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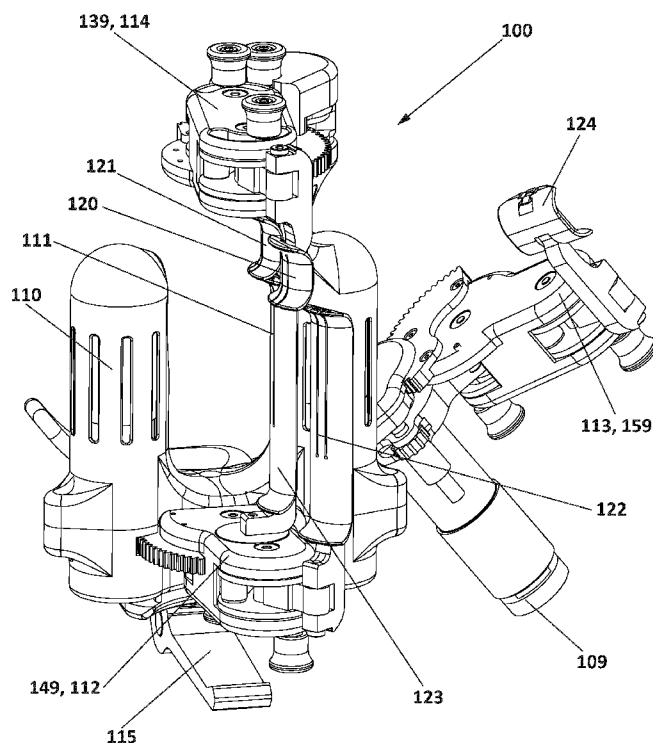
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(54) Title: HAND REHABILITATION DEVICE

**FIG. 1**

(57) Abstract: A hand rehabilitation device (100) comprising: at least one first support (124) configured to support the thumb of a hand, wherein said at least one first support (124) is designed to perform a flexion/extension movement for rehabilitating said thumb, said flexion/extension movement being actioned by a first transmission mechanism to which the at least one first support (124) is connected; at least one second support (120, 121, 120B) configured to support the index finger of said hand, wherein said at least one second support (120, 121, 120B) is designed to perform a flexion/extension movement for rehabilitating said index finger, said flexion/extension movement being actioned by a second transmission mechanism to which the at least one second support (120, 121, 120B) is connected; at least one third support (122, 123, 122B) configured to support the three remaining fingers-middle ring, and little fingers- of said hand, wherein said at least one third support (122, 123, 122B) is designed to perform a flexion/extension movement for rehabilitating said three remaining fingers, said flexion/extension movement being actioned by a third transmission mechanism to which the at least one third support (122, 123, 122B) is connected; wherein said first, second and third transmission mechanisms are actuated by at least one motor; wherein the three flexion/extension movements of said at least one first support (124), said at least one second support (120, 121,) and said at least one third support (122, 123,) are independent from each other.



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HAND REHABILITATION DEVICE

TECHNICAL FIELD

The present invention relates to the field of devices for rehabilitation of impaired limbs and, in particular, to devices for rehabilitation of impaired hands and fingers.

5

STATE OF THE ART

Finger function can be lost or damaged as a result of neurological injuries, such as stroke, spinal cord injuries, traumatic brain injuries or Parkinson disease. For example, stroke may cause paralysis of one side of the body. Examples of damaged finger
10 functions are failure to extend fingers, poor finger coordination, loss of finger independence, poor grasping or manipulation ability and inability to control constant grip force. Since the brain has certain capacity to reorganize the damaged neural connections, a partial (or even complete) recovery of the damaged functions is possible.

15

There exist active apparatuses for hand rehabilitation, including finger rehabilitation. Such rehabilitation aims at stimulating the recovery, usually by performing repeated movements involving the impaired limb.

20 One well-known type of hand rehabilitation systems is based on exoskeletons, which are robotic skeletons that externally embrace a limb or part of the body. For example, United States patent US-5516249-A describes an exoskeletal control apparatus based on a glove framework into which a hand can be inserted. A similar system is disclosed in United States patent US-8574178-B2. This type of devices is complex because they
25 have a lot of moving parts, which results in expensive maintenance. Besides, they require long time to fit a patient's hand to the device.

There are also less-complex finger rehabilitation systems, such as the one disclosed in International patent application WO-2010/140984-A1, which comprises a support on
30 which an impaired arm is fixed and five sub-systems, each of them comprising a finger fixation (strap) and a clutch system. Each finger strap is actuated by means of a cable (guided through a pulley) pulling in one direction and a bow spring in the other. However, this system is hardly portable due to its non-compactness. Besides, a force is

applied on each finger fixation and is therefore concentrated on a finger joint, therefore causing a potential damage on the joint and not optimizing the finger function rehabilitation. Additionally, finger flexion is provided exclusively by the bow spring component, not the motor, which makes the applied control to the fingers harder to control.

Finally, the availability of simple low-cost devices could extend the duration of rehabilitation, allowing robot-supported exercises at the patient's home, under remote monitoring and/or evaluation by the therapists. International patent application number WO2015/024852A1 discloses a hand motion exercising device having a movement unit dedicated to the thumb and a movement unit dedicated to the fingers. Both movement units are driven by a single motor. Besides, conventional hand rehabilitation devices, including the one disclosed in WO2015/024852A1, are designed to be used with either a right hand or a left hand, which results in requiring high investment.

Therefore, there is a need to provide a finger function rehabilitation device which has a simple portable structure and, at the same time, permits an optimized rehabilitation of the five fingers of both a right hand and a left hand.

DESCRIPTION OF THE INVENTION

It is an object of the invention to provide a portable modular device for hand rehabilitation. The different functions of the different fingers are optimized with the proposed device, because it permits independent rehabilitation (functional flexion/extension) of thumb and index finger, involved in most types of grasping. The remaining fingers –middle, ring and little fingers- are simultaneously moved in a single group. The proposed device, which is a hand-held device, mobilizes fingers by constraining fingertips along their natural, stereotypical trajectory for grasping tasks.

According to an aspect of the present invention, a device is provided for a hand rehabilitation device that comprises: at least one first support configured to support the thumb of a hand, wherein said at least one first support is designed to perform a flexion/extension movement for rehabilitating said thumb, said flexion/extension movement being actioned by a first transmission mechanism to which the at least one first support is connected; at least one second support configured to support the index

finger of said hand, wherein said at least one second support is designed to perform a flexion/extension movement for rehabilitating said index finger, said flexion/extension movement being actioned by a second transmission mechanism to which the at least one second support is connected; at least one third support configured to support the
5 three remaining fingers –middle ring, and little fingers- of said hand, wherein said at least one third support is designed to perform a flexion/extension movement for rehabilitating said three remaining fingers, said flexion/extension movement being actioned by a third transmission mechanism to which the at least one third support is connected; wherein said first transmission mechanism is actuated by one motor
10 different from the at least one motor configured to actuate said second and third transmission mechanisms; wherein the three flexion/extension movements of said at least one first support, said at least one second support and said at least one third support are independent from each other.

15 In a particular embodiment, at least one of said first, second and third transmission mechanisms comprises a pinion and a crown configured to move actioned by said pinion, which in turn is configured to rotate actioned by said motor. Still more particularly, upon rotation, said crown is configured to pull two crown gears interconnected by respective protrusions or teeth, causing said supports to move in
20 flexion/extension way. Alternatively, upon rotation, said crown is configured to pull an assembly formed by two wheels and coupling means connecting said two wheels together, wherein the wheel closest to the pinion is fixed and the other wheel and the coupling means move as a result of the movement of the crown.

In a particular embodiment, said at least one second support comprises a single
25 support for the index finger and said at least one third support comprises a single support for the three remaining fingers –middle ring, and little fingers.

In a particular embodiment, said at least one second support comprises one distal support for the distal phalanx of the index finger and one proximal support for the intermediate phalanx of the index finger, and said at least one third support comprises
30 one distal support for the distal phalanx of the three remaining fingers –middle ring, and little fingers and one proximal support for the intermediate phalanx of the three remaining fingers –middle ring, and little fingers. Preferably, said at least one first support, said one distal support for the distal phalanx of the index finger and said one

distal support for the distal phalanx of the three remaining fingers –middle ring, and little fingers- are coupled to the movable wheel of respective transmission mechanisms by means of a part that attaches to a pivot in the respective transmission mechanism.

In a particular embodiment, said at least one first support, said at least one second
5 support and said at least one third support are coupled to respective transmission mechanisms by means of a part that attaches to a pivot in the respective transmission mechanism.

In a particular embodiment, the device is reversible and therefore a same device serves at rehabilitating a right hand and a left hand. The device is reversible: either by
10 moving freely a set formed by a support and a part with respect to a pivoting means, when the transmission mechanism comprises two crown gears interconnected by respective protrusions or teeth; or by lifting pins and turning wheels until the corresponding pin naturally locks into a position in the opposite end of a canal and by
15 moving freely a set formed by a support and a part with respect to a pivoting means, when the transmission mechanism comprises two wheels and coupling means connecting said two wheels together.

In a particular embodiment each one of said first, second and third transmission mechanisms is actuated by one corresponding motor.

It is another object of the invention to provide a portable modular device for hand
20 rehabilitation configured for rehabilitation of at least the index, middle, ring and little fingers in two sections: a first section for the lower (proximal) phalanx and the intermediate phalanx of each finger; and a second section for the upper (distal) phalanx of each finger. With this double movement (movement in two sections) the flexion/extension of each finger is performed in a natural way, without forcing the joints.

25 According to another aspect of the present invention, a hand rehabilitation device is provided, that comprises: at least one first support configured to support the thumb of a hand, wherein said at least one first support is designed to perform a flexion/extension movement for rehabilitating said thumb, said flexion/extension movement being actioned by a first transmission mechanism to which the at least one first support is
30 connected; at least one proximal support configured to support the intermediate phalanx of at least the middle, ring and little fingers of said hand, wherein said at least one proximal support is designed to perform a flexion/extension movement of said

intermediate phalanxes of said fingers, actioned by at least one second transmission mechanism to which the at least one proximal support is connected; at least one distal support configured to support the distal phalanx of at least the middle, ring and little fingers of said hand, wherein said at least one distal support is designed to perform an additional flexion/extension movement of said distal phalanxes of said fingers with respect to the flexion/extension movement of said intermediate phalanxes of said fingers, actioned by said at least one second transmission mechanism to which the at least one distal support is connected; wherein said first transmission mechanism is actuated by one motor different from the at least one motor configured to actuate said at least one second transmission mechanisms; wherein the flexion/extension movement of said at least one first support is independent from the flexion/extension movements of said at least one proximal support and at least one distal support.

In a particular embodiment, at least one of said first and transmission mechanisms comprises a pinion and a crown configured to move actioned by said pinion, which in turn is configured to rotate actioned by said motor. Still more particularly, upon rotation, said crown is configured to pull two crown gears interconnected by respective protrusions or teeth, causing said supports to move in flexion/extension way. Alternatively, upon rotation, said crown is configured to pull an assembly formed by two wheels and coupling means connecting said two wheels together, wherein the wheel closest to the pinion is fixed and the other wheel and the coupling means move as a result of the movement of the crown.

In a particular embodiment, said at least one proximal support comprises a single support for the intermediate phalanxes of said index, middle, ring and little fingers and said at least one distal support comprises a single support for the distal phalanxes of said index, middle, ring and little fingers.

In a particular embodiment, said at least one first support and said at least one proximal support are coupled to respective transmission mechanisms by means of a part that attaches to a pivot in the respective transmission mechanism and said at least one distal support are coupled to respective transmission mechanisms by means of a part that attaches to a pivot in the respective transmission mechanism.

In a particular embodiment, said at least one proximal support comprises a first support for the intermediate phalanx of said index finger and a second support for the

intermediate phalanx of said middle, ring and little fingers; and said at least one distal support comprises a third support for the distal phalanx of said index finger and a fourth support for the distal phalanxes of said middle, ring and little fingers. Preferably, the device further comprises one transmission mechanism for actuating said first proximal support for the intermediate phalanx of the index finger and said third distal support for the distal phalanx of the index finger and another transmission mechanism for actuating said second proximal support for the intermediate phalanx of the middle, ring and little fingers and said fourth distal support for the distal phalanx of the middle, ring and little fingers.

- 10 In a particular embodiment, the device is reversible and therefore a same device serves at rehabilitating a right hand and a left hand. The device is reversible: either by moving freely a set formed by a support and a part with respect to a pivoting means, when the transmission mechanism comprises two crown gears interconnected by respective protrusions or teeth; or by lifting pins and turning wheels until the
- 15 corresponding pin naturally locks into a position in the opposite end of a canal and by moving freely a set formed by a support and a part with respect to a pivoting means, when the transmission mechanism comprises two wheels and coupling means connecting said two wheels together.

In a particular embodiment, each one of said at least two transmission mechanisms is

20 actuated by one corresponding motor.

Additional advantages and features of the invention will become apparent from the detail description that follows and will be particularly pointed out in the appended claims.

25

BRIEF DESCRIPTION OF THE DRAWINGS

To complete the description and in order to provide a better understanding of the invention, a set of drawings is provided. Said drawings form an integral part of the

30 description and illustrate an embodiment of the invention, which should not be interpreted as restricting the scope of the invention, but just as an example of how the invention can be carried out. The drawings comprise the following figures:

Figure 1 shows a view of a hand rehabilitation device configured for rehabilitating a right hand, according to a possible embodiment of the invention.

Figure 2A shows a different view of the hand rehabilitation device of figure 1.

Figure 2B shows the same view as shown in figure 2A, of the hand rehabilitation
5 device, wherein a right hand in its functional position has been illustrated.

Figures 3A and 3B show different views of the hand rehabilitation device of figure 1.

Figure 3C shows in detail the finger supports for the four fingers (hand rehabilitation device of figure 1).

Figures 4A to 4D show different views of a hand rehabilitation device according to a
10 more general embodiment of the invention. In this embodiment, there is a single finger rest for the index finger and a single finger rest for the group of fingers formed by middle, ring and little fingers. Figures 4E to 4H show an alternative implementation of this more general embodiment.

Figures 5A to 5C show different views of a hand rehabilitation device according to an
15 additional alternative embodiment of the invention.

Figure 6 shows a transmission mechanism according to a possible embodiment of the invention.

Figure 7 shows a transmission mechanism according to an alternative embodiment of the invention.

20 Figure 8 shows a break-up of the transmission mechanism in figure 7.

Figures 9A-9F show several positions of the flexion/extension mechanism for the finger support shown in figure 7. In figures 9A-9C, the flexion/extension mechanism for the finger support is configured for rehabilitating a right hand. In figures 9D-9F it is configured for rehabilitating a left hand.

25 Figures 10A-10F show several positions of the mechanism for the flexion/extension of the finger shown in figures 7, 8 and 9A-9F (figures 10A-10C right hand; figures 10D-10F left hand).

Figures 11A-11D show the rehabilitation device in figures 1-3, configured for rehabilitating a left hand, which is included. For clarity reasons the thumb has been
30 erased from the view.

Figures 12A-12D show the rehabilitation device in figures 1-3, configured for rehabilitating a right hand, which is included. For clarity reasons the thumb has been erased from the view.

Figures 13A-13D show the reversibility capability of the transmission mechanism of the device. Figures 13A and 13C show the left hand configuration, while figures 13B and 13D show the corresponding right hand configuration.

5 DESCRIPTION OF A WAY OF CARRYING OUT THE INVENTION

In this text, the term “comprises” and its derivations (such as “comprising”, etc.) should not be understood in an excluding sense, that is, these terms should not be interpreted as excluding the possibility that what is described and defined may include further elements, steps, etc.

10

In the context of the present invention, the term “approximately” and terms of its family (such as “approximate”, etc.) should be understood as indicating values very near to those which accompany the aforementioned term. That is to say, a deviation within reasonable limits from an exact value should be accepted, because a skilled person in the art will understand that such a deviation from the values indicated is inevitable due to measurement inaccuracies, etc. The same applies to the terms “about” and “around” and “substantially”.

The following description is not to be taken in a limiting sense but is given solely for the purpose of describing the broad principles of the invention. Next embodiments of the invention will be described by way of example, with reference to the above-mentioned drawings showing apparatuses and results according to the invention.

20

DESCRIPTION OF A FIRST WAY OF CARRYING OUT THE INVENTION

Figures 1, 2A, 2B, 3A, 3B and 3C show different views of a hand rehabilitation device 100 according to a possible embodiment of the invention. The device 100 is versatile, meaning that it can be configured for rehabilitating either a right hand or a left hand. The configuration shown in these figures is a right-hand configuration, but it can simply be switched to a left-hand configuration, as will be explained later in this text. The device 100 can be attached to another device or apparatus, such as to a tool robot, a manipulator or an arm support (for example a support fixed on a table), or directly to the arm of the user. It can also act as a hand-held device.

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The portable device 100 is configured to be grasped by the hand to be trained, in such a way that the palm, fingers and thumb (inner part of the hand) surround the grasped device 100. In this particular implementation, the structure 110 is to be grasped by a right-hand, as shown in figure 2B. When grasping the hand-held device 100 by an

5 impaired hand, the inner part of the fingers and thumb are disposed on several supports or "finger rests" 120 121 122 123 124 disposed to receive the fingers and thumb, which rest or are supported on the supports. Optionally, a strap can be included, in order to ensure that the fingers are attached to the device. The strap can be especially useful for finger flexion (hand closing movement). In the shown

10 embodiment, two finger rests 120 121 are disposed for receiving the respective distal phalanx and at least a portion of the intermediate phalanx (or the whole intermediate phalanx) of the index finger (inner part thereof) and two finger rests 122 123 are disposed for receiving the respective distal phalanx and at least a portion of the intermediate phalanx (or the whole intermediate phalanx) of another group of fingers,

15 formed by middle, ring and little fingers (inner part thereof). In other words, the two upper finger rests 120 122 end up between the distal and the intermediate phalanx of the index finger and middle, ring and little fingers, respectively, while the two lower finger rests 121 123 end up between the proximal and the intermediate phalanx of the index finger and middle, ring and little fingers, respectively. As shown for example in

20 figure 3A, the supports or rests 120 121 for the index finger are attached to a structure (carriage) 139, which holds the transmission mechanism 114 for those rests 120 121. Figure 3C shows the attaching means 144 141 for supports 120 121, respectively. Similarly, the supports or rests 122 123 for the middle, ring and little fingers are attached to a structure (carriage) 149 which holds the transmission mechanism 112 for

25 those rests 122 123. The view of figure 1 and the rotated view of figure 3A show an additional support or rest 124 for the thumb. The disposition of this thumb rest 124 with respect to the other finger rests has been selected to be adapted to the natural shape of the hand. The support or rest 124 for the thumb is attached to a structure (carriage) 159 which holds the transmission mechanism 113 for that rest 124. In the figures, other

30 elements can be observed, such as: a motor 110 for actuating the supports or rests 122 123 for the middle, ring and little fingers (the casing of this motor 110 functions as a palm rest for a left hand or as a grasp for the device with a left hand when the device is used for rehabilitating a left hand); a motor 111 for actuating the supports or rests

120 121 for the index finger (the casing of this motor 111 functions as a palm rest for a right hand or as a grasp for the device with a right hand when the device is used for rehabilitating a right hand); a motor 109 for actuating the support or rest 124 for the thumb; a transmission mechanism 112 (held in carriage 149) associated to motor 110;
5 a transmission mechanism 113 (held in carriage 159) associated to motor 109; a transmission mechanism 114 (held in carriage 139) associated to motor 111; and a locking arm 115 for a thumb adjustment mechanism.

Figures 4A-4D show a more general embodiment, in which there is a single finger rest 120A for the index finger and a single finger rest 122A for the group of fingers formed
10 by middle, ring and little fingers. In this case, finger rest 120A ends up between the proximal and the intermediate phalanx of the index finger, while finger rest 122A ends up between the proximal and the intermediate phalanx of the middle, ring and little fingers. In these views the thumb and corresponding rehabilitation mechanism have been removed for clarity purposes.

15 Figures 4E-4H show an alternative implementation of the more general embodiment, in which there is a single finger rest 120B for the index finger and a single finger rest 122B for the group of fingers formed by middle, ring and little fingers. In this case, finger rest 120B ends up between the intermediate and the distal phalanx of the index finger, while finger rest 122B ends up between the intermediate and the distal phalanx
20 of the middle, ring and little fingers. In these views the thumb and corresponding rehabilitation mechanism have also been removed for clarity purposes.

As will be explained later, in use of the device, the supports or finger rests 120 121 120A 120B 122 123 122A 122B 124 are moved, actuated by motors 111 110 109, provoking the flexion/extension of the fingers (and thumb) supported on the
25 corresponding finger rests. As can be observed, the device 100 permits independent rehabilitation of the thumb (by means of rest 124 (see for example figure 3A)) and independent rehabilitation of the index finger (by means of finger rest 120A (figures 4A-4D) or by means of finger rest 120B (figures 4E-4H) or by means of finger rests 120 121 (figures 1-3C)) with respect to the three remaining fingers, which are rehabilitated
30 in a single group (either on finger rest 122A or on finger rest 122B or on finger rests 122 123). Thus, the device permits independent rehabilitation (functional flexion/extension) of thumb and index finger, these fingers being the ones involved in most types of grasping movements. The remaining fingers –middle, ring and little

fingers- are simultaneously moved in a single group. The device 100 permits passive rotation of finger supports (finger rests) for self-alignment with hands of varying sizes.

Next, the transmission mechanism 113 112 114 which enables the flexion/extension of the thumb and fingers is explained. Each transmission mechanism 112 113 114 is actuated by a motor 110 109 111. The illustrated embodiments show an independent transmission mechanism 113 for the thumb, an independent transmission mechanism 114 for the index and an independent transmission mechanism 112 for the three fingers. In an alternative embodiment, there is an independent transmission mechanism 113 for the thumb and one single additional independent transmission mechanism for the four fingers. This is achieved by connecting or locking, for example by means of a bar, rest 120A with rest 122A in figure 4A, or rest 120B with rest 122B in figure 4E, or rest 120 with rest 122 and rest 121 with rest 123 in figure 3A or figure 3C. In any of these cases, one of the two motors (motor 111 or motor 110) could be removed. In the particular embodiment in which there is independent rehabilitation of the index finger, there are two independent transmission mechanisms (instead of one): one independent transmission mechanism 114 for the index finger and one independent transmission mechanism 112 for the three remaining fingers. The functioning of the several transmission mechanisms is the same and is described next. Next, two possible embodiments for the transmission mechanism 112 113 114 are described with reference to respective figures 6 and 7. Both embodiments comprise a double gearwheel mechanism 130 131 and are equivalent within the range of motion (ROM) of interest. Figures 9A-9F show several positions of the mechanism of the flexion/extension of the fingers (in this case implemented as shown in figure 7).

