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Description

Field of the invention

[0001] The present invention relates to the field of joint prostheses, which are used in case of partial or total amputations of the upper limbs.

[0002] More in detail, the invention relates to an actuating mechanical finger structure of a total or partial hand prosthesis, which is operated responsive to data obtained from sensors influenced by the intentions of a patient.

Description of the prior art

[0003] As well known, in the past years joint prostheses achieved relevant technological progresses, in particular concerning miniaturisation of electronic and mechanical components, and improved software capable of simulating an anatomical behaviour.

[0004] In particular, relevant known improvements relate to the mechanical transmission and the electronic computation adopted for actuating gripping ends, especially for hand prostheses, very common in prosthetic technology.

[0005] The replacement of a hand, or only of some phalanxes, is, in fact, very requested for the high occurrence of amputations of this area of the body, for example deriving from workplace injuries or other causes such as road accidents.

[0006] The above developments have been achieved by recent hand prostheses having both high biomimetic features and high gripping configuration with respect to those obtained by the former electromechanical prosthesis.

[0007] However, it is not easy to provide prosthesis of the hand or only of phalanxes capable of really meeting the needs of a patient. In fact, the motion of the fingers of a hand is extremely complex to reproduce, for the large number of anatomical parts, in particular joints, tendons and muscles present in a hand.

[0008] On the market various solutions exist of hand prosthesis, or of single phalanxes. Such solutions differ from one another especially for the type of operation of the fingers.

[0009] In US2008319553A1 and WO2010018358A2, for example, prostheses are described where the actuators are arranged in the palm of the hand of the prosthesis.

[0010] In particular, in US2008319553A1 a frame is provided to which at least one finger graft is articulated that rotates about an axis by an actuator and a transmission, arranged in the palm of the hand.

[0011] In WO2010018358A2, instead, an actuator for each finger of the prosthesis is presented. The fingers are, in this case, independent from each other, but they need in any case a complete hand structure for mounting the actuators.

[0012] The above solutions have the disadvantage that fingers cannot be replaced separately, since only the complete limb can be replaced.

[0013] Such drawbacks can be overcome, as suggested in US2010191343A1 and WO2007063266A1, where the actuators are located distally in the fingers same. However, they have further problems.

[0014] In particular, US2010191343A1 describes a prosthesis having a heavy and cumbersome actuation of the fingers. Owing to its large size, it is not possible to provide small hand prosthesis, that would be necessary for achieving an optimal biomimetics in case the patient is a woman or a child. Furthermore, the high weight can cause high loads to the stump of the patient, thus tiring the muscles, in particular at the interface between the stump and the prosthesis.

[0015] In WO2007063266A1, instead, an attempt is made to solve the problem of the encumbrance and of the weight, by simplifying the phalanx joints.

[0016] However, such solution is very stiff. In particular, an excessive stiffness of the phalanxes prevents the prosthesis from dampening compressing stresses applied, even incidentally, to the fingers. Such loads are therefore transferred integrally to the stump of the user, resulting tiring and painful.

[0017] There are also sensors for hand prosthesis, i.e. the parts that detect and transmit data relating to the will of the patient to carry out movements.

[0018] In this field, contrarily to prosthetic mechanical transmissions and electronic computerizations, in the last years only minor developments have been made.

[0019] The known techniques provide normally an acquisition of ElectroMyoGraphic signals, or myoelectric, by means of EMG sensors arranged in contact with the skin of the stump of the patient. This way, it is possible to measure the muscle activity of the stump of the patient by a measurement of the voltage at the skin level.

[0020] An example of this technique is given in WO0113778, in which at least one EMG sensor is used for detecting the muscle contractions of the patient and triggering the subsequent operation of the prosthesis.

[0021] However, to ensure a sufficient detection precision several EMG sensors are needed.

[0022] More in detail, usually a first EMG sensor is arranged at the agonist muscle and a second EMG sensor is arranged at the antagonist muscle.

