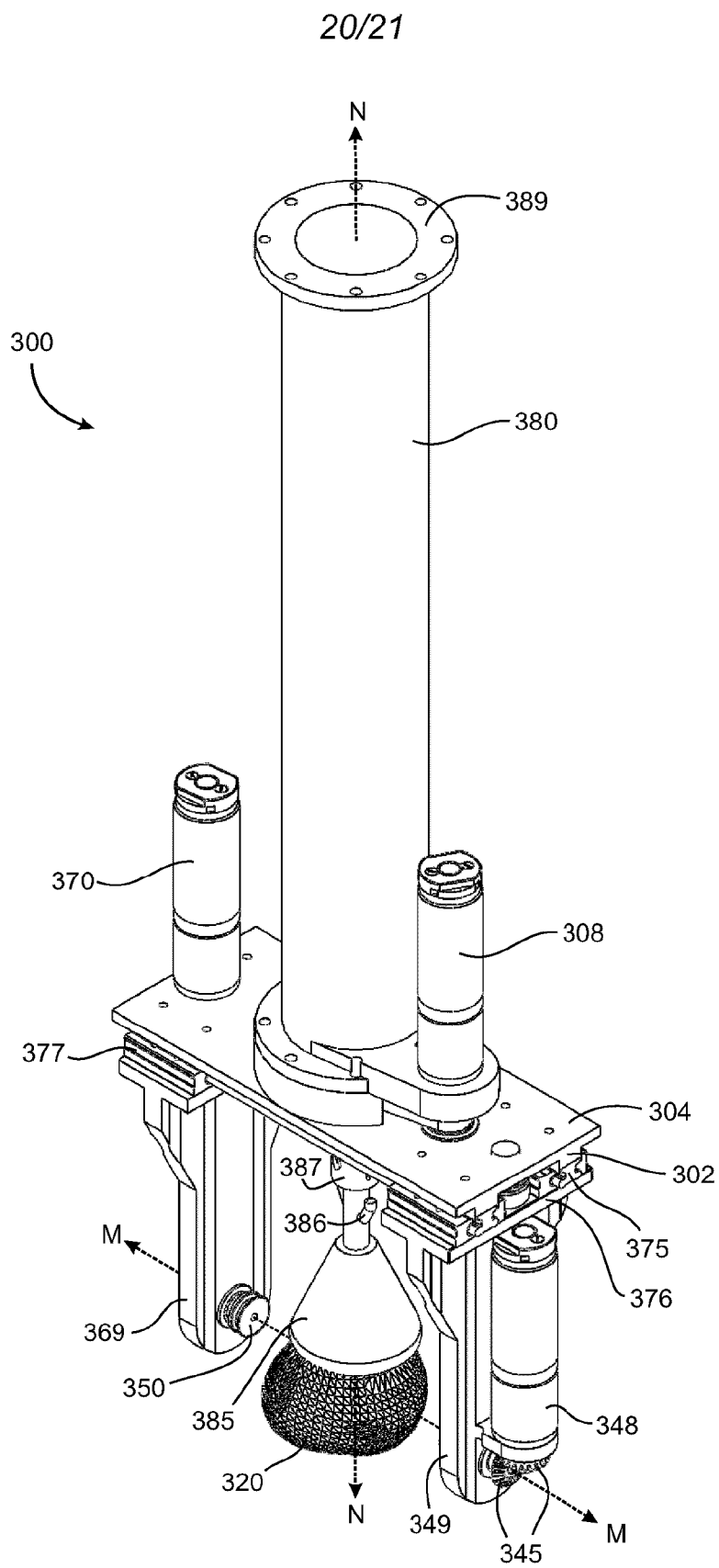


Fig. 14

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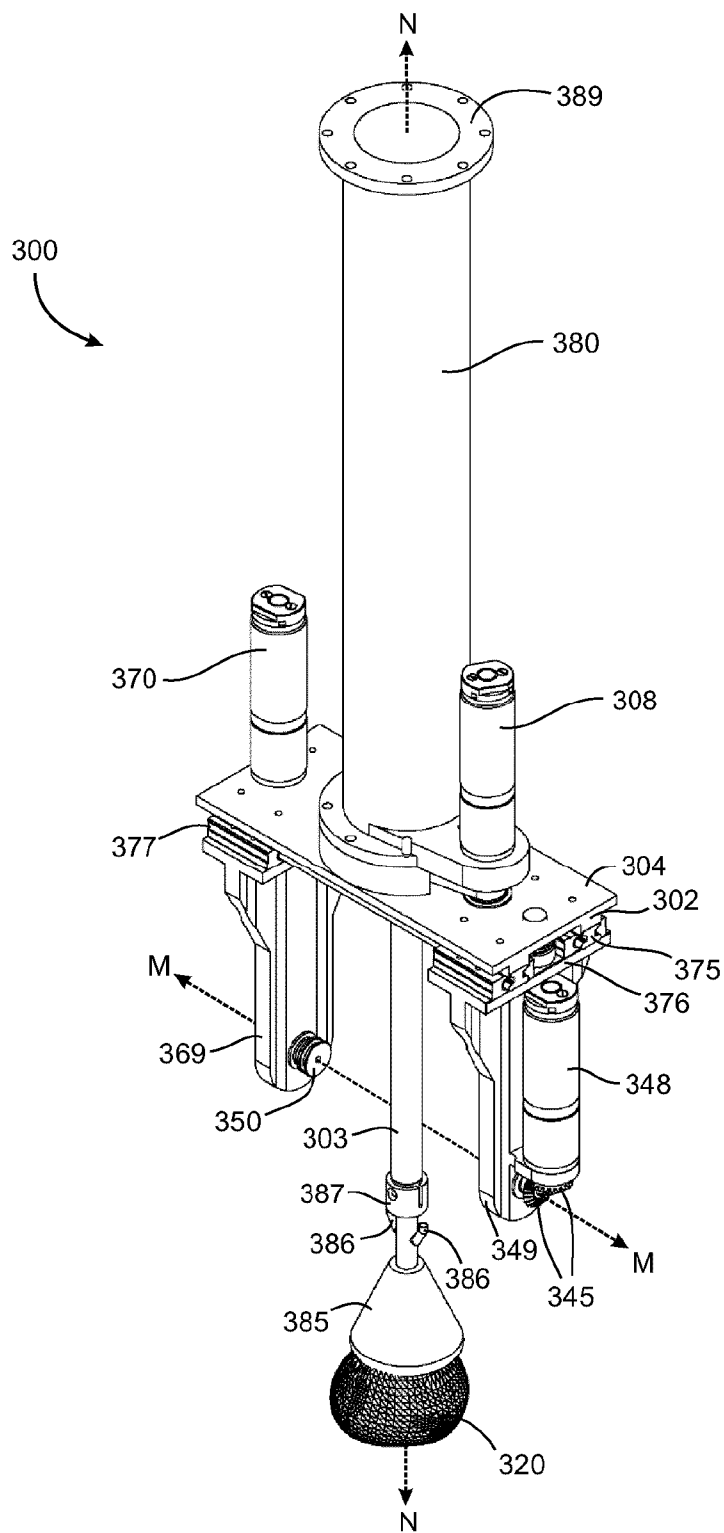