Figures 6 and 7 show two possible embodiments of the double gearwheel mechanism 130 131. The double gearwheel mechanism 130 in figure 6 is based on a double toothed gearwheel. The double gearwheel mechanism 131 in figure 7 is based on a double wheel with mechanical coupling. In both implementations 130 131 of the mechanism, a respective motor 111 110 109, not shown in figures 6 and 7, actuates on a pinion 132, which is rotated by the motor. The pinion 132 in turn makes a crown 133 move (the crown 133 is shown in figures 9A-9F). The crown 133 is fixed to the carriage 139 149 159, which houses inside the transmission mechanism 114 112 113 (in this embodiment, double gearwheel mechanism 130 131). In its movement (rotation), the crown 133 drags the carriage 139 149 159. Next we refer to the

particular case of the structure for rehabilitating an index finger. However, the following explanation refers similarly to the structures for rehabilitating the three fingers (see for example figures 4A to 4H) and to the structure for rehabilitating a thumb. The support for the intermediate phalanx of the fingers (intermediate support or proximal support) is
5 fixed to the carriage 139 such that the movement of the motor 111 produces an angular displacement of the carriage 139 (by means of the rotation of the crown 133) and a corresponding angular displacement of the support 121 123 for the intermediate phalanx. The transmission mechanism 130 131 (double gearwheel) comprises an input wheel 135A 136A and an output wheel 135B 136B. Input wheel 135A 136A and output
10 wheel 135B 136B are connected to each other such that the input wheel 135A 136A does not move when the carriage 139 moves (angular displacement) but produces a rotation of the output wheel 135B 136B. Additional features applicable to the particular embodiment in which each finger (index on the one hand and middle, ring and little fingers on the other hand) is rehabilitated in two sections (figures 1-3C), are explained
15 next. The following explanation fully applies to the thumb because the distal phalanx support is the same in all three modules (index, fingers, thumb). The support 120 122 for the distal phalanx of the finger (distal support) is fixed to the output wheel 125B 136B such that the movement of the motor 110 111 109 produces an angular displacement of the carriage 139 and a corresponding angular displacement of the
20 support 120 122 for the distal phalanx. In addition, the movement of the carriage 139 produces a rotation of the output wheel 135B 136B and that rotation produces and angular displacement of the support 120 122 for the distal phalanx with respect to the position of the carriage 139. As explained, the angular displacement of the distal phalanx support 121 123 is greater than the angular displacement of the intermediate
25 phalanx support 120 122.

The motor 110 111 109 can be selectively activated by the user (or by a therapist) for operation of the device. In a preferred embodiment, the motor is battery powered a. Alternatively, it could be powered by conventional available electricity or pressurized fluid such as compressed air in the case of a device fitted with pneumatic motors. For
30 simplicity reasons, in figures 6 and 7 the pinion 132 and the crown 133 are not shown because they are housed in a casing, housing or base 134. Figure 3B clearly shows motor 109 and its pinion 162, motor 110 and its pinion 172 and motor 111 and its pinion 132.

In figure 6, the transmission mechanism (double gearwheel mechanism) 130 is formed by two toothed gearwheels: an input toothed gearwheel 135A and an output toothed gearwheel 135B (also referred to as gear train) engaged by respective teeth. The input toothed gearwheel 135A is mounted in the rotational axis 160 of the carriage 139 such that when the carriage rotates by the rotation of the crown 133, the input gearwheel 135A does not move. The output gearwheel 135B is mounted in the carriage 139 through its axis 180 so the output gearwheel 135B moves when the carriage 139 moves but can rotate freely in the carriage 139. As the input gearwheel 135A is engaged to the output gearwheel 135B (through a toothed edge) when the movement of the carriage 139 drags the output gearwheel 135A, the output wheel 135B is forced to rotate over the input gearwheel 135A. The intermediate phalanx support 121 123 is fixed to the carriage 139 whilst the distal phalanx support 120 122 is fixed to the output gearwheel 135B. That way, the angular displacement of the intermediate phalanx support 121 123 is the displacement of the carriage 139 whilst the angular displacement of the distal phalanx support 120 122 is the displacement of the carriage plus the rotation of the output gearwheel 135B. The angular displacement of the distal phalanx support 121 123 and intermediate phalanx support 120 122 produce the flexion/extension of the fingers (either index finger, thumb or remaining fingers).

In figure 7, the transmission mechanism (double gearwheel mechanism) 131 is formed by two discs or wheels, an input wheel 136A and an output wheel 136B which do not touch directly each other and a coupling means or mechanical coupling (such as a coupling rod) 137 connecting the two discs or wheels together. The coupling means 137 is fixed to the input and output wheels 136A 136B such that the distance between the connecting points of the input and output wheels 136A 136B is fixed.

The input wheel 136A is mounted in the rotational axis 160 of the carriage 139, such that when the carriage rotates by the rotation of the crown 133, the input wheel 136A does not move. The output wheel 136B is mounted in the carriage through its axis 180. So the output wheel 136B moves when the carriage 139 moves, but can rotate freely in the carriage 139. As the input wheel 136A is engaged to the output wheel 136B (through a coupling rod 137), when the movement of the carriage 139 drags the output wheel 136B, the output wheel 136B is forced to rotate by the connecting rod 137 to maintain the distance between the connecting points of the input and output wheels 136A 136B. The proximal phalanx support 121 123 is fixed to the carriage 139 whilst

the distal phalanx support 120 122 is fixed to the output wheel 136B. That way the angular displacement of the proximal phalanx support 121 123 is the displacement of the carriage 139, whilst the angular displacement of the distal phalanx support 120 122 is the displacement of the carriage plus the rotation of the output wheel 136B. The angular displacement of the distal phalanx support 120 122 and proximal phalanx support 121 123 can produce the flexion/extension of the fingers (either index finger, thumb or remaining fingers).

Figure 8 shows a break-up of the transmission mechanism (double gearwheel mechanism) 131 in figure 7. A first casing, housing or base 134 houses the pinion 132 and partially the crown 133. Note that we refer generally to pinion 132 but we could refer correspondingly to pinion 162 172 (see for example figure 3B). This is the same as in the transmission mechanism 130 shown in figure 6. A second casing or carriage 139 houses the fixed wheel 136B, the moving wheel 136A and the mechanical coupling 137 (in the transmission mechanism 130 in figure 6, the carriage 139 houses the double toothed gearwheel). Like in the transmission mechanism (double gearwheel mechanism) 130 in figure 6, the crown 133 is fixed to the lower part of the carriage 139. In the shown embodiment, the input wheel 136A and the output wheel 136B are identical, and are formed by two flat discs disposed parallel to each other and fixed one another by any kind of mechanical attachment 137 (connecting rod) which establishes a fixed distance between the connecting points of the input and output wheels 136A 136B. The input wheel 136A and the carriage 139 comprise an elongated canal 141A, which defines two end positions P1 P2 for the angular displacement of the carriage 139, to control the maximum extension movement possible for the fingers. Pin 138B is used to constrain the proximal pivot point for link (mechanical attachment) 137. For a right hand configuration, the pivot point is on the left (figure 8 top). For a left hand configuration, the pivot point is on the right. Pin 138B has the exact function as pin 138A, that is to say, to define the position of the distal pivot point for link (mechanical attachment) 137. For a right hand configuration, the distal pivot point is on the right. For a left hand configuration, the point is on the left. Pin 138C is mounted on the carriage 139. The shaft 238C of pin 138C is housed in the elongated canal 141B so that during the angular displacement of the carriage 139, the canal 141B moves around pin 138C, but collides with the shaft 238C of the pin at the end of the stroke imposed for the carriage 139 (depending on the maximum extension movement established for the

fingers). These two positions P1 P2 defined in the input wheel 136A also permit the implementation of the reversibility feature of the device. They also contribute to security, since for example they prevent damage on the user in the event a motor fails. When the device is configured to rehabilitate a left hand, pin 138C is in position P1. On
5 the contrary, when the device needs to be reconfigured in order to rehabilitate a right hand, pin 138C is placed in position P2. The support or rest for the intermediate phalanx (121 in the case of index finger, 123 in the case of middle, ring or little fingers) is coupled to carriage 139 by means of attaching means 141.

Figure 8 shows the particular embodiment in which rehabilitation of the fingers is done
10 in two sections. In order to achieve this two-section rehabilitation, the support or rest for the distal phalanx (120 in the case of index finger, 122 in the case of middle, ring or little fingers) is coupled to the output wheel 136B by means of a part 144 on which the support (120, 122) is fixed. This part 144 is connected to the output wheel 136B by means of pivoting means 142 connected in one end to part 144 (for example by means
15 of a screw 145) and in the other end 142B to the output wheel 136B and second housing 139 (for example by means of a screw 146 as shown in figure 6). This connection permits additional travel of the distal support 120 (or 122) with respect to the maximum rotation achieved by the carriage 139. The angle travelled by the distal phalanx is therefore larger than the angle travelled by the proximal phalanx. In a
20 particular embodiment, the device is designed for the distal phalanx to travel an angle which is around twice the travel of the angle travelled by the proximal phalanx. Figure 8 also shows the support for the proximal phalanx (121 in the case of index finger, 123 in the case of middle, ring or little fingers) and the part 141 on which the support is fixed. This part 141 is connected to the support. These parts 141 144 and their corresponding
25 supports are also shown in figure 3C.

Figures 9A-9F show several positions of the mechanism of the flexion/extension of the fingers (in this case the mechanism 131 is implemented as shown in figure 7). These positions can refer to the index finger, or to the three other fingers and even to the thumb, if two-sections for the two phalanxes were implemented. Figures 9A-9C refer to
30 a sequence for a right hand. Figure 9A refers to a position with substantially maximum extension while figure 9C refers to a position with substantially maximum flexion. Figures 9D-9F refer to sequence for a left hand. Figure 9D refers to a position with substantially maximum extension while figure 9F refers to a position with substantially

maximum flexion. As can be observed, wheel 136A and pin 138B remain fixed with respect to the housing, casing or base 134. The carriage 139 rotates actioned by crown 133 in turn actioned by the pinion 162 (or 132 172) moved by a motor (not shown). The crown 133 drags carriage 139 and in turn the mechanical coupling 137 moves the output wheel 136B.

Figures 10A-10F show several positions of the mechanism of the flexion/extension of the index finger (right hand in figures 10A-10C and left hand in figures 10D-10F).

Figures 11A-11D show different views of the hand rehabilitation device shown for example in figure 1, but in this case configured to rehabilitate a left hand, which is illustrated in its functional position for rehabilitation. In this figures, the casings of the transmission mechanism 114 for the index finger has been erased, in order to show the functioning of the double gearwheel mechanism 131. The transmission mechanism 112 for the group of middle, ring and little fingers works in a similar way. In figure 11B the casing 151 in which the motor 110 which actuates the transmission mechanism 112 for the group of middle, ring and little fingers is shown. It is remarked that the location of the motors may vary in different designs of the device. Reference 152 is the casing in which motor 111 is housed. The casing that houses the transmission mechanism 114 for the index has been erased, in order to show the transmission mechanism 114. The transmission mechanism 112 for the three fingers is also shown (in this case hidden by its casing). The thumb has been erased from these views for clarity purposes. Figures 12A-12D show different views of the same hand rehabilitation device, in this case configured to rehabilitate a right hand. Again, the thumb has been erased from these views for clarity purposes.

As already mentioned, the device is reversible. This means that the same device can be used to rehabilitate both a right hand and a left hand. The transmission mechanism illustrated in figure 6 does not require any reconfiguration in order to switch from a "right hand configuration" to a "left hand configuration" or vice versa. That is to say, reversibility is automatic. Figures 13A-13D illustrate the reversibility capability of the transmission mechanism of figure 7. Since there are 3 transmission mechanisms in one device (index finger, 3 fingers and thumb), the reconfiguration must be done three times, because each finger requires reorienting wheels 136A and 136B and lock with pins 138B and 138C. That is to say, in order to perform reconfiguration, the pins 138B 138C must be lifted, then wheels must be turned, so that the pin naturally locks into

position in the opposite end of the circular groove (canal) with the round holes in the ends. Alternatively, pins 138B 138C could be one single mechanism in order to simplify the process. Additionally, the thumb lock mechanism also needs to be reconfigured. Turning back to figure 8, during reconfiguration, the set formed by support 120 (or 122) and part 144 moves freely with respect to screw 145. Similarly, the set formed by support 121 (or 123) and part 141 moves freely with respect to corresponding screw (both if the transmission mechanism in figure 6 and in that in figure 7).

Figures 13A and 13C show the left hand configuration, while figures 13B and 13D show the corresponding right hand reconfiguration. In the reconfiguration process from left to right hand (it would be similar from right to left hand), the housing or base does not change position. Pin 138B, which in left-hand configuration is positioned in position P2 (see figure 8) in output wheel 136B is moved to position P1 (see figure 8). The mechanical coupling (transmission bar) 137 becomes naturally re-oriented when the wheels 136A 136B change position. Pin 138B also changes position from position P2' (left hand configuration) to position P1' (right hand configuration). Pivoting axis 160 is maintained in both left-hand and right-hand configurations, independently from the positions of motors. The casing, housing or carriage 139 pivotes or rotates around this pivoting axis 160. Pin 138A does not have any influence in reconfiguration. As already mentioned, the transmission mechanism shown in figure 6 does not need any change in order to be reconfigured, except for the free movement of the set formed by support 120 (or 122) and part 144 and the free movement of the set formed by support 121 (or 123) and part 141. In both mechanisms, it is possible to add safety pins in order to prevent over-travel of the hand in the event of failure of a motor.

The device 100 permits two symmetrical grasp modes supported for each of left-hand and right-hand operation: cylindrical mode (for grasping for example a glass) and "open pinch/clamp" for 3-fingered grasp (predominantly MCP action).

DESCRIPTION OF A SECOND WAY OF CARRYING OUT THE INVENTION

Figures 1, 2A, 2B, 3A, 3B and 3C show different views of a hand rehabilitation device 100 according to a possible embodiment of the invention. The device 100 is versatile, meaning that it can be configured for rehabilitating either a right hand or a left hand. The configuration shown in these figures is a right-hand configuration, but it can simply

be switched to a left-hand configuration, as will be explained later in this text. The device 100 can be attached to another device or apparatus, such as to a tool robot, a manipulator or an arm support (for example a support fixed on a table), or directly to the arm of the user. It can also act as a hand-held device.

- 5 The portable device 100 is configured to be grasped by the hand to be trained, in such a way that the palm, fingers and thumb (inner part of the hand) surround the grasped device 100. In this particular implementation, the structure 110 is to be grasped by a right-hand, as shown in figure 2B. When grasping the hand-held device 100 by an impaired hand, the inner part of the fingers and thumb are disposed on several
- 10 supports or "finger rests" 120 121 122 123 124 disposed to receive the fingers and thumb, which rest or are supported on the supports. Optionally, a strap can be included, in order to ensure that the fingers are attached to the device. The strap can be especially useful for finger flexion (hand closing movement). In the shown embodiment, two finger rests 120 121 are disposed for receiving the respective distal
- 15 phalanx and at least a portion of the intermediate phalanx (or the whole intermediate phalanx) of the index finger (inner part thereof) and two finger rests 122 123 are disposed for receiving the respective distal phalanx and at least a portion of the intermediate phalanx (or the whole intermediate phalanx) of another group of fingers, formed by middle, ring and little fingers (inner part thereof). In other words, the two
- 20 upper finger rests 120 122 end up between the distal and the intermediate phalanx of the index finger and middle, ring and little fingers, respectively, while the two lower finger rests 121 123 end up between the proximal and the intermediate phalanx of the index finger and middle, ring and little fingers, respectively. As shown for example in figure 3A, the supports or rests 120 121 for the index finger are attached to a structure
- 25 (carriage) 139, which holds the transmission mechanism 114 for those rests 120 121. Figure 3C shows the attaching means 144 141 for supports 120 121, respectively. Similarly, the supports or rests 122 123 for the middle, ring and little fingers are attached to a structure (carriage) 149 which holds the transmission mechanism 112 for those rests 122 123. The view of figure 1 and the rotated view of figure 3A show an
- 30 additional support or rest 124 for the thumb. The disposition of this thumb rest 124 with respect to the other finger rests has been selected to be adapted to the natural shape of the hand. The support or rest 124 for the thumb is attached to a structure (carriage) 159 which holds the transmission mechanism 113 for that rest 124. In the figures, other

elements can be observed, such as: a motor 110 for actuating the supports or rests 122 123 for the middle, ring and little fingers (the casing of this motor 110 functions as a palm rest for a left hand or as a grasp for the device with a left hand when the device is used for rehabilitating a left hand); a motor 111 for actuating the supports or rests
5 120 121 for the index finger (the casing of this motor 111 functions as a palm rest for a right hand or as a grasp for the device with a right hand when the device is used for rehabilitating a right hand); a motor 109 for actuating the support or rest 124 for the thumb; a transmission mechanism 112 (held in carriage 149) associated to motor 110; a transmission mechanism 113 (held in carriage 159) associated to motor 109; a
10 transmission mechanism 114 (held in carriage 139) associated to motor 111; and a locking arm 115 for a thumb adjustment mechanism.

Figures 5A to 5C show three views of a more general embodiment, in which there is a single proximal finger rest or support 123C for the proximal phalanx and the intermediate phalanx of index, middle, ring and little fingers; and a single distal finger
15 rest or support 122C for the distal phalanx of index, middle, ring and little fingers. Thus, the device permits rehabilitation of at least the index, middle, ring and little fingers in two sections: a first section including the proximal phalanx and the intermediate phalanx of each finger; and a second section including the distal phalanx of each finger. In this case, the distal finger rest 122C ends up between the distal and the
20 intermediate phalanx of the index, middle, ring and little fingers, while the proximal finger rest 123C ends up between the proximal and the intermediate phalanx of the index, middle, ring and little fingers. With this double movement (movement in two sections) the flexion/extension of each finger is performed in a natural way, without forcing the joints. In these views the thumb and corresponding rehabilitation
25 mechanism have been removed for clarity purposes. In a most preferred embodiment, shown in figures 1-3C, apart from this two-section rehabilitation, there is independent rehabilitation of the index finger with respect to the group formed by the middle, ring and little fingers.

As will be explained later, in use of the device, the supports or finger rests 120 121 122
30 123 122C 123C 124 are moved, actuated by motors 110 111 109 110B (motor 110B is not shown, being the motor for the 4 fingers in figures 5A-5C), provoking the flexion/extension of the fingers (and thumb) supported on the corresponding finger rests. As can be observed, the device 100 permits independent rehabilitation of the

thumb (by means of rest 124 (see for example figure 3A)) and rehabilitation in two sections of the four fingers (by means of finger rests 122C 123C (figures 5A-5C) or finger rests 120 121 122 123 (figures 1-3C). In this particular embodiment, independent rehabilitation of the index finger, with respect to the three remaining fingers, is achieved, which are rehabilitated in a single group. Thus, in this particular embodiment, apart from rehabilitating the fingers in two sections (a first one for proximal and intermediate phalanxes and a second one for distal phalanxes), the device permits independent rehabilitation (functional flexion/extension) of thumb and index finger, these fingers being the ones involved in most types of grasping movements. The remaining fingers –middle, ring and little fingers- are simultaneously moved in a single group. The device 100 permits passive rotation of finger supports (finger rests) for self-alignment with hands of varying sizes.

Next, the transmission mechanism 112 113 114 112B (112 113 114 in figures 1-3C and 112B in figures 5A-5C) which enables the flexion/extension of the thumb and fingers is explained next. Each transmission mechanism 112 113 114 112B is actuated by a motor 110 109 111 110B. There is an independent transmission mechanism 113 for the thumb and at least one additional independent transmission mechanism 112B for the four fingers. In the particular embodiment in which there is independent rehabilitation of the index finger, there are two additional independent transmission mechanisms 112 114 (instead of one 112B): one independent transmission mechanism 114 for the index finger and one independent transmission mechanism 112 for the three remaining fingers. In an alternative embodiment, there is an independent transmission mechanism 113 for the thumb and one single additional independent transmission mechanism for the four fingers, even when there is an independent rest of the index. This is achieved by connecting or locking, for example by means of a bar, rest 120A with rest 122A in figure 4A, or rest 120B with rest 122B in figure 4E, or rest 120 with rest 122 and rest 121 with rest 123 in figure 3A. In any of these cases, one of the two motors (motor 111 or motor 110) could be removed. The functioning of the several transmission mechanisms is the same and is described next. Next, two possible embodiments for the transmission mechanism are described with reference to respective figures 6 and 7. Both embodiments comprise a double gearwheel mechanism 130 131 and are equivalent within the range of motion (ROM) of interest.

Figures 9A-9F show several positions of the mechanism of the flexion/extension of the fingers (in this case implemented as shown in figure 7).