[0023] This causes a high cost owing to the high cost of the EMG sensors.

[0024] Furthermore, by an EMG sensor the zone of skin where the electric signal is higher is detected, and this zone, as understandable, changes from patient to patient.

[0025] A system of sensors comprising only EMG sensors requires a customization of the prosthesis that increases further the costs of the product.

[0026] Other examples of prosthetic systems of the prior art with similar drawbacks are described also in WO2011/087382, EP1195151 and WO03/017876.

Summary of the invention

[0027] It is therefore a feature of the present invention to provide a prosthetic hand structure capable of measuring the intentions of a patient, through the acquisition of a plurality of data, and of operating the mechanical fingers of a total or partial hand prosthesis responsive to data computed as above described.

[0028] It is also a feature of the present invention to provide a prosthetic structure for a hand that provides a finger actuation of minimum encumbrance, in order to replace a hand of small size, like that of a woman or of a child, ensuring also high biomimetic features.

[0029] It is another feature of the present invention to provide such a structure which is light enough to avoid tiring the stump of a user.

[0030] It is a further feature of the present invention to provide such a structure that dampens the compressive stress on the fingers, to avoid painful effects on the stump.

[0031] It is also a feature of the present invention to provide such a structure in which the finger actuators are located in the fingers, in such a way that each finger is independent, so that said structure can be implemented to replace not only a hand, but even separate fingers or phalanxes.

[0032] It is a further feature of the present invention to provide such a structure where the fingers are modular elements, interchangeable with each other, in order to maximize the use of each component, with subsequent savings.

[0033] It is still a feature of the present invention to provide such a structure where the finger actuation ensures a high speed of opening and closing the fingers to ensure high biomimetic characteristics.

[0034] It is also a feature of the present invention to provide a structure of prosthesis that can be operated by the patient in a way much easier than the presently existing solutions.

[0035] It is also a feature of the present invention to provide a prosthetic structure for the hand for carrying out a plurality of possible movements of the mechanical fingers, each of them corresponding to a particular gripping pattern, or to a predetermined action.

[0036] It is also a feature of the present invention to provide a prosthetic hand structure having a system of sensors capable of selecting, among the above described plurality of possible movements of the mechanical fingers, movements that are as close as possible to those desired by the patient.

[0037] It is a further feature of the present invention to provide a prosthetic hand structure having a system of sensors that makes the above selection on the basis of the spatial position, of the speed and of the accelerations of the arm, as well as on the basis of the relative location of some parts of the prosthesis.

[0038] It is also a feature of the present invention to provide a prosthetic hand structure for which it is not necessary to produce a customized prosthesis for each patient, with noticeable savings in the production.

[0039] In particular, an object to be achieved is that force sensors can be used of the type with adjustable resistances; these sensors involve lower costs and feature a linear proportion between the force to which they are subjected and their conductance.

[0040] These and other objects are achieved by a prosthetic structure for a hand comprising:

- at least one mechanical finger comprising:
    - a metacarpal support;
    - a proximal stiff link connected to the metacarpal support by a proximal cylindrical joint, said proximal stiff link arranged for carrying out a rotation of predetermined amplitude φ with respect to the metacarpal support about an axis of the proximal cylindrical joint;
- a transmission member connected to the proximal stiff link and arranged to actuate the proximal stiff link for causing said rotation of predetermined amplitude φ;
- an actuator arranged to move the transmission member;

wherein the transmission member comprises:

- a worm screw integral to the proximal stiff link and having a threaded profile, said worm screw arranged for carrying out a rotation about an own longitudinal axis;
- a rack, in particular a flexible rack, having a first end portion, pivotally connected to the metacarpal support, and a second end portion which is adapted to engage with the threaded profile of the worm screw at an engagement zone of the rack;

wherein the actuator is mounted to the mechanical finger and is adapted to actuate the worm screw, causing it to rotate about said longitudinal axis, in such a way that, when the actuator moves the worm screw, a moving away/approaching movement of the engagement zone is caused away from/towards the first end portion, causing said rotation of predetermined amplitude, in a direction of rotation, or in an opposite direction, of the proximal stiff link about the axis of the proximal cylindrical joint, said rotation of predetermined amplitude φ corresponding to the extension/flexion movement of the mechanical finger.