Fig. 15

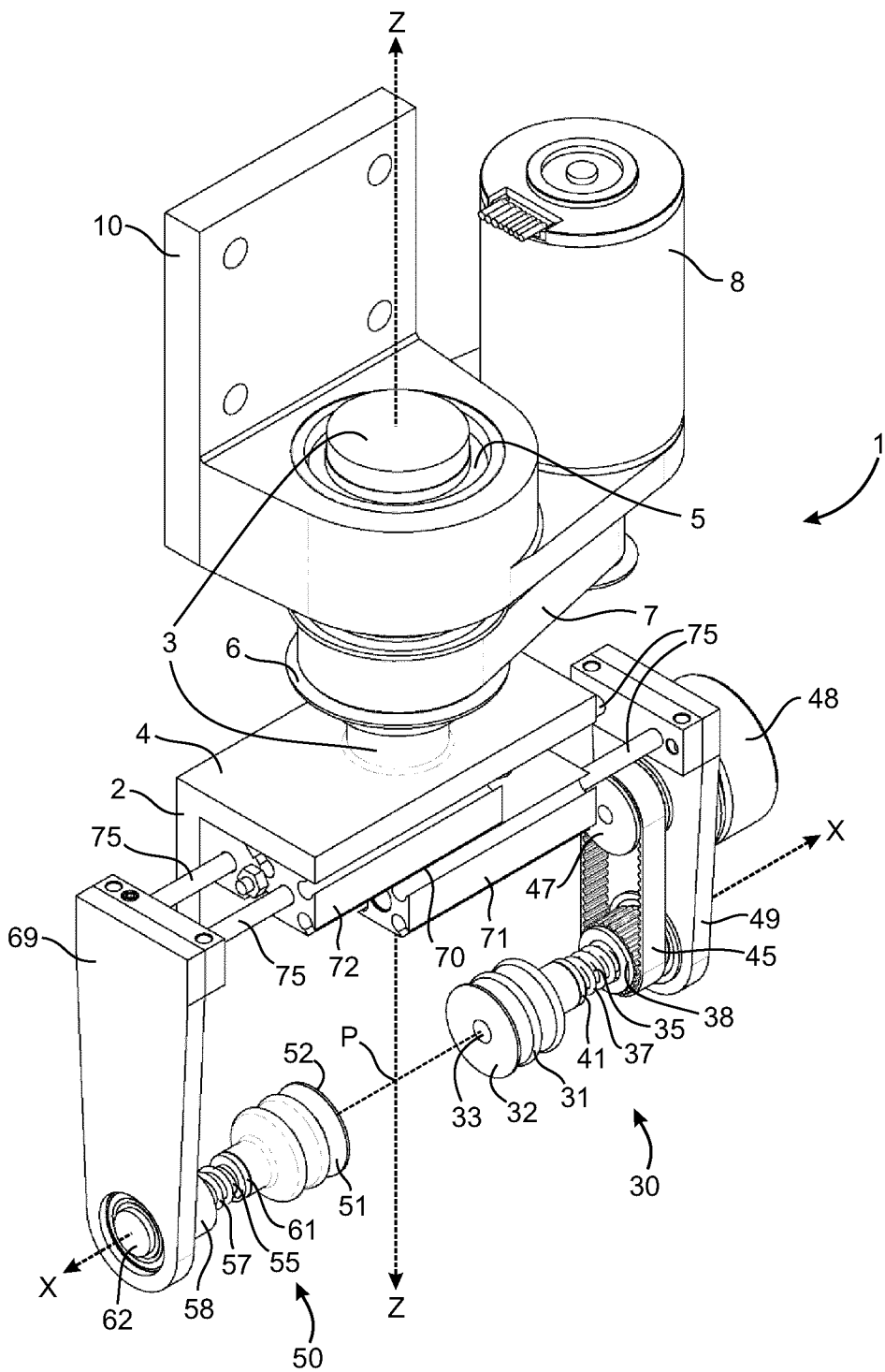


Fig. 1