Figures 6 and 7 show two possible embodiments of the double gearwheel mechanism 130 131. The double gearwheel mechanism 130 in figure 6 is based on a double toothed gearwheel. The double gearwheel mechanism 131 in figure 7 is based on a double wheel with mechanical coupling. In both implementations 130 131 of the mechanism, a respective motor 111 110 109, not shown in figures 6 and 7, actuates on a pinion 132, which is rotated by the motor. The pinion 132 in turn makes a crown 133 move (the crown 133 is shown in figures 9A-9F). The crown 133 is fixed to the carriage 139 149 159, which houses inside the transmission mechanism 114 112 113 (in this embodiment, double gearwheel mechanism 130 131). In its movement (rotation), the crown 133 drags the carriage 139 149 159. Next description applies to a rehabilitating structure for the index finger, or for the 3 fingers (middle, ring and little), or for the 4 fingers (index, middle, ring and little), or for the thumb. The support for the intermediate phalanx of the fingers (intermediate support or proximal support) 121 123 123C is fixed to the carriage 139 such that the movement of the motor 111 110 110B produces an angular displacement of the carriage 139 (by means of the rotation of the crown 133) and a corresponding angular displacement of the support 121 123 123C for the intermediate phalanx. The transmission mechanism 130 131 (double gearwheel) comprises an input wheel 135A 136A and an output wheel 135B 136B. Input wheel 135A 136A and output wheel 135B 136B are connected to each other such that the input wheel 135A 136A does not move when the carriage 139 moves (angular displacement) but produces a rotation of the output wheel 135B 136B. Additional features applicable to the particular embodiment in which each finger (index on the one hand and middle, ring and little fingers on the other hand) is rehabilitated in two sections (figures 1-3C), are explained next. The following explanation fully applies to the thumb because the distal phalanx support is the same in all three modules (index, fingers, thumb). The support 120 122 122C for the distal phalanx of the finger (distal support) is fixed to the output wheel 135B 136B such that the movement of the motor 110 111 109 110B produces an angular displacement of the carriage 139 and a corresponding angular displacement of the support 120 122 for the distal phalanx. In addition, the movement of the carriage 139 produces a rotation of the output wheel 135B 136B and that rotation produces and angular displacement of the support 120

122 for the distal phalanx with respect to the position of the carriage 139. As explained, the angular displacement of the distal phalanx support 120 122 122C is greater than the angular displacement of the intermediate phalanx support 121 123 123C.

The motor 110 111 109 110B can be selectively activated by the user (or by a therapist) for operation of the device. In a preferred embodiment, the motor is powered by battery. Alternatively, it could be powered by conventional available electricity. For simplicity reasons, in figures 6 and 7 the pinion 132 and the crown 133 are not shown because they are housed in a casing, housing or base 134. Figure 3B clearly shows motor 109 and its pinion 162, motor 110 and its pinion 172 and motor 111 and its pinion 132.

In figure 6, the transmission mechanism (double gearwheel mechanism) 130 is formed by two toothed gearwheels: an input toothed gearwheel 135A and an output toothed gearwheel 135B (also referred to as gear train) engaged by respective teeth. The input toothed gearwheel 135A is mounted in the rotational axis 160 of the carriage 139 such that when the carriage rotates by the rotation of the crown 133, the input gearwheel 135A does not move. The output gearwheel 135B is mounted in the carriage 139 through its axis 180 so the output gearwheel 135B moves when the carriage 139 moves but can rotate freely in the carriage 139. As the input gearwheel 135A is engaged to the output gearwheel 136B (through a toothed edge) when the movement of the carriage 139 drags the output gearwheel 135A, the output wheel 136B is forced to rotate over the input gearwheel 136A. The proximal phalanx support 121 123 123C is fixed to the carriage 139 whilst the distal phalanx support 120 122 122C is fixed to the output gearwheel 135B. That way, the angular displacement of the lower phalanx support 121 123 123C is the displacement of the carriage 139 whilst the angular displacement of the distal phalanx support 120 122 122C is the displacement of the carriage plus the rotation of the output gearwheel 135B. The angular displacement of the distal phalanx support 120 122 122C and proximal phalanx support 121 123 123C can produce the flexion/extension of the fingers (either index finger, thumb or remaining fingers).

In figure 7, the transmission mechanism (double gearwheel mechanism) 131 is formed by two discs or wheels, an input wheel 136A and an output wheel 136B which do not touch directly each other and a coupling means or mechanical coupling (such as a coupling rod) 137 connecting the two discs or wheels together. The coupling means

137 is fixed to the input and output wheels 136A 136B such that the distance between the connecting points of the input and output wheels 136A 136B is fixed.

The input wheel 136A is mounted in the rotational axis 160 of the carriage 139, such that when the carriage rotates by the rotation of the crown 133, the input wheel 136A
5 does not move. The output wheel 136B is mounted in the carriage through its axis 180. So the output wheel 136B moves when the carriage 139 moves, but can rotate freely in the carriage 139. As the input wheel 136A is engaged to the output wheel 136B (through a coupling rod 137), when the movement of the carriage 139 drags the output wheel 136B, the output wheel 136B is forced to rotate by the connecting rod 137 to
10 maintain the distance between the connecting points of the input and output wheels 136A 136B. The proximal phalanx support 121 123 123C is fixed to the carriage 139 whilst the distal phalanx support 120 122 122C is fixed to the output wheel 136B. That way the angular displacement of the proximal phalanx support 121 123 123C is the displacement of the carriage 139, whilst the angular displacement of the distal phalanx
15 support 120 122 122C is the displacement of the carriage plus the rotation of the output wheel 136B. The angular displacement of the distal phalanx support 120 122 122C and proximal phalanx support 121 123 123C can produce the flexion/extension of the fingers (either index finger, thumb or remaining fingers).

Figure 8 shows a break-up of the transmission mechanism (double gearwheel
20 mechanism) 131 in figure 7. A first casing, housing or base 134 houses the pinion 132 and partially the crown 133. Note that we refer generally to pinion 132 but we could refer correspondingly to pinion 162 172 (see for example figure 3B). This is the same as in the transmission mechanism 130 shown in figure 6. A second casing or carriage 139 houses the fixed wheel 136B, the moving wheel 136A and the mechanical coupling
25 137 (in the transmission mechanism 130 in figure 6, the carriage 139 houses the double toothed gearwheel). Like in the transmission mechanism (double gearwheel mechanism) 130 in figure 6, the crown 133 is fixed to the lower part of the carriage 139. In the shown embodiment, the input wheel 136A and the output wheel 136B are identical, and are formed by two flat discs disposed parallel to each other and fixed one
30 another by any kind of mechanical attachment 137 (connecting rod) which establishes a fixed distance between the connecting points of the input and output wheels 136A 136B. The input wheel 136A and the carriage 139 comprise an elongated canal 141A, which defines two end positions P1 P2 for the angular displacement of the carriage

139, to control the maximum extension movement possible for the fingers. Pin 138B is used to constrain the proximal pivot point for link (mechanical attachment) 137. For a right hand configuration, the pivot point is on the left (figure 8 top). For a left hand configuration, the pivot point is on the right. Pin 138B has the exact function as pin 138A, that is to say, to define the position of the distal pivot point for link (mechanical attachment) 137. For a right hand configuration, the distal pivot point is on the right. For a left hand configuration, the point is on the left. Pin 138C is mounted on the carriage 139. The shaft 238C of pin 138C is housed in the elongated canal 141B so that during the angular displacement of the carriage 139, the canal 141B moves around pin 138C, but collides with the shaft 238C of the pin at the end of the stroke imposed for the carriage 139 (depending on the maximum extension movement established for the fingers). These two positions P1 P2 defined in the input wheel 136A also permit the implementation of the reversibility feature of the device. They also contribute to security, since for example they prevent damage on the user in the event a motor fails. When the device is configured to rehabilitate a left hand, pin 138C is in position P1. On the contrary, when the device needs to be reconfigured in order to rehabilitate a right hand, pin 138C is placed in position P2. The support or rest for the intermediate phalanx (121 in the case of index finger, 123 in the case of middle, ring or little fingers, 122C in the case of a single proximal support for the four fingers together) is coupled to carriage 139 by means of attaching means 141.

Figure 8 shows the particular embodiment in which rehabilitation of the fingers is done in two sections. In order to achieve this two-section rehabilitation, the support or rest for the distal phalanx (120 in the case of index finger, 122 in the case of middle, ring or little fingers, 123C in the case of a single distal support for the four fingers together) is coupled to the output wheel 136B by means of a part 144 on which the support (120, 122, 123C) is fixed. This part 144 is connected to the output wheel 136B by means of pivoting means 142 connected in one end to part 144 (for example by means of a screw 145) and in the other end 142B to the output wheel 136B and second housing 139 (for example by means of a screw 146). This connection permits additional travel of the distal support 120 (or 122, 123C) with respect to the maximum rotation achieved by the carriage 139. The angle travelled by the distal phalanx is therefore larger than the angle travelled by the proximal phalanx. In a particular embodiment, the device is designed for the distal phalanx to travel an angle which is around twice the travel of the

angle travelled by the proximal phalanx. Figure 8 also shows the support for the proximal phalanx (121 in the case of index finger, 123 in the case of middle, ring or little fingers, 123C in the case of 4 fingers) and the part 141 on which the support is fixed. This part 141 is connected to the support. These parts 141 144 and their corresponding
5 supports are also shown in figure 3C.

Figures 9A-9F show several positions of the mechanism of the flexion/extension of the fingers (in this case the mechanism 131 is implemented as shown in figure 7). These positions can refer to the index finger, or to the three other fingers, or to the four fingers together, and even to the thumb, if two-sections for the two phalanxes were
10 implemented. Figures 9A-9C refer to a sequence for a right hand. Figure 9A refers to a position with substantially maximum extension while figure 9C refers to a position with substantially maximum flexion. Figures 9D-9F refer to sequence for a left hand. Figure 9D refers to a position with substantially maximum extension while figure 9F refers to a position with substantially maximum flexion. As can be observed, wheel 136A and pin
15 138B remain fixed with respect to the housing, casing or base 134. The carriage 139 rotates actioned by crown 133 in turn actioned by the pinion 162 (or 132 172) moved by a motor (not shown). The crown 133 drags carriage 139 and in turn the mechanical coupling 137 moves the output wheel 136B.

Figures 10A-10F show several positions of the mechanism of the flexion/extension of
20 the index finger (right hand in figures 10A-10C and left hand in figures 10D-10F).

Figures 11A-11D show different views of the hand rehabilitation device shown for example in figure 1, but in this case configured to rehabilitate a left hand, which is illustrated in its functional position for rehabilitation. In this figures, the casings of the transmission mechanism for the index finger has been erased, in order to show the
25 functioning of the double gearwheel mechanism 131. The transmission mechanism 112 for the group of middle, ring and little fingers works in a similar way. The transmission mechanism 112C for the group of index, middle, ring and little fingers works in a similar way. In figure 11B the casing 151 in which the motor 110 which actuates the transmission mechanism 112 for the group of middle, ring and little fingers is shown. It
30 is remarked that the location of the motors may vary in different designs of the device. Reference 152 is the casing in which motor 111 is housed. The casing that houses the transmission mechanism 114 for the index has been erased, in order to show the transmission mechanism 114. The transmission mechanism 112 for the three fingers is

also shown (in this case hidden by its casing). The thumb has been erased from these views for clarity purposes. Figures 12A-12D show different views of the same hand rehabilitation device, in this case configured to rehabilitate a right hand. Again, the thumb has been erased from these views for clarity purposes.

- 5 As already mentioned, the device is reversible. This means that the same device can be used to rehabilitate both a right hand and a left hand. The transmission mechanism illustrated in figure 6 does not require any reconfiguration in order to switch from a "right hand configuration" to a "left hand configuration" or vice versa. That is to say, reversibility is automatic. Figures 13A-13D illustrate the reversibility capability of the
- 10 transmission mechanism of figure 7. Since there are 3 transmission mechanisms in one device (index finger, 3 fingers and thumb), the reconfiguration must be done three times, because each finger requires reorienting wheels 136A and 136B and lock with pins 138B and 138C. That is to say, in order to perform reconfiguration, the pins 138B 138C must be lifted, then wheels must be turned, so that the pin naturally locks into
- 15 position in the opposite end of the circular groove (canal) with the round holes in the ends. Alternatively, pins 138B 138C could be one single mechanism in order to simplify the process. Additionally, the thumb lock mechanism also needs to be reconfigured. Turning back to figure 8, during reconfiguration, the set formed by support 120 (or 122) and part 144 moves freely with respect to screw 145. Similarly, the set formed by
- 20 support 121 (or 123) and part 141 moves freely with respect to corresponding screw (both if the transmission mechanism in figure 6 and in that in figure 7).

- Figures 13A and 13C show the left hand configuration, while figures 13B and 13D show the corresponding right hand reconfiguration. In the reconfiguration process from left to right hand (it would be similar from right to left hand), the housing or base does
- 25 not change position. Pin 138B, which in left-hand configuration is positioned in position P2 (see figure 8) in output wheel 136B is moved to position P1 (see figure 8). The mechanical coupling (transmission bar) 137 becomes naturally re-oriented when the wheels 136A 136B change position. Pin 138B also changes position from position P2' (left hand configuration) to position P1' (right hand configuration). Pivoting axis 160 is
- 30 maintained in both left-hand and right-hand configurations, independently from the positions of motors. The second casing, housing or carriage 139 pivotes or rotates around this pivoting axis 160. Pin 138A does not have any influence in reconfiguration. As already mentioned, the transmission mechanism shown in figure 6 does not need

any change in order to be reconfigured, except for the free movement of the set formed by support 120 (or 122) and part 144 and the free movement of the set formed by support 121 (or 123) and part 141. In both mechanisms, it is possible to add safety pins in order to prevent over-travel of the hand in the event of failure of a motor.

- 5 The device 100 permits two symmetrical grasp modes supported for each of left-hand and right-hand operation: cylindrical mode (for grasping for example a glass) and “open pinch/clamp” for 3-fingered grasp (predominantly MCP action).

In conclusion, a simple, portable, hand-held device for rehabilitation has been provided.

- 10 The device permits independent rehabilitation (flexion/extension) of the thumb and independent rehabilitation (flexion/extension) of the index finger with respect to the remaining fingers (middle, ring and little fingers), which are rehabilitated in a group. What is more, the device permits rehabilitation of the fingers in two flexion/extension sections: a first one for the proximal and intermediate phalanxes and a second one of
- 15 the distal phalanxes. This double-section rehabilitation permits to open a finger in a natural way, without forcing its joints. Finally, the device is reversible, meaning that with a simple reconfiguration that can be done by the user or by a therapist, the very same device can be used to rehabilitate an impaired right hand and an impaired left hand.
- 20 On the other hand, the invention is obviously not limited to the specific embodiment(s) described herein, but also encompasses any variations that may be considered by any person skilled in the art (for example, as regards the choice of materials, dimensions, components, configuration, etc.), within the general scope of the invention as defined in the claims.

CLAIMS

1. A hand rehabilitation device (100) characterized in that it comprises:

-at least one first support (124) configured to support the thumb of a hand, wherein said at least one first support (124) is designed to perform a flexion/extension movement for
5 rehabilitating said thumb, said flexion/extension movement being actioned by a first transmission mechanism (113) to which the at least one first support (124) is connected;

-at least one second support (120, 121, 120A, 120B) configured to support the index finger of said hand, wherein said at least one second support (120, 121, 120A, 120B) is
10 designed to perform a flexion/extension movement for rehabilitating said index finger, said flexion/extension movement being actioned by a second transmission mechanism (114) to which the at least one second support (120, 121, 120A, 120B) is connected;

-at least one third support (122, 123, 122A, 122B) configured to support the three remaining fingers –middle ring, and little fingers- of said hand, wherein said at least one
15 third support (122, 123, 122A, 122B) is designed to perform a flexion/extension movement for rehabilitating said three remaining fingers, said flexion/extension movement being actioned by a third transmission mechanism (112) to which the at least one third support (122, 123, 122A, 122B) is connected;

wherein said first transmission mechanism (113) is actuated by one motor (109)
20 different from the at least one motor (111, 110) configured to actuate said second and third transmission mechanisms (114, 112);

wherein the three flexion/extension movements of said at least one first support (124), said at least one second support (120, 121, 120A, 120B) and said at least one third support (122, 123, 122A, 122B) are independent from each other.

25 2. The hand rehabilitation device (100) of claim 1, wherein at least one of said first, second and third transmission mechanisms (113, 114, 112) comprises a pinion (132) and a crown (133) configured to move actioned by said pinion (132), which in turn is configured to rotate actioned by said motor (109, 111, 110).

30 3. The hand rehabilitation device (100) of claim 2, wherein upon rotation, said crown (133) is configured to pull two crown gears (135A, 135B) interconnected by respective protrusions or teeth, causing said supports (120, 121, 120A, 120B; 122, 123, 122A, 122B; 124) to move in flexion/extension way.

4. The hand rehabilitation device (100) of claim 2, wherein upon rotation, said crown (133) is configured to pull an assembly formed by two wheels (136A, 136B) and coupling means (137) connecting said two wheels (136A, 136B) together, wherein the wheel (136B) closest to the pinion (132) is fixed and the other wheel (136A) and the coupling means (137) move as a result of the movement of the crown (133).

5. The hand rehabilitation device (100) of any preceding claim, wherein said at least one second support (120, 121, 120A, 120B) comprises a single support (120A, 120B) for the index finger and said at least one third support (122, 123, 122A, 122B) comprises a single support (122A, 122B) for the three remaining fingers –middle ring, and little fingers.

6. The hand rehabilitation device (100) of any claim 1-4, wherein said at least one second support (120, 121, 120A, 120B) comprises one distal support (120) for the distal phalanx of the index finger and one proximal support (121) for the intermediate phalanx of the index finger, and said at least one third support (122, 123, 122A, 122B) comprises one distal support (122) for the distal phalanx of the three remaining fingers –middle, ring, and little fingers and one proximal support (123) for the intermediate phalanx of the three remaining fingers –middle, ring, and little fingers.

7. The hand rehabilitation device (100) of any preceding claim, the device being reversible and therefore a same device (100) serves at rehabilitating a right hand and a left hand, the device (100) being reversible:

either by moving freely a set formed by a support (120, 122) and a part (144) with respect to a pivoting means (142), when the transmission mechanism (113, 114, 112, 112B) comprises two crown gears (135A, 135B) interconnected by respective protrusions or teeth;

or by lifting pins (138B, 138C) and turning wheels until the corresponding pin naturally locks into a position in the opposite end of a canal (141A, 141B) and by moving freely a set formed by a support (120, 122) and a part (144) with respect to a pivoting means (142), when the transmission mechanism (113, 114, 112, 112B) comprises two wheels (136A, 136B) and coupling means (137) connecting said two wheels (136A, 136B) together.

8. A hand rehabilitation device (100) characterized in that it comprises:

-at least one first support (124) configured to support the thumb of a hand, wherein said at least one first support (124) is designed to perform a flexion/extension movement for rehabilitating said thumb, said flexion/extension movement being actioned by a first transmission mechanism (113) to which the at least one first support (124) is connected;

-at least one proximal support (123C, 121, 123) configured to support the intermediate phalanx of at least the middle, ring and little fingers of said hand, wherein said at least one proximal support (123C, 121, 123) is designed to perform a flexion/extension movement of said intermediate phalanxes of said fingers, actioned by at least one second transmission mechanism (112B, 114, 112) to which the at least one proximal support (123C, 121, 123) is connected;

-at least one distal support (122C, 120, 122) configured to support the distal phalanx of at least the middle, ring and little fingers of said hand, wherein said at least one distal support (123C, 120, 122) is designed to perform an additional flexion/extension movement of said distal phalanxes of said fingers with respect to the flexion/extension movement of said intermediate phalanxes of said fingers, actioned by said at least one second transmission mechanism (112B, 114, 112) to which the at least one distal support (122C, 120, 122) is connected;

wherein said first transmission mechanism (113) is actuated by one motor (109) different from the at least one motor (111, 110) configured to actuate said at least one second transmission mechanisms (112B, 114, 112);

wherein the flexion/extension movement of said at least one first support (124) is independent from the flexion/extension movements of said at least one proximal support (123C, 121, 123) and at least one distal support (122C, 120, 122).

9. The hand rehabilitation device (100) of claim 8, wherein at least one of said first and transmission mechanisms (130, 131) comprises a pinion (132) and a crown (133) configured to move actioned by said pinion (132), which in turn is configured to rotate actioned by said motor (109, 110B).

10. The hand rehabilitation device (100) of claim 9, wherein upon rotation, said crown (133) is configured to pull two crown gears (135A 135B) interconnected by respective protrusions or teeth, causing said supports (124; 123C, 121, 123; 122C, 120, 122) to move in flexion/extension way.

11. The hand rehabilitation device (100) of claim 9, wherein upon rotation, said crown (133) is configured to pull an assembly formed by two wheels (136A, 136B) and coupling means (137) connecting said two wheels together, wherein the wheel (136B) closest to the pinion (132) is fixed and the other wheel (136A) and the coupling means
5 (137) move as a result of the movement of the crown (133).

12. The hand rehabilitation device (100) of any claim 8-11, wherein said at least one proximal support (123C, 121, 123) comprises a single support (123C) for the intermediate phalanxes of said index, middle, ring and little fingers and said at least one distal support (122C, 120, 122) comprises a single support (122C) for the distal
10 phalanxes of said index, middle, ring and little fingers.

13. The hand rehabilitation device (100) of any claim 8-11, wherein said at least one proximal support (123C, 121, 123) comprises a first support (121) for the intermediate phalanx of said index finger and a second support (123) for the intermediate phalanx of said middle, ring and little fingers; and said at least one distal support (122C, 120, 122)
15 comprises a third support (120) for the distal phalanx of said index finger and a fourth support (122) for the distal phalanxes of said middle, ring and little fingers.