[0041] In particular, said moving away/approaching movement generates the extension/flexion movement of the mechanical finger.

[0042] The use of a flexible rack has the advantage of allowing the use of the same component, i.e. the rack, both as pulling element, in a flexion movement, and as pushing element, in an extension movement.

[0043] This determines a system of actuation of the mechanical fingers that is light and has minimum lateral encumbrance, in order to provide also a hand prosthesis of small size.

[0044] Furthermore, the prosthetic structure of the invention, owing to the minimum weight, minimizes tiring the stump which can thus bear many load types.

[0045] The mechanical finger structure above described, in particular by providing the actuator mounted directly to the mechanical finger, allows also the change of separate fingers of the patient in case of partial amputation of the hand.

[0046] Furthermore, the high flexibility of the rack allows buckling, such that compressive loads receive a high damping and are not transferred integrally to the stump, as it would occur in case of stiff mechanical fingers.

[0047] Advantageously, a voltage source is provided which can supply electric energy for operating the prosthetic structure, and, in particular the actuators and the sensors. Such source can be, for example, an accumulator or a rechargeable battery.

[0048] In this case, the use of a screw/rack system allows further advantages like a high energy efficiency.

[0049] In fact, this screw/rack system that has a very low mechanical efficiency, for example lower than about 0.5, ensures an irreversibility of the movement which keeps the prosthesis blocked, once reached the predetermined position, without making use of external energy.

[0050] The screw/rack system requires therefore the use of this source of electric current only during the step of arranging the mechanical fingers in the working predetermined configuration.

[0051] Advantageously, the rotation of predetermined amplitude φ of the proximal stiff link with respect to the metacarpal support lays in a plane π substantially orthogonal to the axis of the proximal cylindrical joint.

[0052] In particular, the longitudinal axis about which the worm screw is adapted to carry out its own rotation lays in the plane π.

[0053] In particular, each mechanical finger also comprises a distal stiff link connected to the proximal stiff link by a distal cylindrical joint, which is adapted to carry out a rotation of predetermined amplitude with respect to the proximal stiff link about an axis of the distal cylindrical joint.

[0054] In particular, the distal cylindrical joint can be under-actuated by a mechanical reduction carried out by a couple of gears or by a belt that is wound/unwound in guiding grooves.

[0055] The solution of under-actuation allows a higher biomimetics of the prosthetic limb and assists to grip objects, for example cylinders of small diameter, with a precision otherwise not obtainable in an easy way.

[0056] Alternatively, the distal cylindrical joint can provide a condition of stiff constraint, in such a way that the mechanical finger is substantially a mono-phalangeous finger, which ensures a reduction of costs of the product and an increase of performances versus force, since a certain amount of the energy for the system is not consumed by operating the distal part.

[0057] Advantageously, the prosthetic hand structure comprises a plurality of mechanical fingers and a metacarpal base connected to the metacarpal support of each mechanical finger.

[0058] This way, the prosthetic structure can replace a whole hand, comprised the metacarpal portion of the hand same.

[0059] Advantageously, if the mechanical finger is a mechanical finger for the thumb, then the metacarpal base is connected to the mechanical finger for the thumb by a rotational joint for enabling a rotation about its own longitudinal axis, in order to provide to the mechanical finger for the thumb an abduction/adduction degree of freedom.

[0060] The rate of abduction/adduction, as well known, allows enlarging the range of possible gripping configurations that the hand can carry out.

[0061] Advantageously, a selection device which is adapted to select a predetermined working configuration among a plurality of possible predetermined working configurations is also provided, said selection device which is adapted to operate said or each actuator to obtain said selected working configuration.