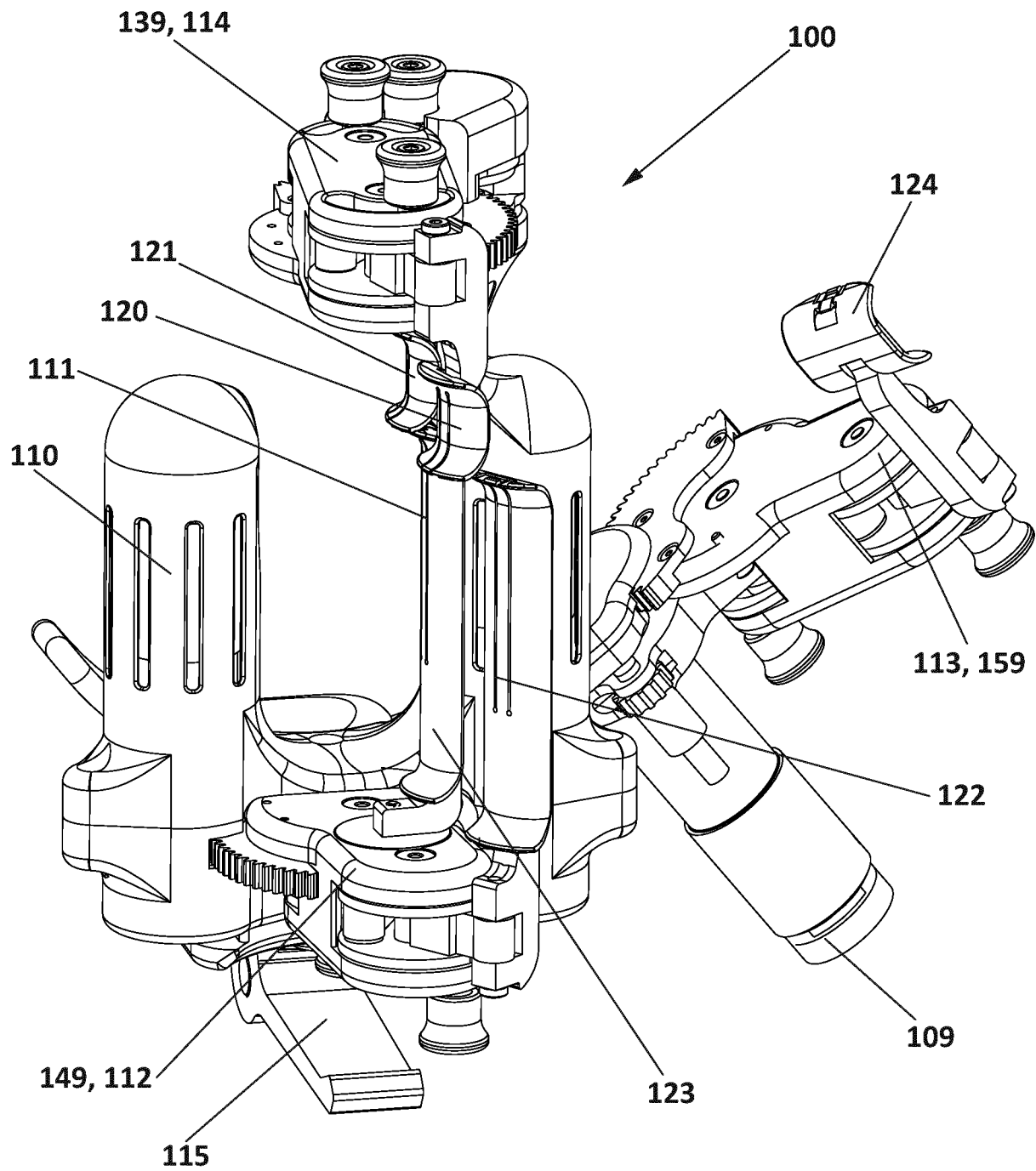
14. The hand rehabilitation device (100) of claim 13, further comprising one transmission mechanism (114) for actuating said first proximal support (121) for the intermediate phalanx of the index finger and said third distal support (120) for the distal
20 phalanx of the index finger and another transmission mechanism (112) for actuating said second proximal support (123) for the intermediate phalanx of the middle, ring and little fingers and said fourth distal support (122) for the distal phalanx of the middle, ring and little fingers.

15. The hand rehabilitation device (100) of any claim 8-14, the device being reversible and therefore a same device (100) serves at rehabilitating a right hand and a left hand, the device (100) being reversible:
25

either by moving freely a set formed by a support (120, 122) and a part (144) with respect to a pivoting means (142), when the transmission mechanism (113, 114, 112, 112B) comprises two crown gears (135A, 135B) interconnected by respective
30 protrusions or teeth;

or by lifting pins (138B, 138C) and turning wheels until the corresponding pin naturally locks into a position in the opposite end of a canal (141A, 141B) and by moving freely a

set formed by a support (120, 122) and a part (144) with respect to a pivoting means (142), when the transmission mechanism (113, 114, 112, 112B) comprises two wheels (136A, 136B) and coupling means (137) connecting said two wheels (136A, 136B) together.

**FIG. 1**

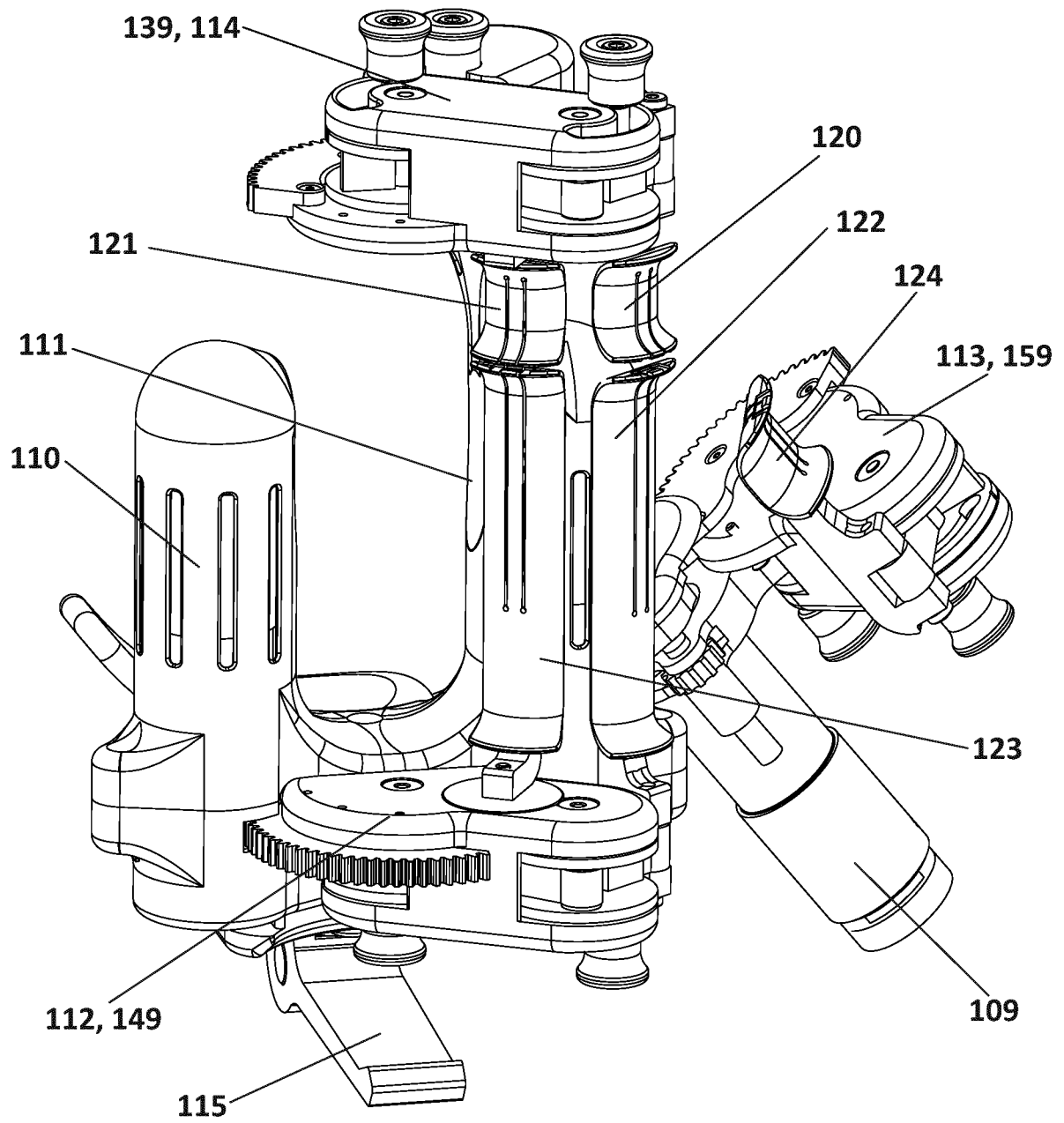


FIG. 2A

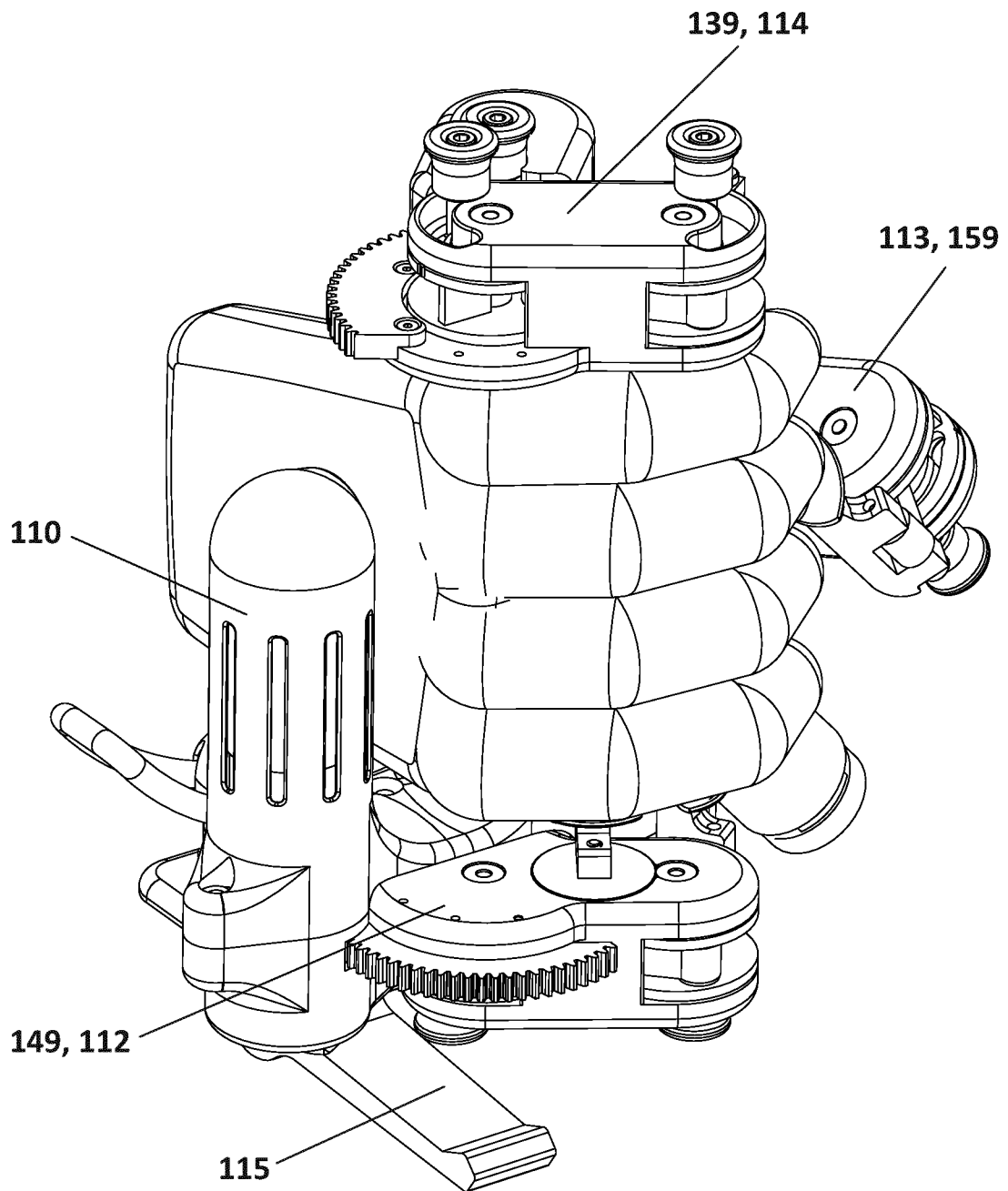
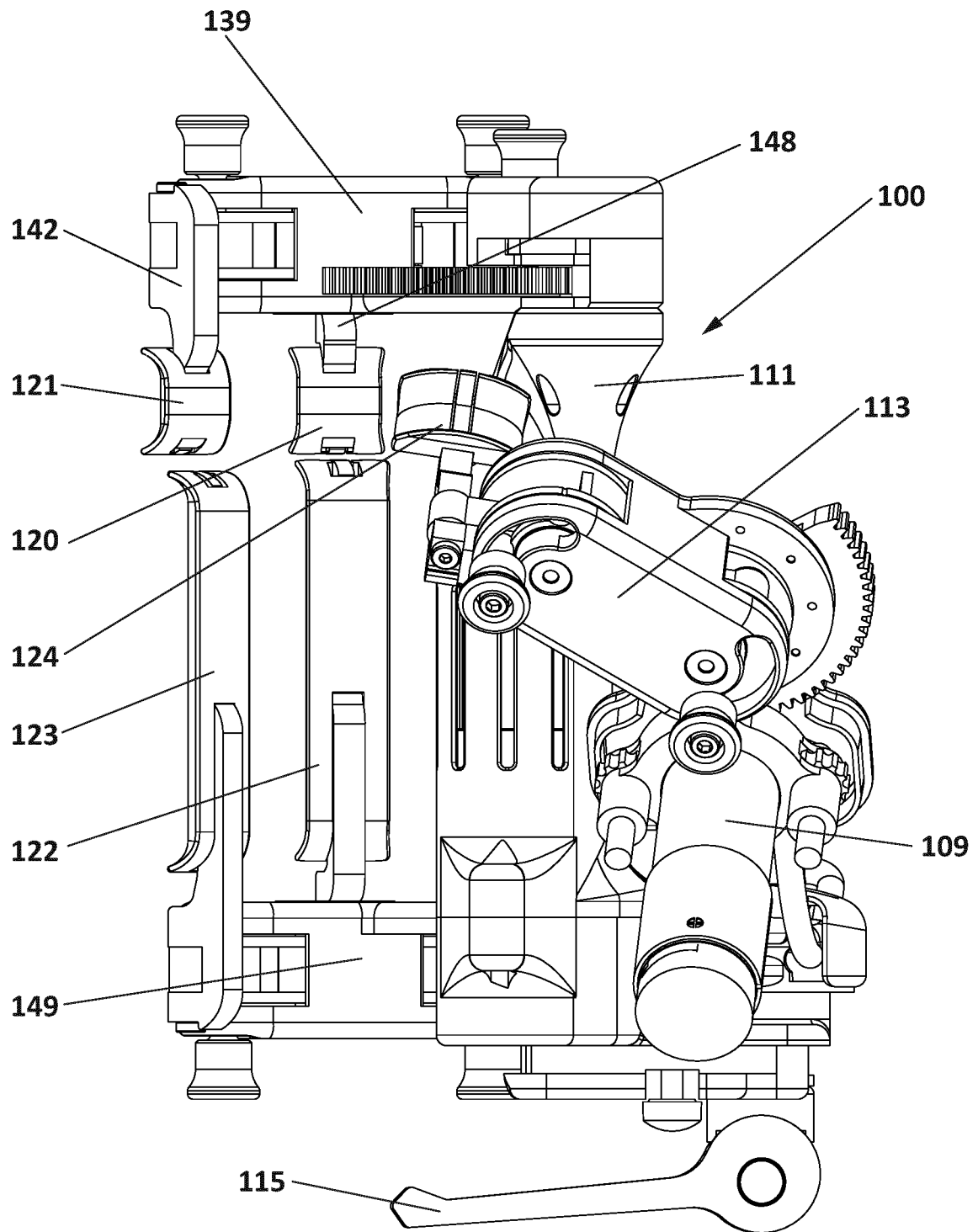


FIG. 2B

**FIG. 3A**

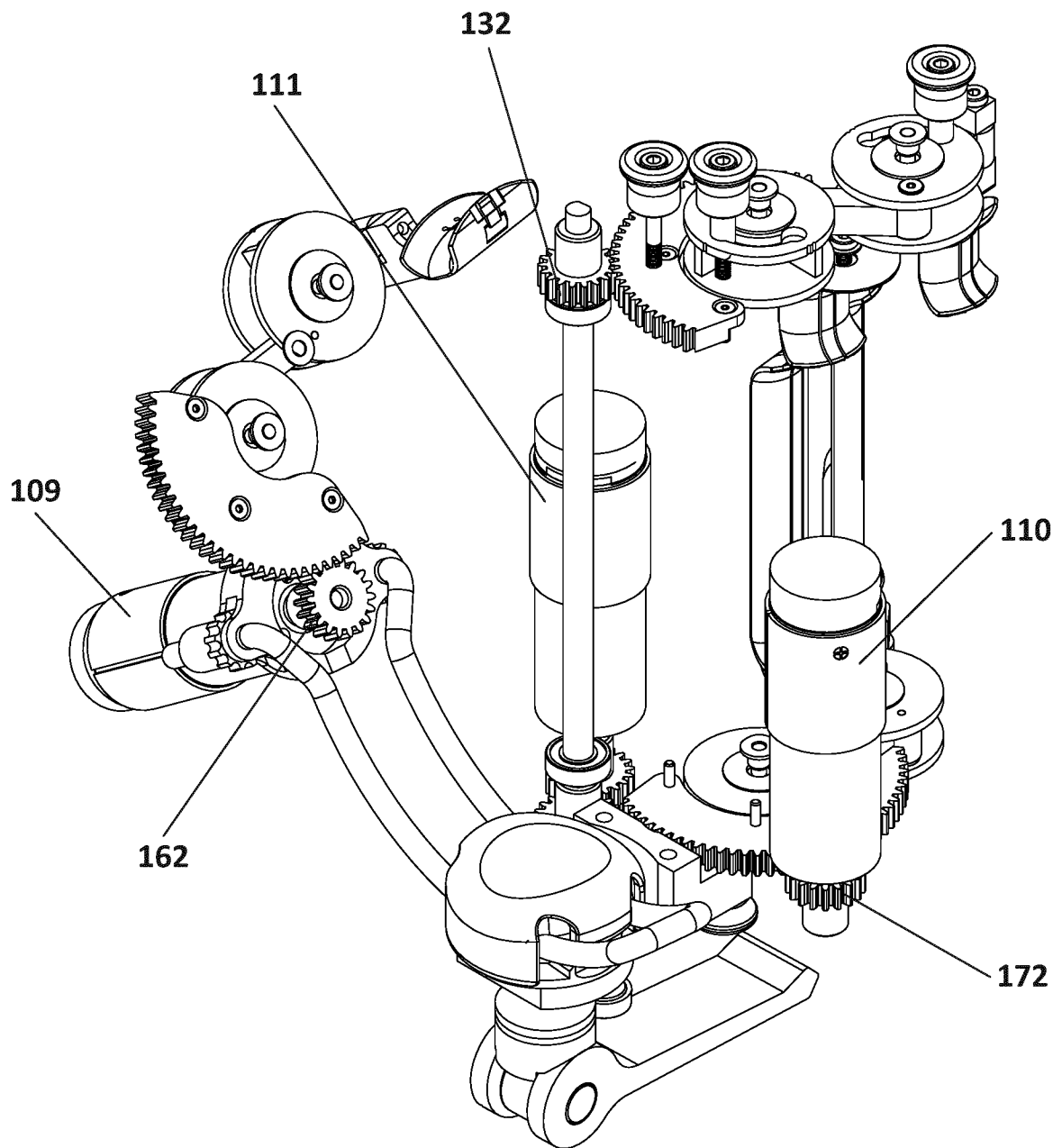


FIG. 3B

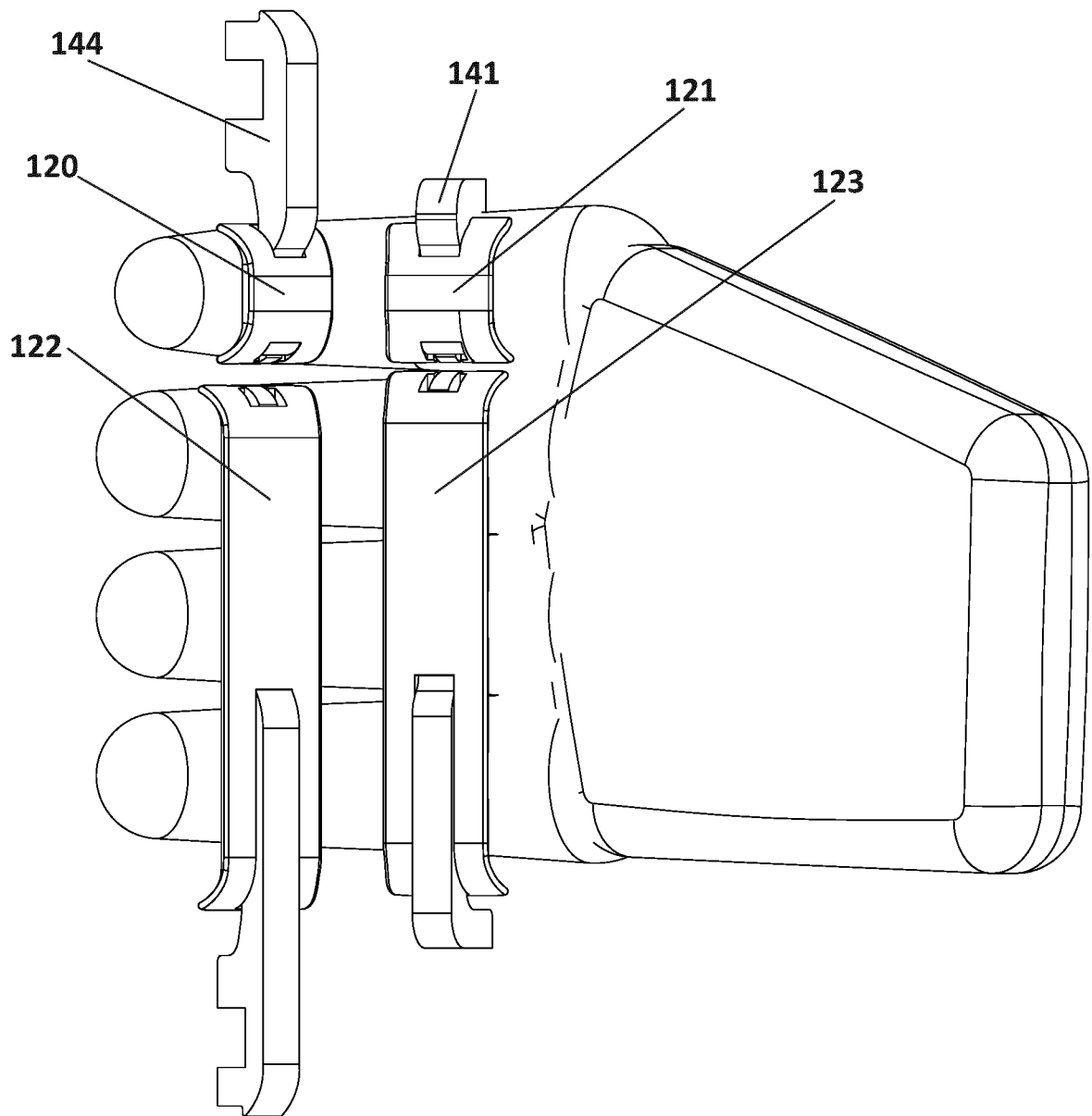


FIG. 3C

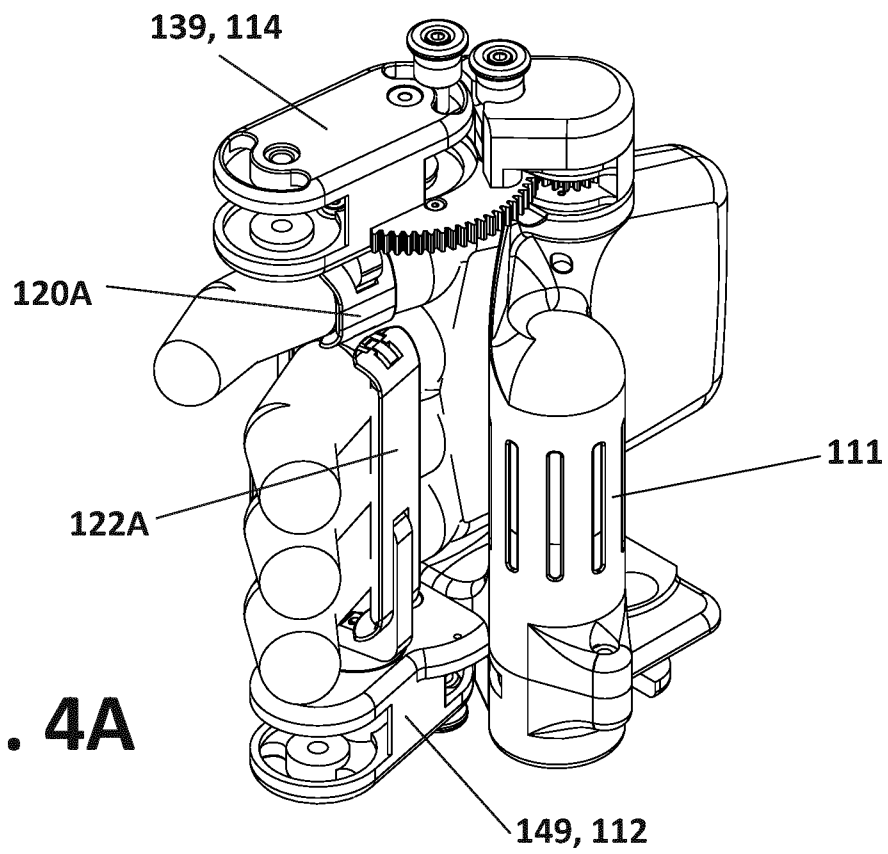


FIG. 4A

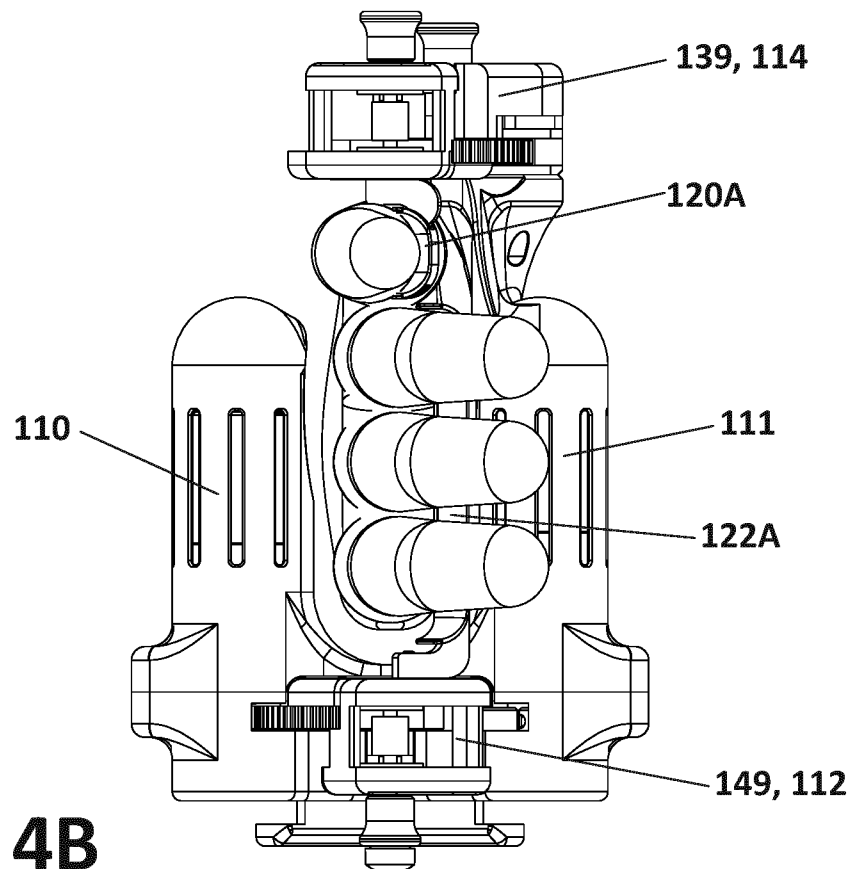
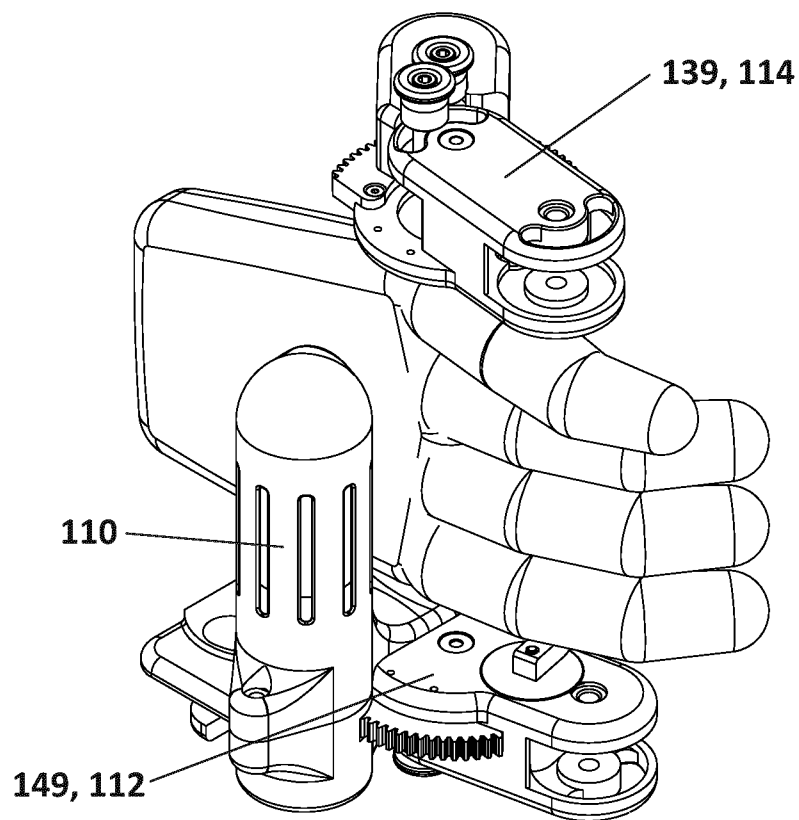
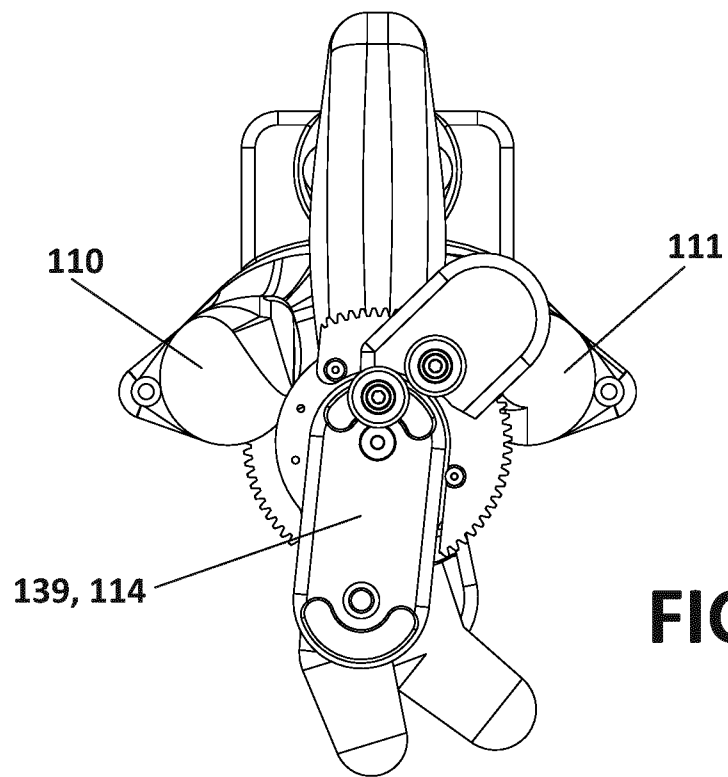
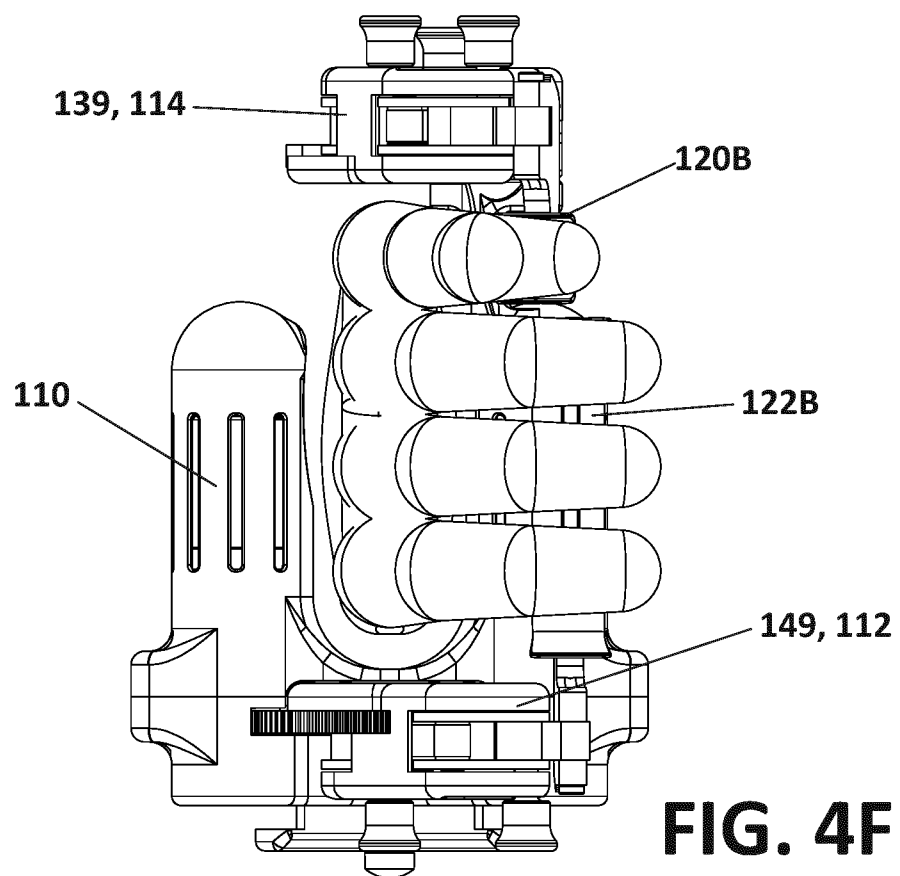
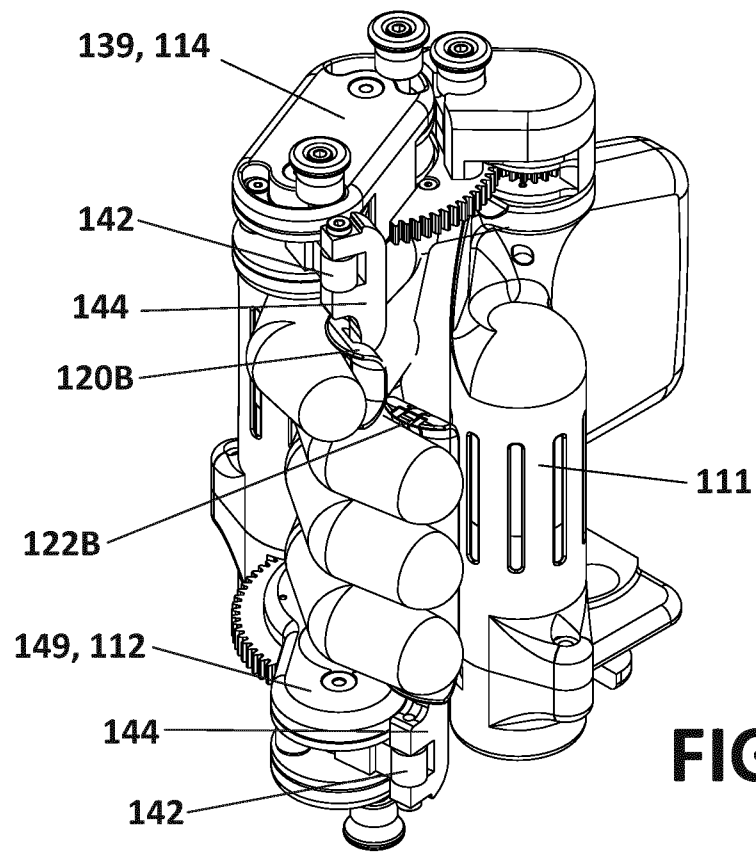
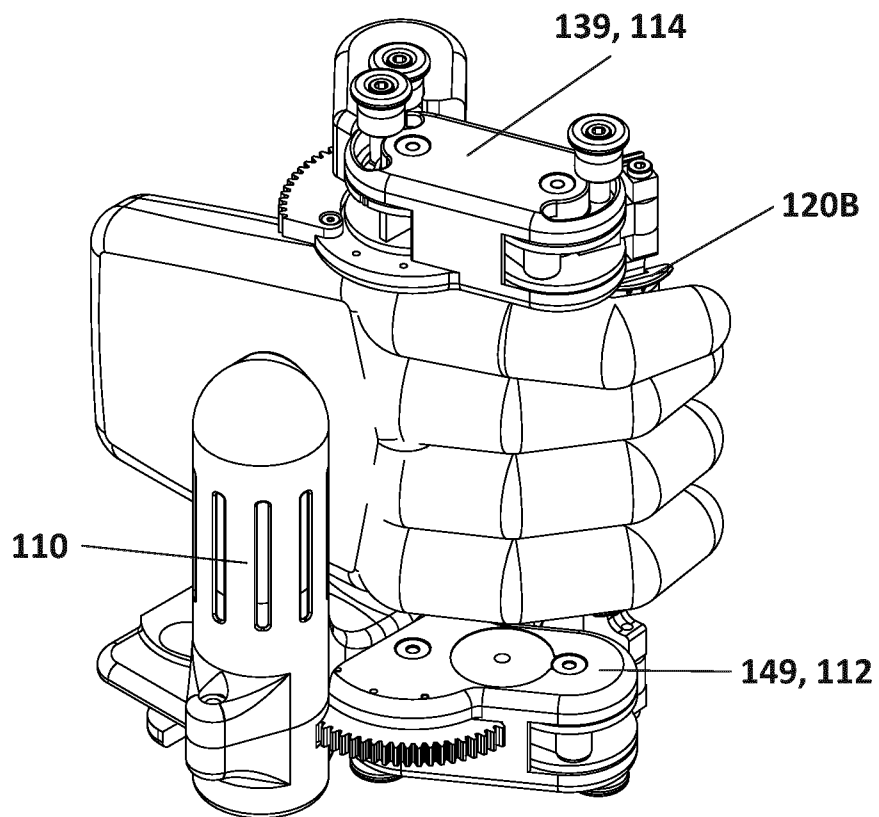
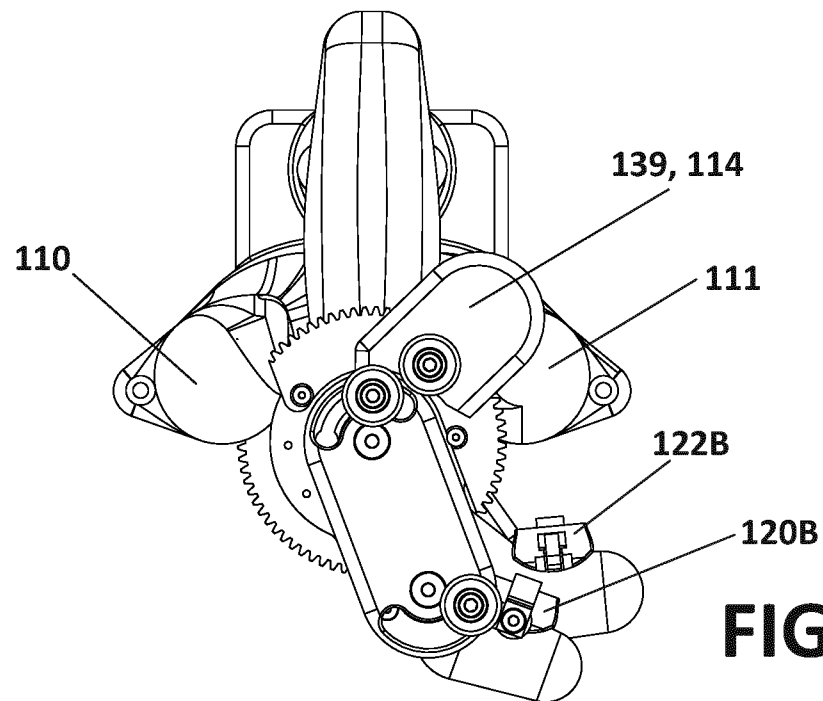
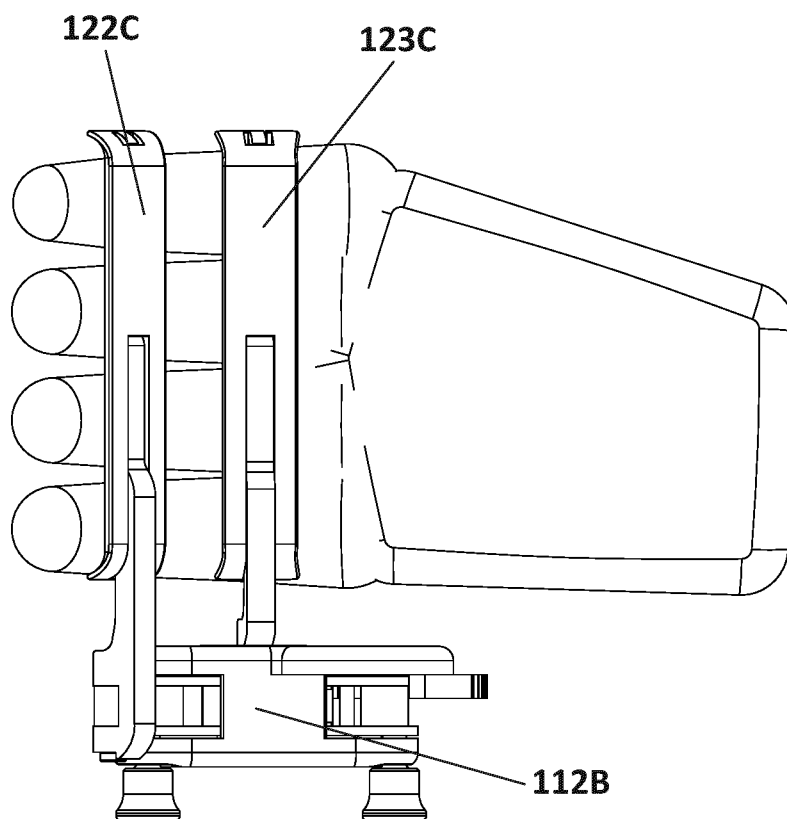
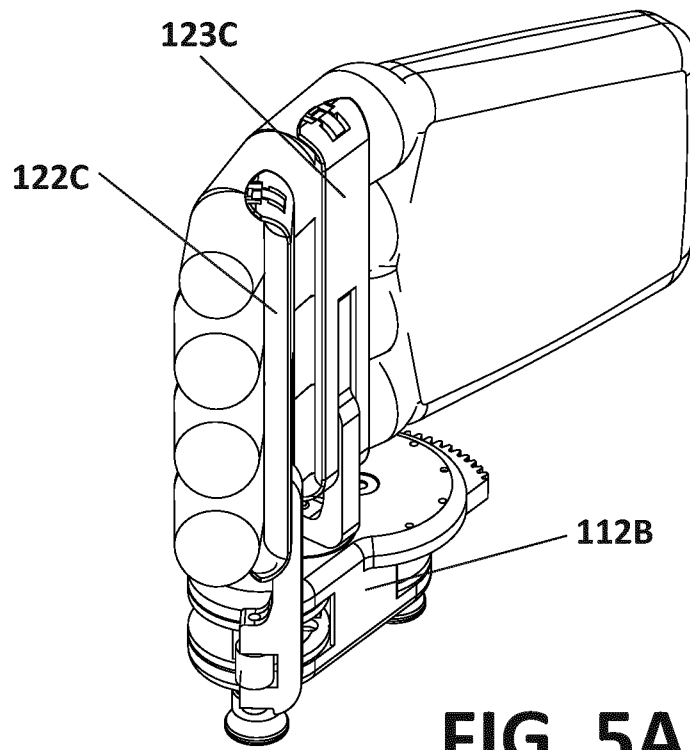