[0062] Advantageously, in the prosthetic structure at least one feedback position sensor is further provided, in particular a Hall-effect sensor, associated with said, or each, mechanical finger. The feedback position sensor is adapted to measure the position of the proximal stiff link with respect to the metacarpal support, and then to determine in real time the amplitude (φ) of said rotation. The feedback position sensor is also configured to generate instantly a corresponding feedback signal and to transmit this feedback signal to a control unit. The control unit is configured to analyse said feedback signal and to operate the actuator for actuating the worm screw until the amplitude (φ) determined in real time reaches a predetermined amplitude (φ).

[0063] This way, it is possible to make a operation feedback loop control that allows a higher precision in handling the mechanical finger.

[0064] The use of Hall-effect sensors allows avoiding contacts of mechanical type between the proximal stiff link and the metacarpal support, resulting also a solution particularly cheap with respect to other systems for detecting the position.

[0065] In particular, in the prosthetic structure the following features are further provided:

- at least one myoelectric sensor, or EMG sensor, which is arranged, in use, in contact with the stump of the patient, said or each myoelectric sensor configured to measure a voltage associated with activation of an agonist and/or antagonist muscle of the stump of the patient and to generate a relative myoelectric signal;

- a plurality of force sensors arranged, in use, in contact with the stump of the patient and distributed on a predetermined surface of the stump, said plurality of force sensors configured to measure a plurality of pressure data corresponding to a predetermined muscle configuration achieved by the patient and to generate at least one corresponding pressure distribution signal on the stump;
- a control unit configured to analyse said or each myoelectric signal and said or each signal of pressure and to carry out a selection of a predetermined working configuration, for example a gripping configuration, among a plurality of possible predetermined gripping configurations, said control unit configured to operate said or each actuator to obtain said selected working configuration.

[0066] In particular, the selection obtained from the control unit is carried out comparing the myoelectric signal and the pressure distribution signal predetermined by the sensors with a plurality of signals associated with predetermined working configurations.

[0067] This makes it possible for a patient to use, for handling the mechanical fingers, the same muscles that a person without amputations would use, so that the prosthetic integration is as natural as possible.

[0068] The solution described by the invention makes it possible to install on the prosthesis a single EMG sensor, and to compensate for the lack of a second or of a third EMG sensor using force sensors.

[0069] Given the significant cost differences between EMG sensors and force sensors, the solution proposed by the invention allows installation of many force sensors, forming a kind of matrix of sensors, which can be distributed on a wide area of the stump, without the need for a preliminary step to define a specific zone of application where the muscle signal is more intense, as instead it has to be done for EMG sensors.

[0070] This provides substantially all-purpose prosthesis, or that in any case does not require adjusted according to the needs of each patient, which can be used for patients with morphological features also very different from each other.

[0071] The solution proposed by the invention, then, has the double advantage of being cheaper than the prior art, because it has cheaper parts and a less expensive production, since it does not require customization work for the patient.

[0072] Preferably, the EMG sensor is located near the elbow of the patient.

[0073] In particular, the prosthetic structure can provide also an inertial sensor selected from the group consisting of:

- an inertial sensor configured to measure the spatial orientation of the prosthetic structure with respect to a predetermined direction, to generate a corresponding spatial position signal, and to transmit said spatial position signal to said control unit;
- an inertial sensor configured to measure at least one linear and/or angular speed and/or acceleration, of said prosthetic structure, to generate a corresponding kinematic signal, and to transmit said kinematic signal to said control unit;
- a combination thereof;
  said control unit configured, in the latter case, to carry out said selection of the possible working configurations also .on the basis of said spatial position signal and/or said kinematic signal.

[0074] Such solution allows, substantially, of adding a filter further in the search of the working configurations that the user wishes carry out, allowing enlarge the field of configurations obtainable and/or speeding up the procedure of selection.