FIG. 4B









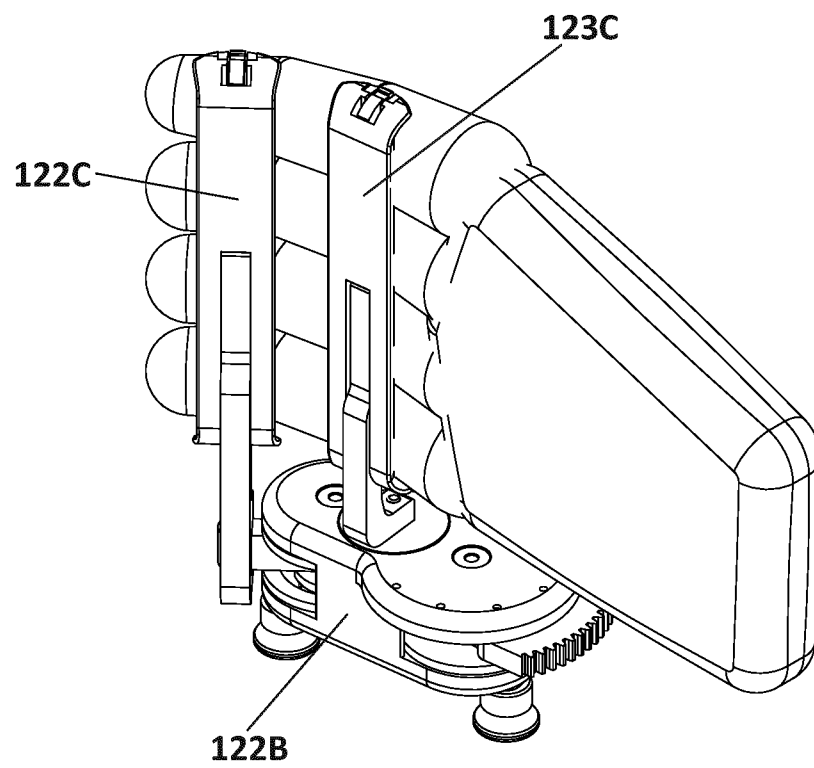


FIG. 5C

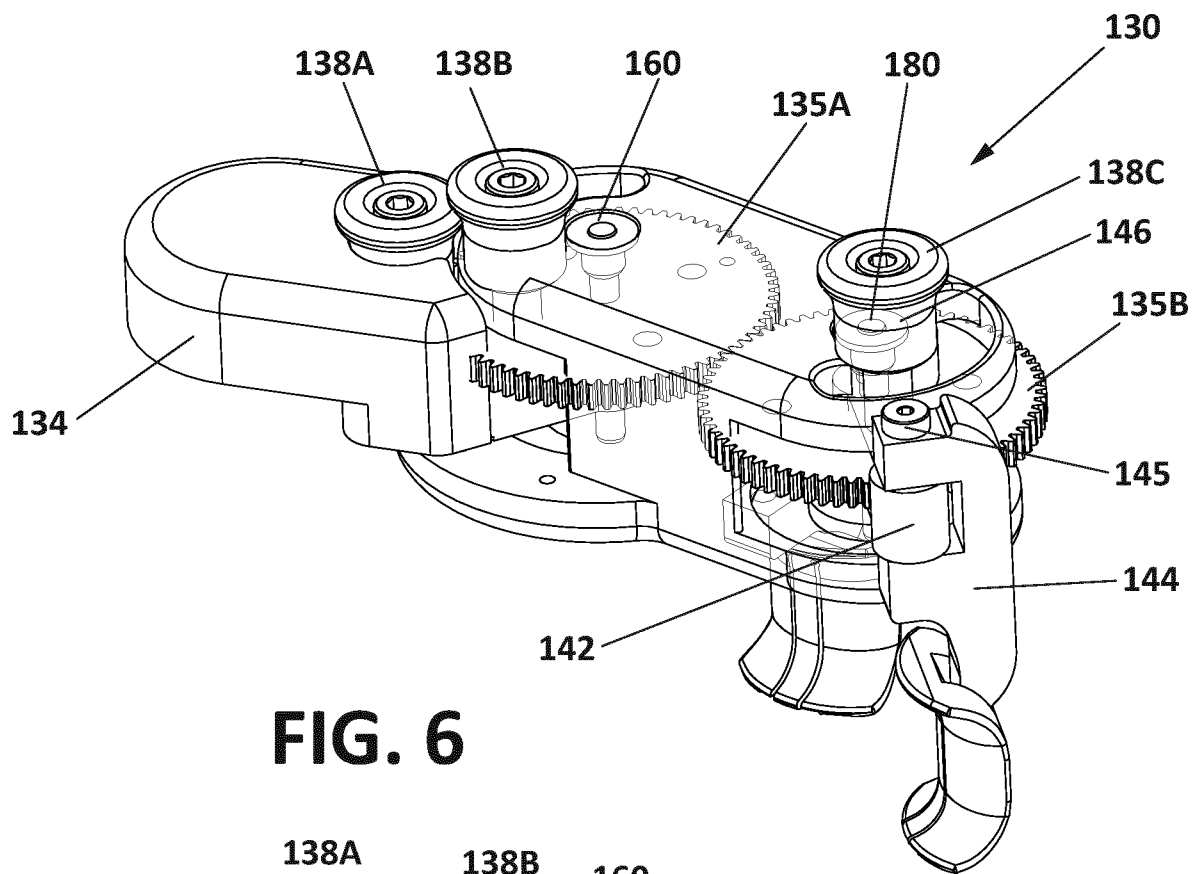


FIG. 6

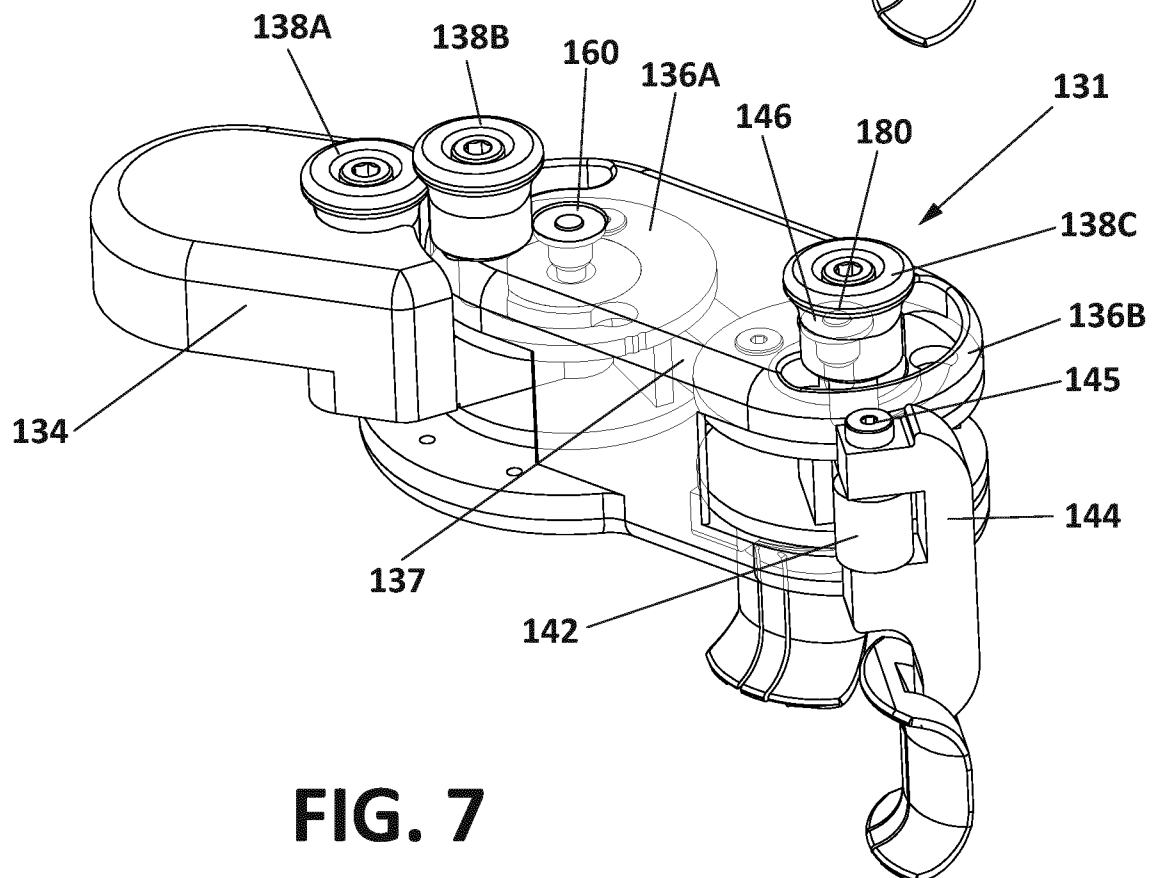
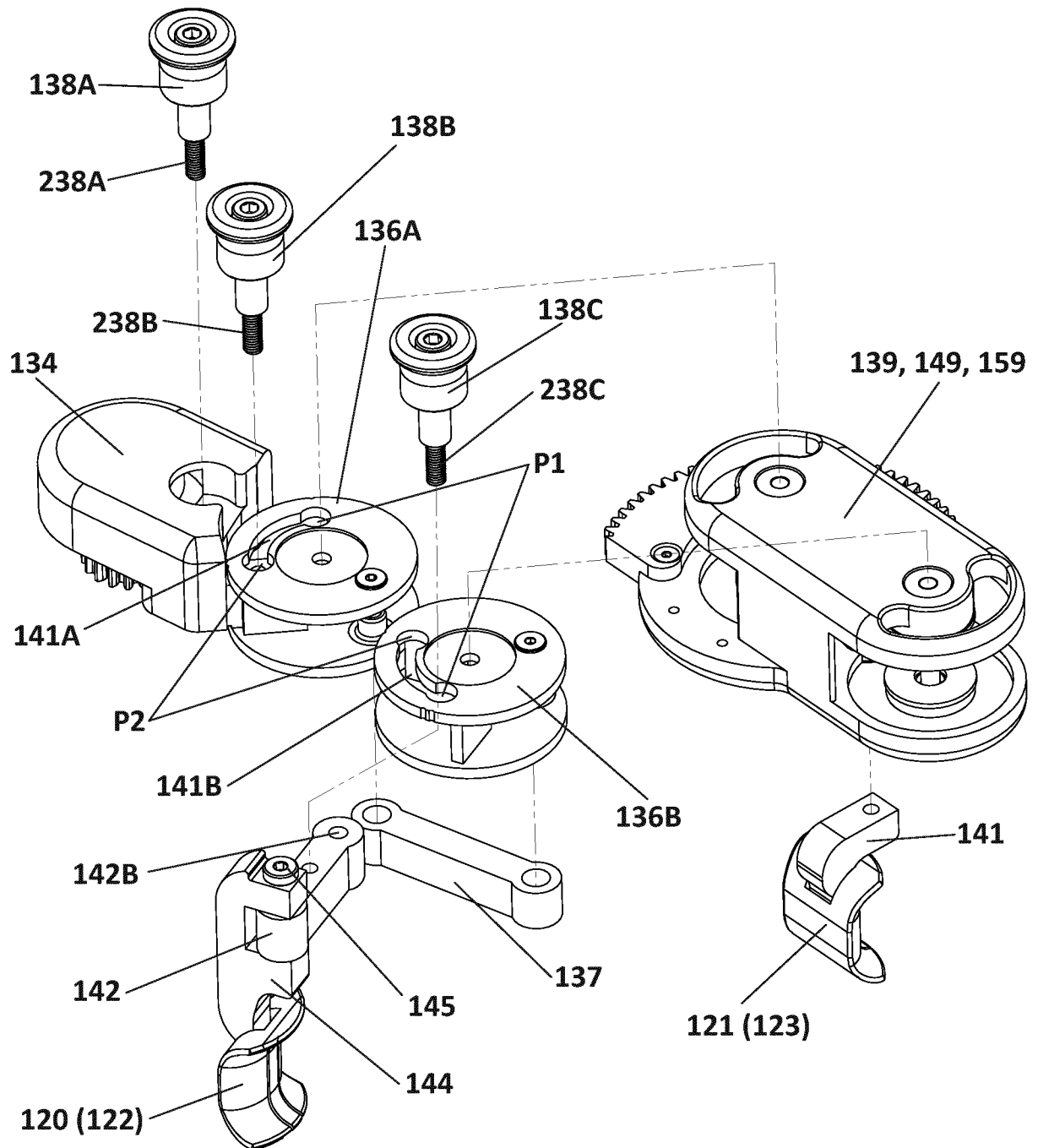
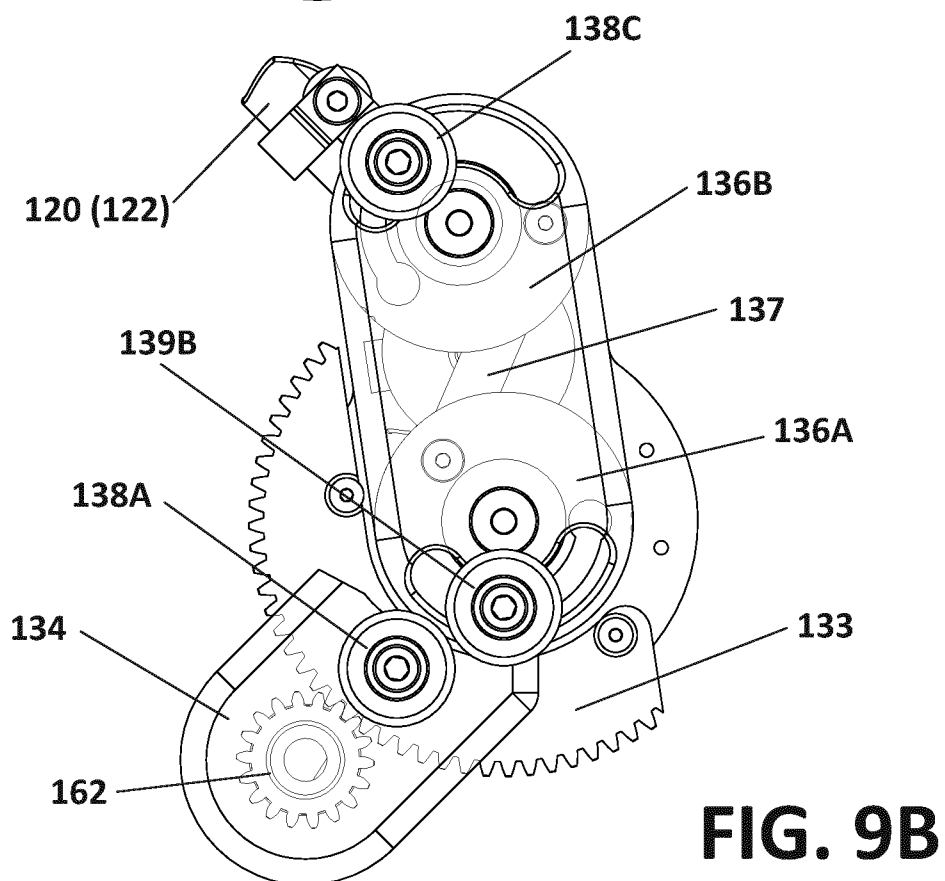
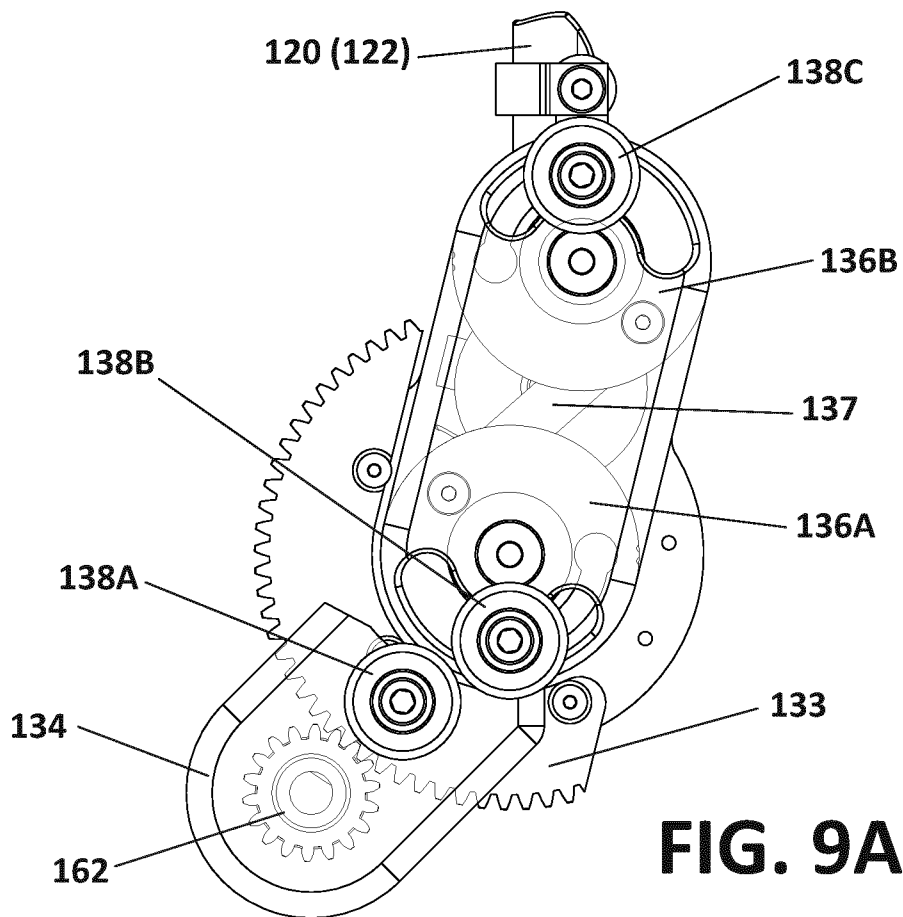


FIG. 7

**FIG. 8**



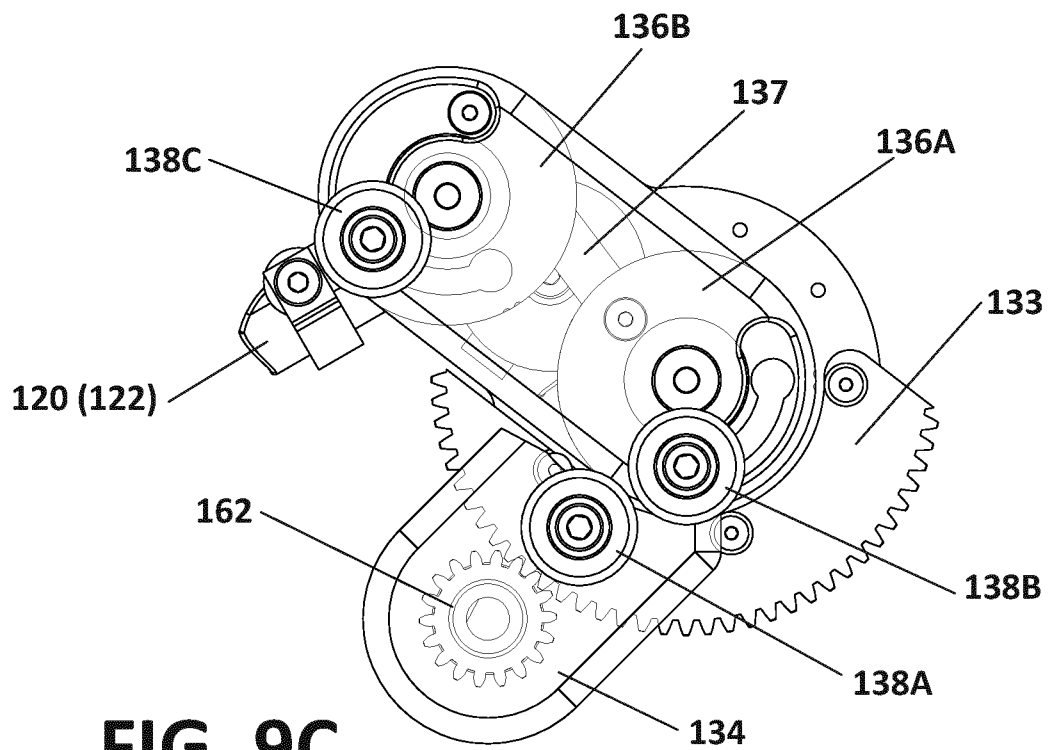


FIG. 9C

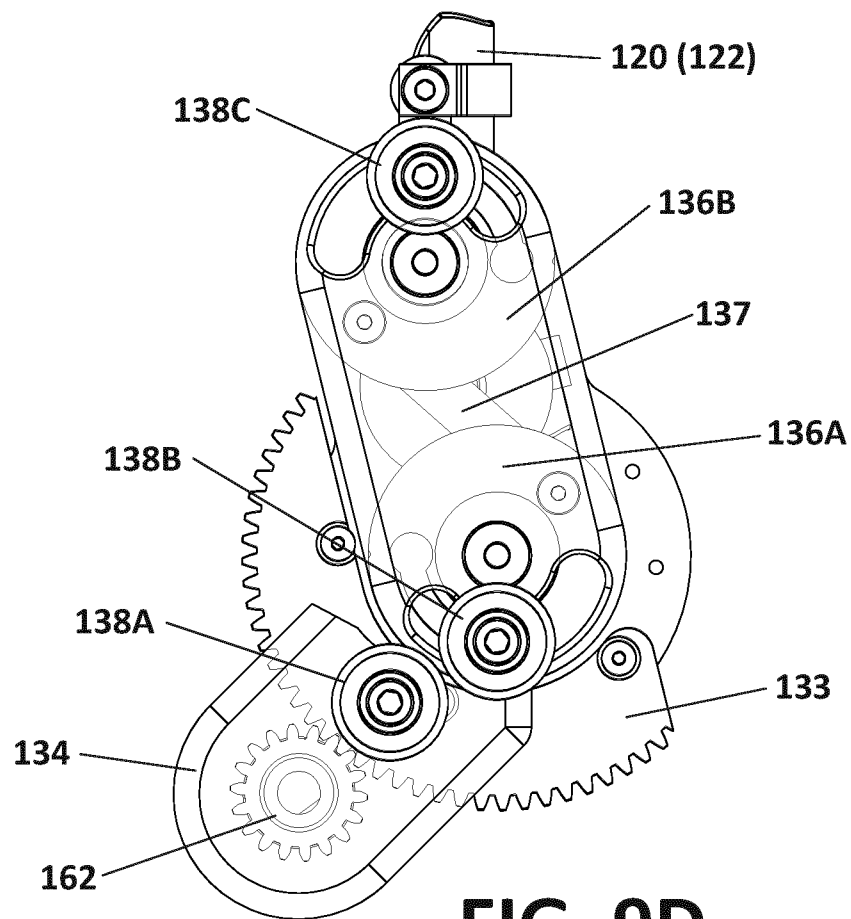


FIG. 9D

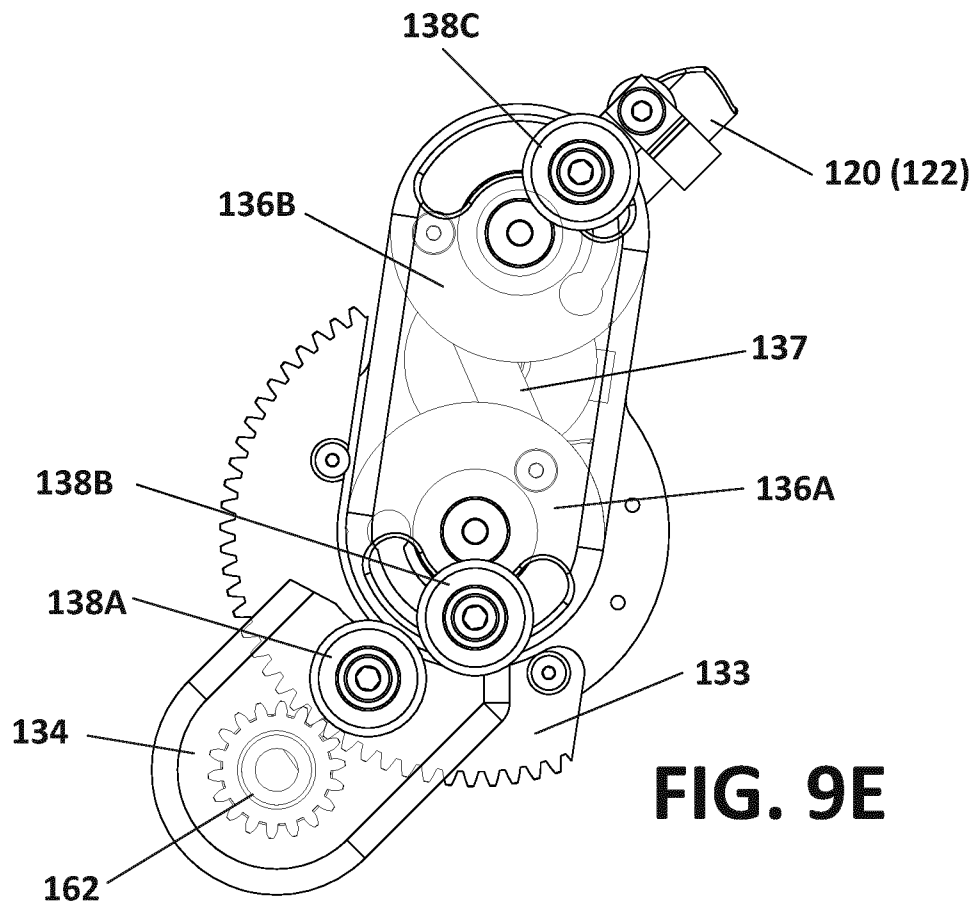


FIG. 9E

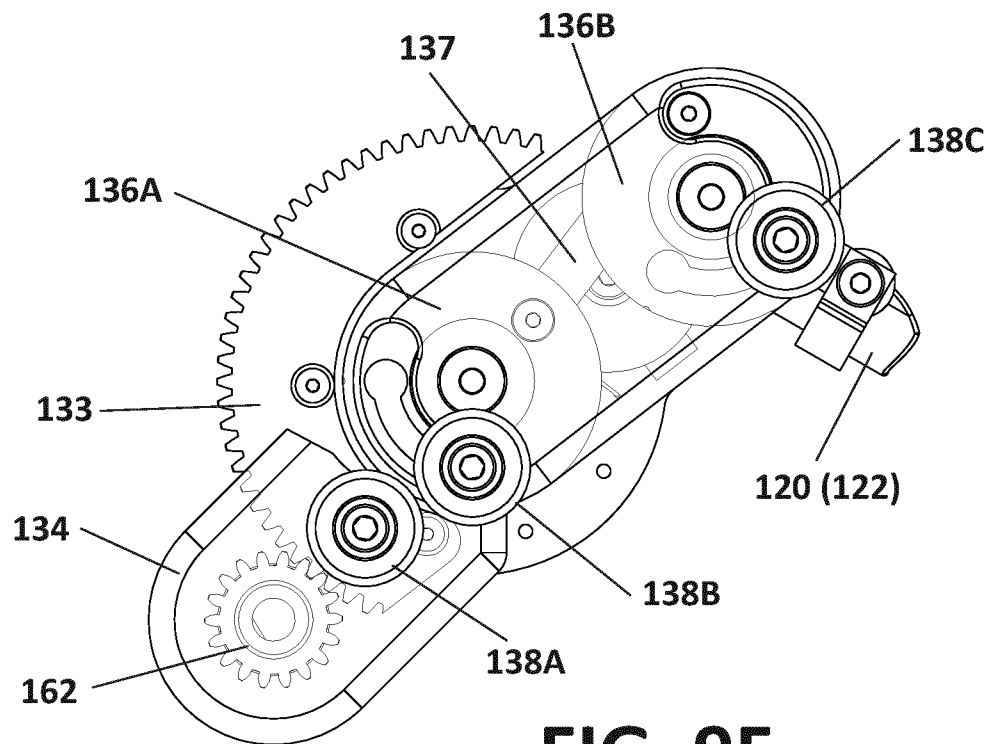
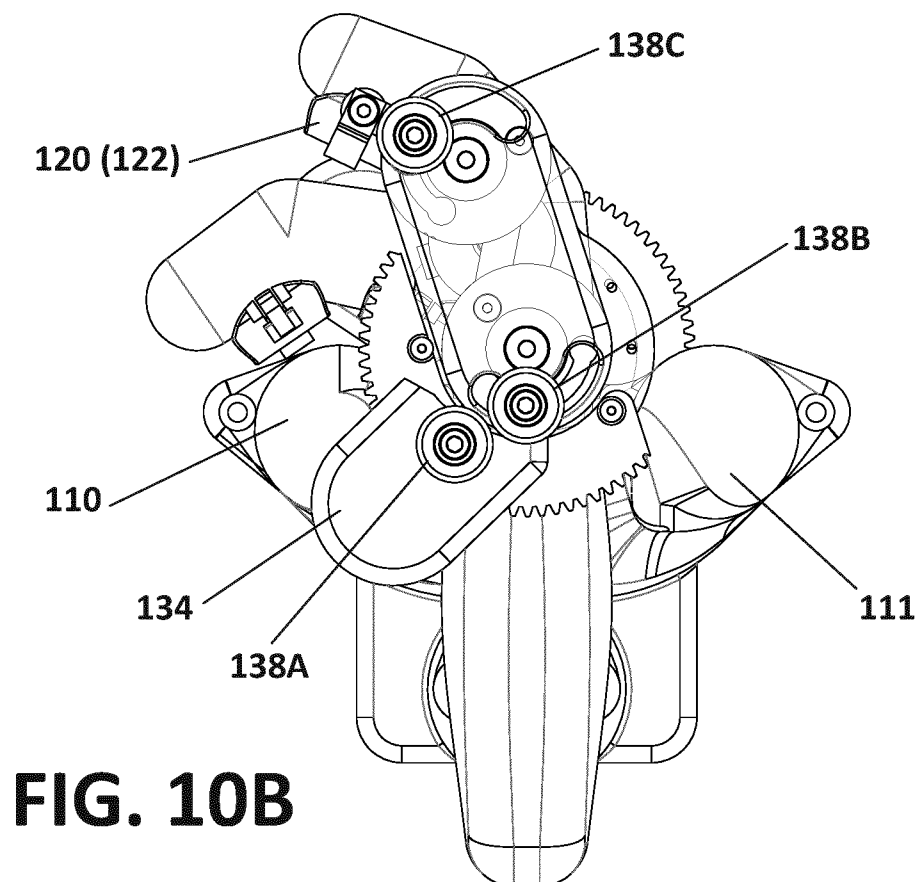
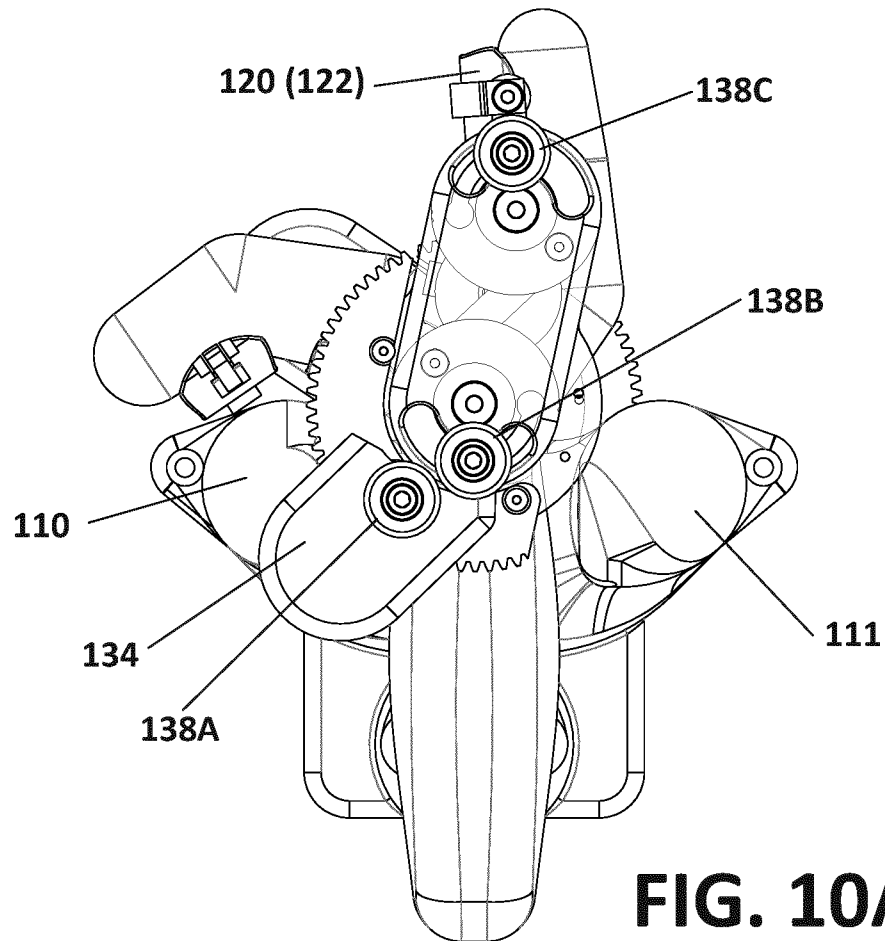
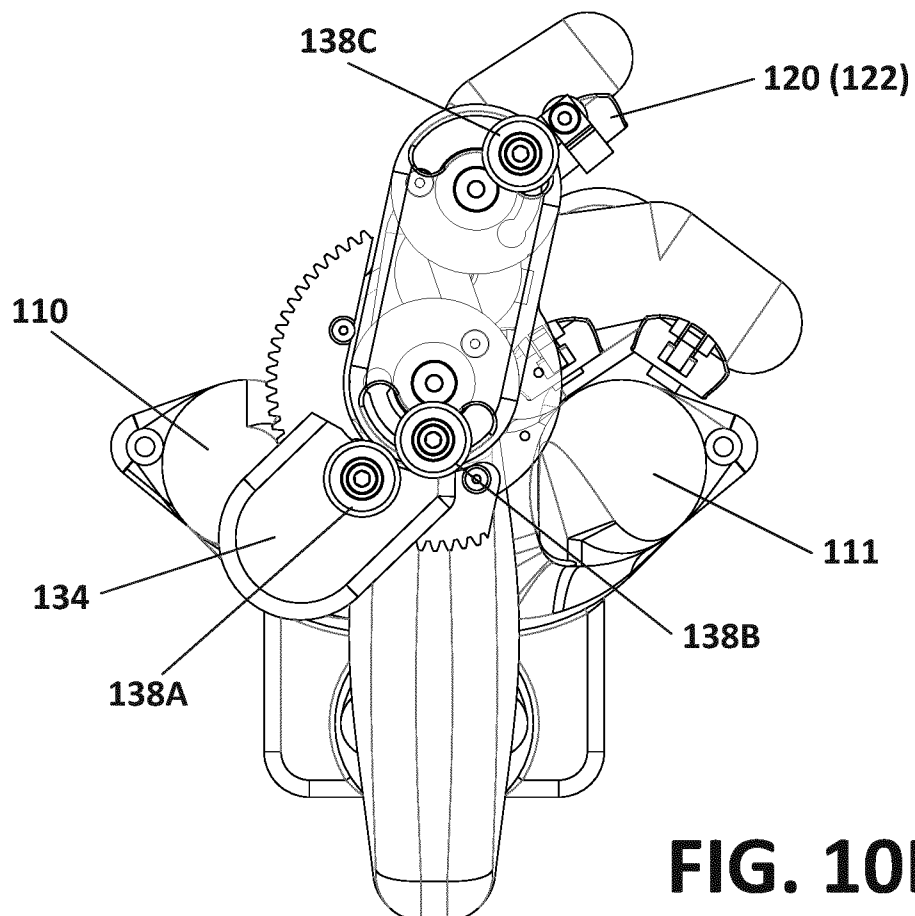
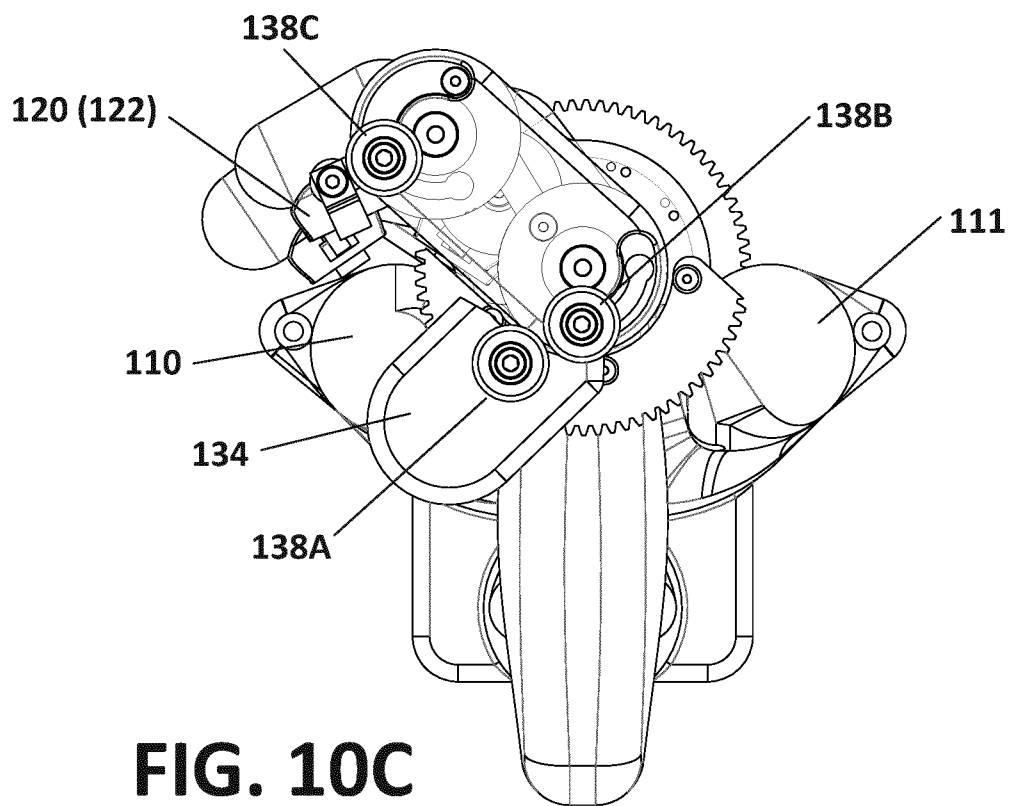