[0075] Advantageously, in the prosthetic structure the following features are further provided:

- a first inertial sensor configured to measure at least one linear and/or angular speed and/or acceleration, of said prosthetic structure, to generate a corresponding kinematic signal, and to transmit said kinematic signal to said control unit;
- a second inertial sensor, which is located on the forearm, if said first inertial sensor is located on the hand, or on said hand if said first inertial sensor is located on the forearm, said second inertial sensor arranged for:
  - measuring at least one linear and/or angular speed and/or acceleration, respectively, of the forearm or the hand;
  - generating a corresponding reference spatial position signal, and
  - transmitting said reference spatial position signal to said control unit;

  said control unit configured to compare said spatial position signal with said reference position signal, obtaining a relative position value between hand and forearm, said control unit also configured for carrying out said selection of possible gripping configurations on the basis of said relative position value between hand and forearm.

[0076] The relative position between the arm and the hand allows determining the configuration of the wrist, which can give a further discrimination with respect to possible actions that the user wishes to carry out.

[0077] In particular, in the prosthetic structure at least one position sensor the thumb is further provided, in particular a Hall-effect sensor, configured to measure the direction of the mechanical finger for the thumb with respect to said metacarpal base, to generate a corresponding thumb position signal, and to transmit said thumb position signal to said control unit, said control unit configured, in this case, to carry out said selection of possible gripping configurations also on the basis of said thumb position signal.

[0078] The position sensor for the thumb can coincide, structurally, with the feedback position sensor used for mechanical operation in feedback loop, even if the object of the signal generated is radically different.

[0079] In this case, in fact, the position of the thumb detected by the actual position sensor is used for giving data concerning, mainly, the angle of abduction/adduction of the thumb, which is essential in this selection.

[0080] Such angle does not correspond with one actuated degree of freedom, and therefore it can be changed only esternally, for example using the other hand. For this reason this angle is unknown to the control unit, and has to be detected by a suitable sensor.

[0081] The prosthesis structure, according to the present invention, can comprise a single type of sensors as above described, or any combination thereof.

[0082] According to another aspect of the invention, a prosthetic hand structure comprises:

- at least one mechanical finger comprising:

  - a metacarpal support;
  - a proximal stiff link connected to said metacarpal support by a proximal cylindrical joint, said proximal stiff link arranged for carrying out a rotation of predetermined amplitude φ with respect to said metacarpal support about an axis of said proximal cylindrical joint;

- an actuator arranged to cause said rotation of predetermined amplitude φ of said proximal stiff link with respect to said metacarpal support;
- a control unit configured to operate said actuator to obtain said rotation of predetermined amplitude φ;

the prosthetic structure provides also at least one sensor selected from the group consisting of:

- a myoelectric sensor arranged, in use, in contact with the stump of the patient, said myoelectric sensor configured to measure a voltage associated with activation of an agonist and/or antagonist muscle of the stump of the patient and to generate a relative myoelectric signal;
- a plurality of force sensors arranged, in use, in contact with the stump of the patient and distributed on a predetermined surface of the stump, said plurality of force sensors configured to measure a plurality of pressure data corresponding to a predetermined muscle configuration achieved by the patient and to generate at least one corresponding pressure distribution signal on the stump;
- an inertial sensor configured to measure the spatial orientation of the prosthetic structure with respect to a predetermined direction, to generate a corresponding spatial position signal, and to transmit said spatial position signal to said control unit;
- an inertial sensor configured to measure at least one linear and/or angular speed and/or acceleration, of said prosthetic structure, to generate a corresponding kinematic signal, and to transmit said kinematic signal to said control unit;
- a position sensor, in particular a Hall-effect sensor, configured to measure the direction of the mechanical finger for the thumb with respect to said metacarpal base, to generate a corresponding thumb position signal, and to transmit said thumb position signal to said control unit, said control unit configured, in this case, to carry out said selection of possible gripping configurations also on the basis of said thumb position signal.
- a combination thereof;

  said control unit configured to analyse said or each myoelectric signal and/or said or each pressure distribution signal and/or said or each spatial position signal and/or said or each kinematic signal and/or said or each thumb position signal, to carry out a selection of a predetermined working configuration, in particular a gripping configuration, among a plurality of possible predetermined gripping configurations, and to operate said or each actuator to obtain said selected working configuration.

Brief description of the drawings

[0083] Further characteristic and/or advantages of the hand prosthetic structure, according to the present invention, will be made clearer with the following description of an exemplary embodiment thereof, exemplifying but not limitative, with reference to the attached drawings in which:

- Fig. 1 shows a perspective view of an exemplary embodiment of the hand prosthetic structure, according to the invention, where a single mechanical finger is provided;
- Fig. 2 shows a cross section of the mechanical finger of the exemplary embodiment of prosthetic structure of Fig. 1;
- Fig. 2A shows an enlarged view of the portion of mechanical finger of Fig. 2 where it is shown that is in mesh between worm screw and rack;
- Figs. 3A and 3B show a cross section, respectively in an extension and bending movement, of an alternative exemplary embodiment of the hand prosthetic structure, where the rack is made of two segments, a stiff segment and a flexible segment;
- Fig. 4 shows an exemplary embodiment of the hand prosthetic structure, according to the invention, where a plurality of mechanical fingers and a metacarpal base are provided;
- Fig. 5 shows the same exemplary embodiment of Fig. 4, where the palm cover of the metacarpal base

is removed for depicting the cylinder-piston mechanism;

- Fig. 6 shows the same exemplary embodiment of Fig. 4, where the metacarpal base is omitted and the control unit is shown;
- Figs. 7 and 8 show in a view, respectively, from the above and lateral, the exemplary embodiment of Fig. 6;
- Fig. 9 shows an exemplary embodiment of a hand prosthetic structure, applied to a patient, and comprising also a support body for sensors in the structure;
- Fig. 10 shows a possible diagrammatical view of the operation of an algorithm configured to analyse the signals detected by different sensors;
- Fig. 11 shows an example of a 3D vector space generated by the signals detected by the sensors;
- Figs. 12a-12e show some of the possible working configurations obtainable from the above described prosthetic structure.

Description of a preferred exemplary embodiment

[0084] With reference to Fig. 1, an exemplary embodiment of the prosthetic hand structure 100, comprises a mechanical finger 110a-110e, in turn comprising a metacarpal support 111, a proximal stiff link 112 and a distal stiff link 114.

[0085] Proximal stiff link 112 can rotate an angle φ, about an axis 113', with respect to metacarpal support 111 by a proximal cylindrical joint 113.

[0086] Similarly, distal stiff link 114 can rotate an angle ω, about an axis 115', with respect to proximal stiff link 112 a distal cylindrical joint 115.

[0087] Both rotation axes 113' and 115' are substantially orthogonal to a plane n, in which angles φ and ω lay.

[0088] In this exemplary embodiment, the distal cylindrical joint 115 can be under-actuated by a belt 119 that is wound/unwound in guiding grooves or by a mechanical reduction gear made by a couple of gears (not shown in the figures).

[0089] The choice of under-actuation allows a higher biomimetic of the prosthetic limb and assists a grip of objects, for example cylinders of small diameter, with a grip that otherwise would be achievable in a difficult way.

[0090] Alternatively, the distal cylindrical joint 115 can be missing, or be subject to a condition of stiff constraint, i.e. it is rigidly connected to the proximal stiff link, in such a way that the mechanical finger is substantially a monophalangeous finger, which ensures a reduction of costs of the product and an increase of performances versus force, since a certain amount of the energy available to the system is not consumed by under-actuating distal stiff link 114.

[0091] With reference to Figs. 2 and 2A, mechanical finger 110a-110e also comprises a worm screw 116, arranged in proximal stiff link 112, a flexible rack 117 that meshes worm screw 116, and an actuator 118 arranged to cause the rotation of worm screw 116 about an axis 116'.