FIG. 9F





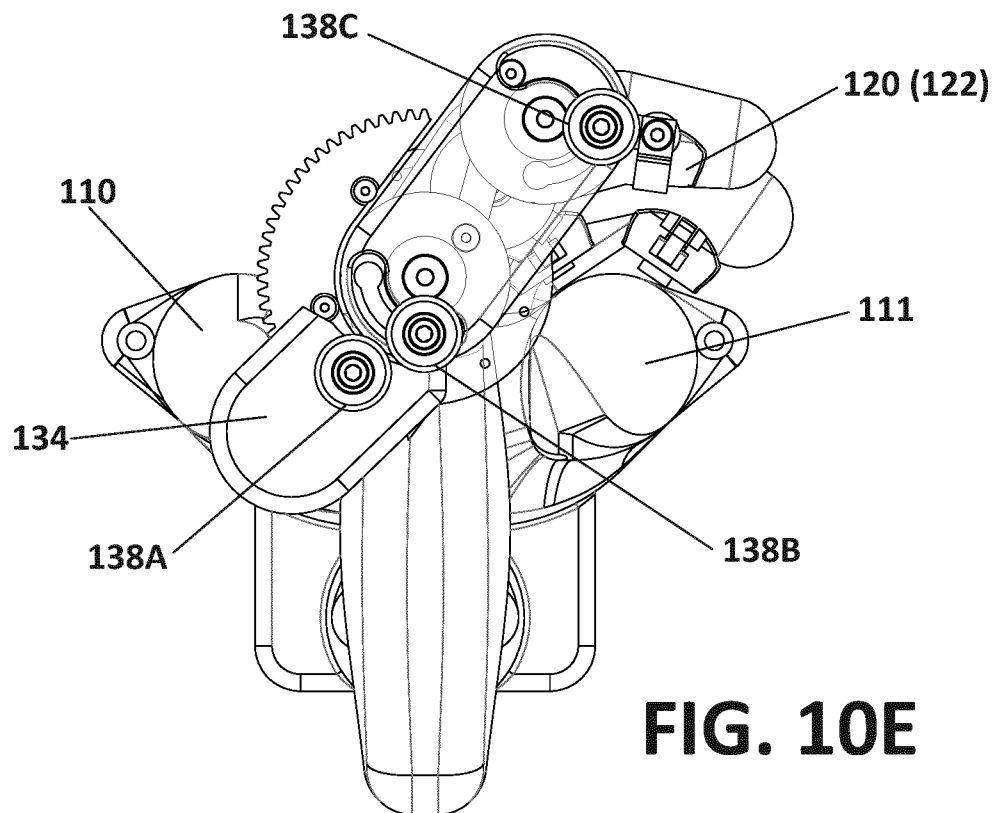


FIG. 10E

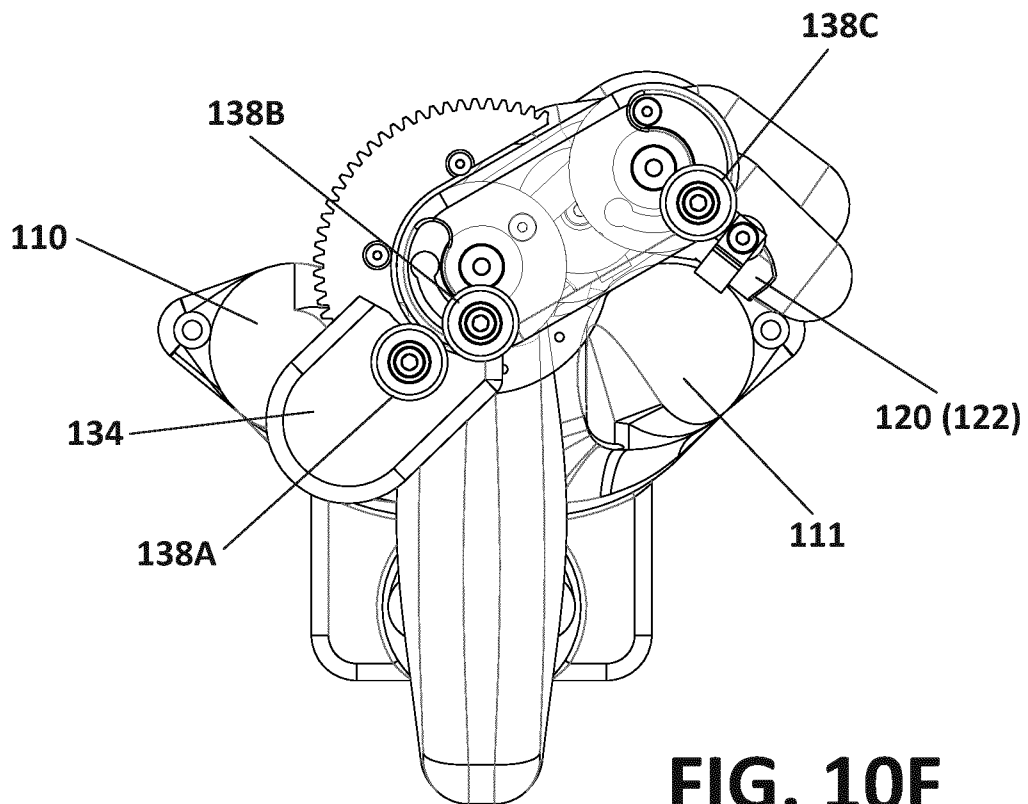


FIG. 10F

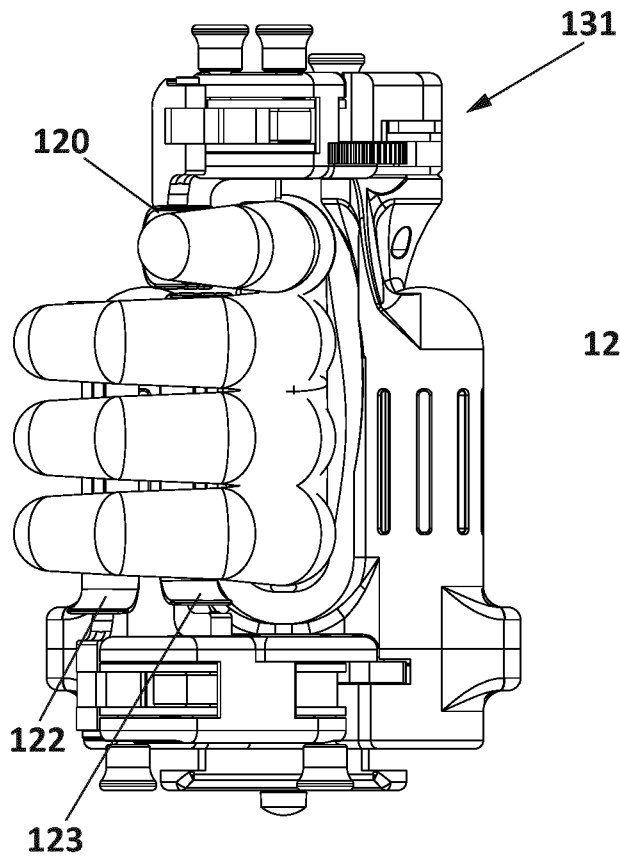


FIG. 11A

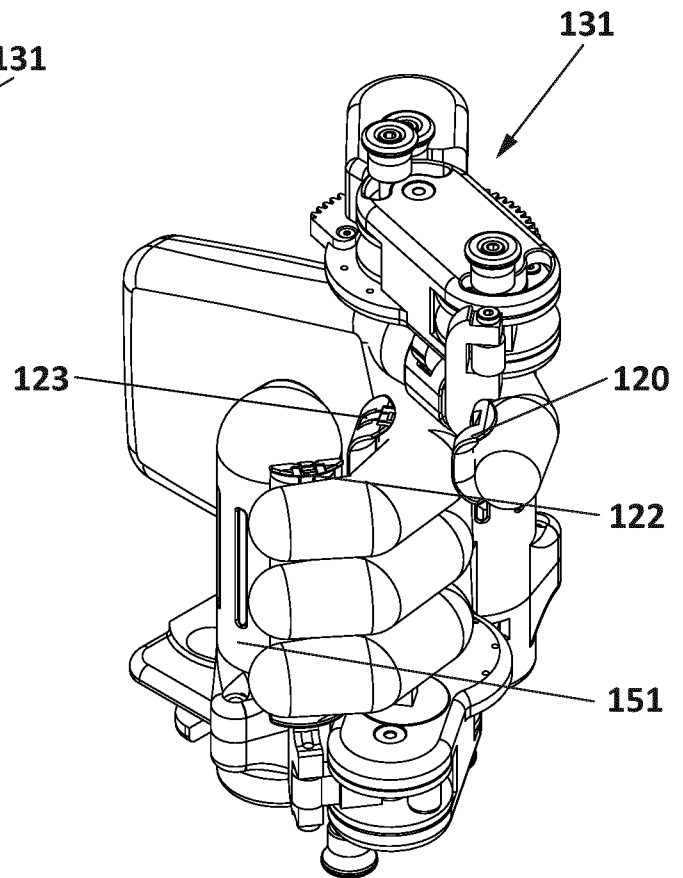


FIG. 11B

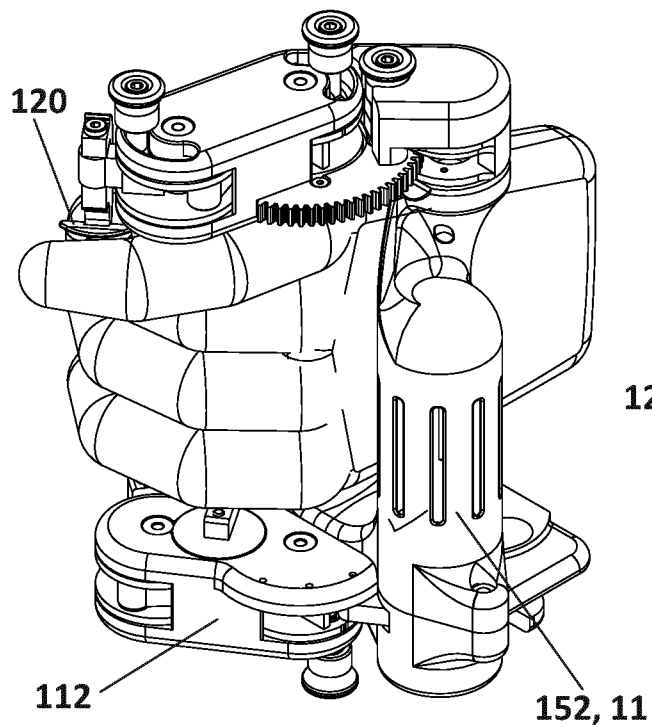


FIG. 11C

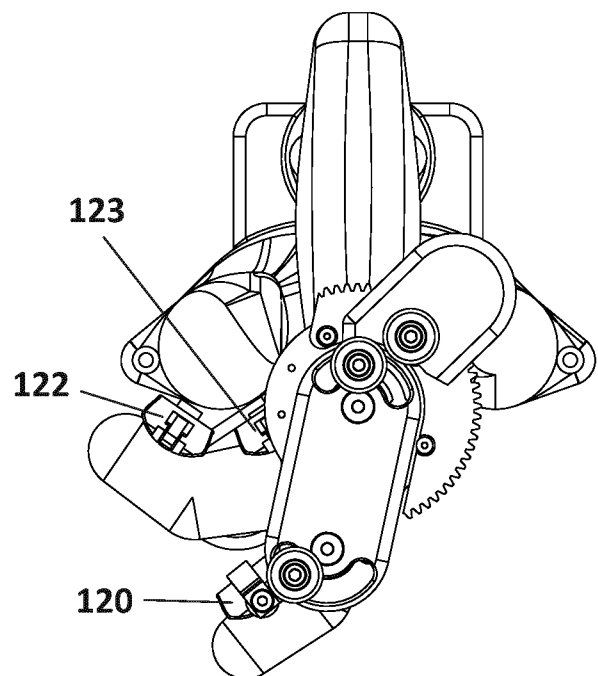


FIG. 11D

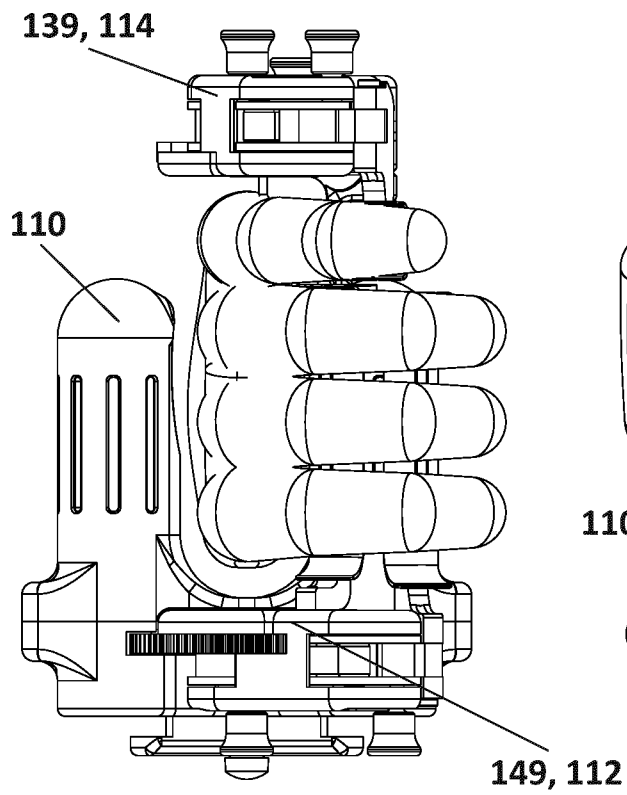


FIG. 12A

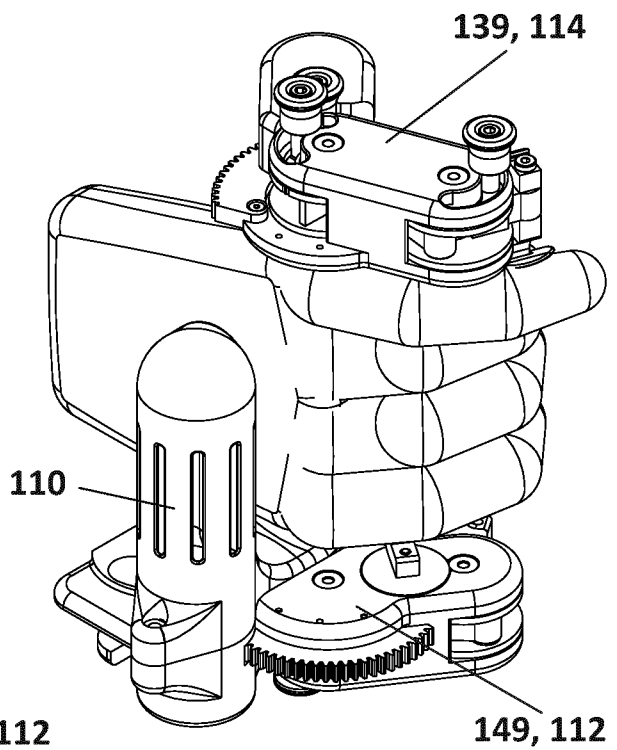


FIG. 12B

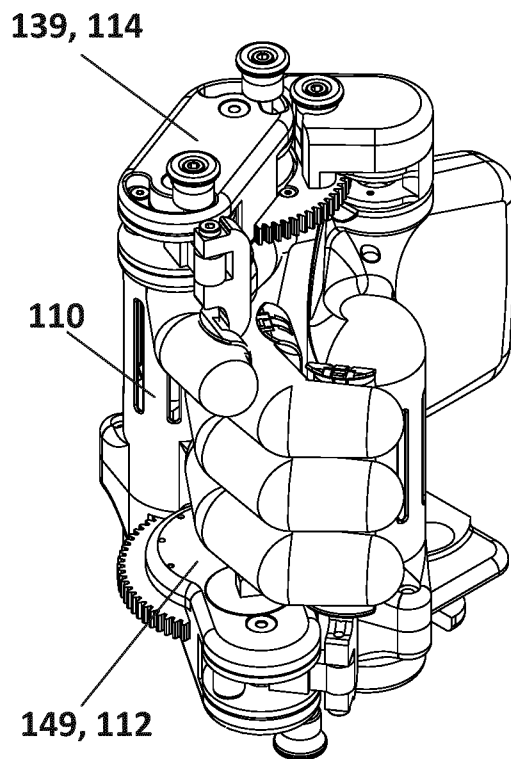


FIG. 12C

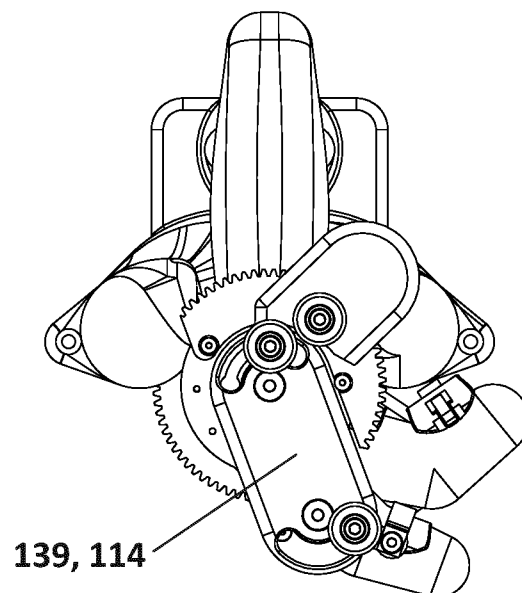
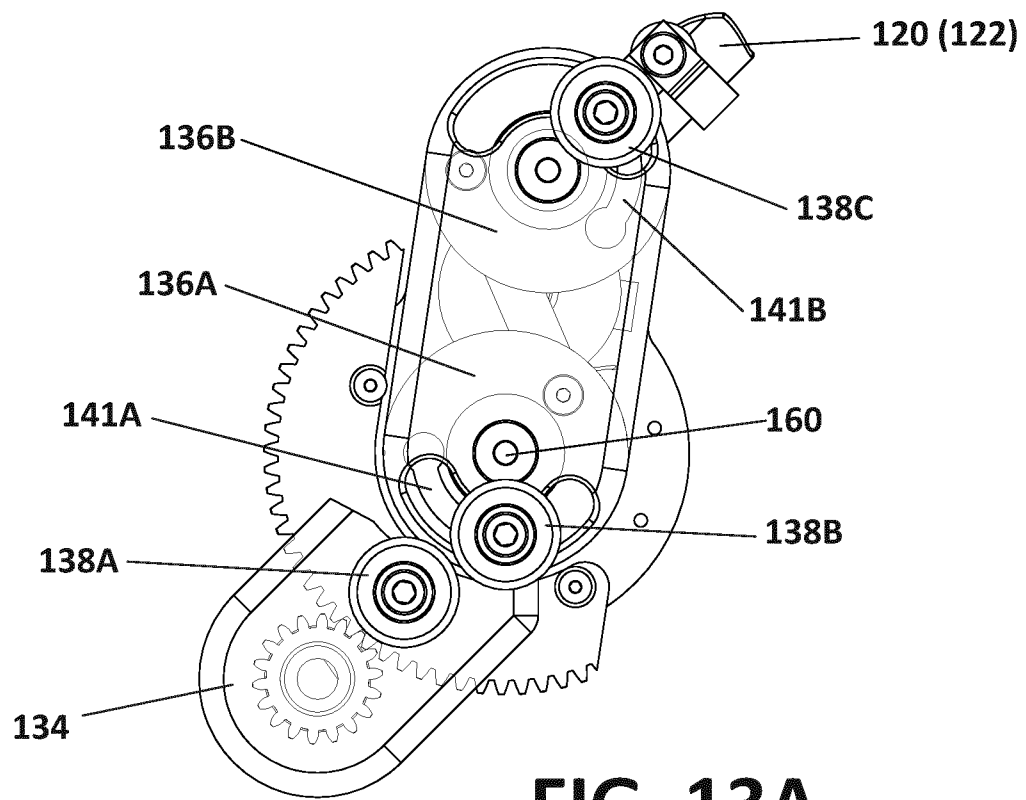
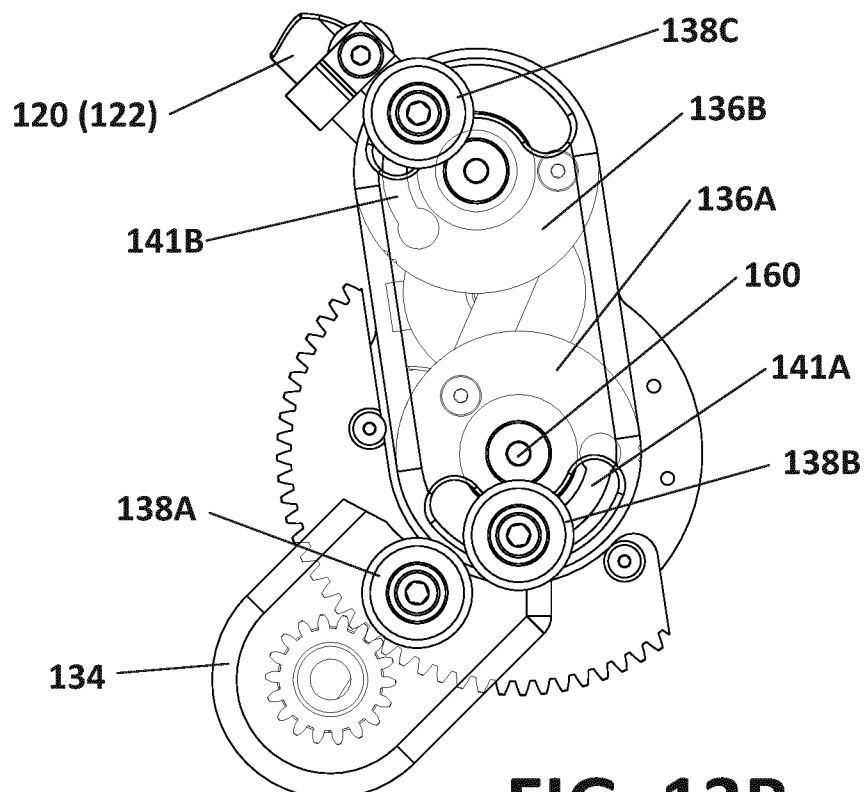


FIG. 12D

**FIG. 13A****FIG. 13B**

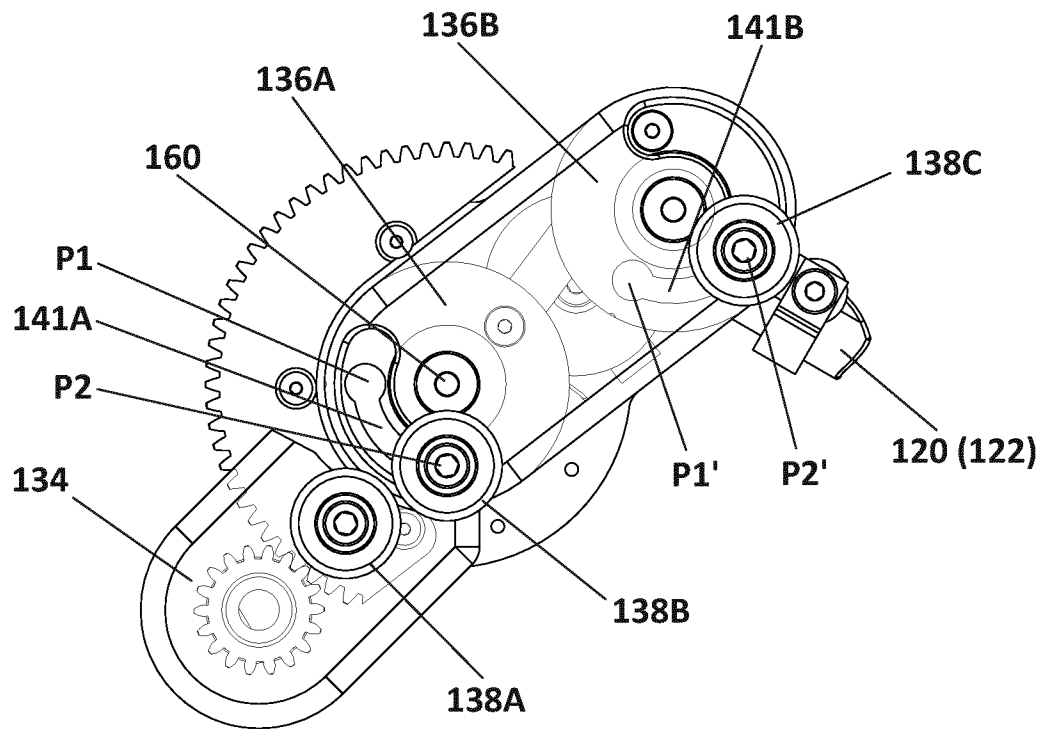


FIG. 13C

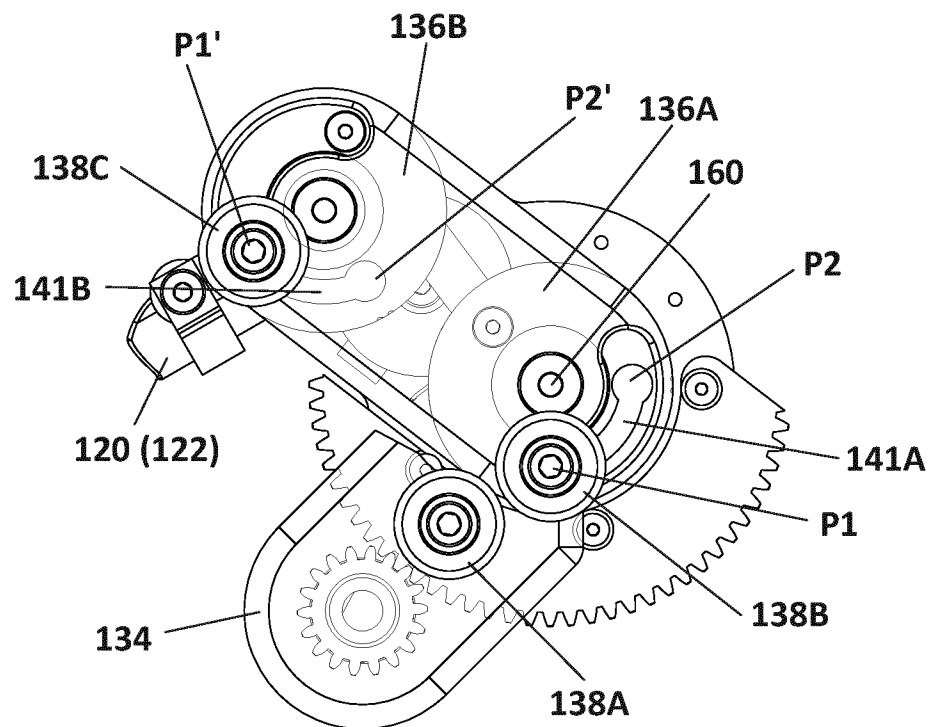


FIG. 13D

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/051840

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61H1/02
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61H

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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/305717 A1 (TONG KAI YU [HK] ET AL) 2 December 2010 (2010-12-02) the whole document -----	1-15
X	CN 103 750 977 A (HARBIN INST OF TECHNOLOGY) 30 April 2014 (2014-04-30) the whole document -----	1-15
X	WO 2014/068509 A2 (UNIV CAPE TOWN [ZA]) 8 May 2014 (2014-05-08) page 3, line 27 - page 4, line 16; figures -----	1,5,6,8, 12-14
A	WO 2015/024852 A1 (HOCOMA AG [CH]) 26 February 2015 (2015-02-26) cited in the application the whole document -----	1,8



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

24 April 2017

Date of mailing of the international search report

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Fax: (+31-70) 340-3016

Authorized officer

Squeri, Michele

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2017/051840

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			WO	2014068509 A2		08-05-2014

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			WO	2015024852 A1		26-02-2015