[0092] In particular, flexible rack 117 comprises a first end portion 117a, connected to metacarpal support 111, in order to rotate with respect to the latter, and a second end portion 117b that meshes the threaded profile of worm screw 116 at the gear P.

[0093] This way, when the actuator 118 causes worm screw 116 to rotate, the second end portion 117b of flexible rack 117 translates along a direction substantially parallel to axis 116', distancing/ approaching engagement zone P away from/towards first end 117a, with subsequent rotation, of a predetermined amplitude φ, of proximal stiff link 112 about its axis 113'.

[0094] In particular, by approaching engagement zone P to first end 117a a rotation suitable for bending mechanical finger 110a-110e corresponds. Vice-versa, by distancing engagement zone P to first end 117a corresponds to an extension of mechanical finger 110a-110e.

[0095] The particular mechanical nature of flexible rack 117 allows the latter to work as pulling element, like a human tendon, when bending the mechanical finger 110a-110e, and also it works as pushing element during the extension.

[0096] Furthermore, the high flexibility of rack 117 allows buckling, such that compressive loads are not transferred integrally to the stump, as it would occur in case of fingers stiff, but that receive a high damping, exactly as it happens with the fingers humane.

[0097] Advantageously, the rack can be made of superelastic material, in order to meet as far as possible the flexibility requirement.

[0098] In figures 3A and 3B an exemplary alternative embodiment is shown of mechanical finger 110a-110e, where flexible rack 117 is made of two segments 117', 117" pivotally connected by pivot A.

[0099] More in detail, segment 117', comprising first end 117a, is made of a material having a predetermined flexibility. It can correspond to the predetermined flexibility for flexible rack 117, or it can be lower than it. In the latter case, the predetermined flexibility of segment 117' is obtained introducing at least one spring.

[0100] Segment 117" comprising second end 117b is instead made of stiff material, so that it can mesh better, at zone P, with worm screw 116.

[0101] The operation of rack 117, in this alternative exemplary embodiment is completely similar to that of rack 117 of Fig. 2.

[0102] With reference to Figs. 4 and 5, an exemplary embodiment of the prosthetic hand structure 100 comprises five mechanical fingers 110a-110e, which can be in the form shown in Fig. 1, and a metacarpal base 120 connected to metacarpal supports 111 of mechanical fingers 110a-110e.

[0103] As shown, metacarpal base 120, further to connecting mechanical fingers 110a-110e with each other, provides also higher biomimetic features to the whole prosthetic structure.

[0104] The mechanical finger used as index finger 110b, the mechanical finger used as middle finger 110C, the mechanical finger used as ring finger 110d and the mechanical finger used as little finger 110e can be arranged in such a way that the planes π of each mechanical finger 110b-110e are parallel to each other, whereas the mechanical finger used as thumb 110a lays in a plane not parallel to the planes n.

[0105] However, in exemplary embodiments provided by the invention, but not shown in the figure, for mechanical fingers 110b-110e that correspond to the index, middle, ring and little fingers, the planes π can be incident to each other to generate the adduction/abduction movement of the fingers.

[0106] In particular, with reference to Fig. 5, metacarpal support 111 of the mechanical finger used as thumb 110a is connected to the metacarpal base 120 by a rotational joint 121 that allows mechanical finger 110a rotating about an axis 121' substantially orthogonal to rotation axes 113' and 115'.

[0107] This way, the mechanical finger for the thumb 110a is equipped with the abduction/adduction degree of freedom, essential for broadening the range of the possible grips that can be made with the above described prosthetic structure 100.

[0108] Rotational joint 121 can be passive, as in the case of the figures, or actuated.

[0109] In the case of a passive joint, the user can position the other hand with the thumb in a predetermined working configuration, selected from the group consisting of a variety of possible gripping configurations.

[0110] In Fig. 5 the feedback position sensor 140 of the thumb is also shown, configured to measure the position of proximal stiff link 112 of mechanical finger 110a with respect to metacarpal support 111, and then to determine in real time the amplitude φ of the rotation of proximal stiff link 112 about its axis 113', in order to generate instantly a corresponding feedback signal and to transmit this feedback signal to a control unit 130 (as shown in Fig. 6).

[0111] The feedback position sensor 140 of the thumb needs, for a correct operation, measuring magnetic field changes.

[0112] To this purpose, at joint 113 a housing 140a is arranged in which a magnet is inserted 140b (Fig. 6). Such magnet is integral to proximal stiff link 112 of mechanical finger 110a and allows Hall-effect sensor 140 detecting the rotation about its axis 113', allowing the generation of the feedback signal.

[0113] Control unit 130 computes then the feedback signal and operates the actuator 118 for actuating worm screw 116, until the amplitude φ determined in real time fits predetermined amplitude φ.

[0114] In figures 6, 7 and 8 the same exemplary embodiment of prosthetic structure 100 of Figs. 4 and 5 is shown, where however, for simplicity, the control unit is shown 130 metacarpal base 120 is hidden.

[0115] In Fig. 7 and 8 the feedback sensors 140 relative to mechanical fingers 110b-110e is shown.

[0116] Furthermore, in Fig. 8, the housing 140a and the magnet 140b relative to feedback sensor 140 of mechanical finger 110b are shown.

[0117] Fig. 9 shows a prosthesis structure 100, according to the invention, also comprising a support body, or cup 180, with substantially cylindrical or frustoconical shape, which is put on the stump of the patient and arranged to support part of the sensor types necessary to detect the intentions of the patient, and to transmit it to control unit 130, in order to carry out correctly mechanical fingers 110a-110e.

[0118] In the exemplary embodiment of Fig. 9, on this support body 180 the following elements can be arranged:

- a myoelectric sensor 150 configured to measure a voltage associated with the activation of an agonist and/or antagonist muscle of the stump of the patient and to generate a relative myoelectric signal;
- a plurality of force sensors 160 configured to measure a plurality of pressure data corresponding to a predetermined muscle configuration achieved by the patient and to generate at least one corresponding signal responsive to the distribution of pressure on the stump.

[0119] The myoelectric signal and the pressure distribution signal are then computed by control unit 130, in such a way that control unit 130 selects a predetermined working configuration. Such working configuration, in particular a gripping configuration, corresponds to one among a plurality of predetermined configurations, better interpreting the will of the patient. Control unit 130 operates then the actuators 118 in such a way that mechanical fingers 110a-110e perform the selected configuration.

[0120] In addition to the above described sensors, prosthetic structure 100, according to the invention, may also comprise other sensors that allow a quicker and more precise selection of the predetermined configuration chosen by the patient and/or that allow having a high number of predetermined configurations among which to carry out the selection.

[0121] For example, such sensors can be:

- an inertial sensor 170, which is located for example on the metacarpal base 120 or in control unit 130 (Fig. 6), configured to measure the spatial orientation of prosthetic structure 100 with respect to a predetermined direction x, to generate a corresponding spatial position signal, and to transmit this spatial position signal to control unit 130;
- an inertial sensor 171, which is located for example on the metacarpal base 120 or in control unit 130 (Fig. 6), configured to measure at least one linear and/or angular speed and/or acceleration, of metacarpal base 120, to generate a corresponding kinematic signal, and to transmit this kinematic signal to

said control unit (130);

- an inertial sensor 172, which is located for example on cup 180 and coupled to sensor 171, configured to measure at least one linear and/or angular speed and/or acceleration, of the forearm, to generate a corresponding reference spatial position signal, and to transmit this reference spatial position signal to the control unit (130), in order to calculate the relative position between hand and forearm and therefore the rate of inclination of the wrist;
- a position sensor for the thumb 141 (Fig. 5), in particular a Hall-effect sensor, configured to measure the direction of the mechanical finger for the thumb 110a with respect to the metacarpal base 120, in particular the angle of abduction/adduction, to generate a corresponding thumb position signal, and to transmit this thumb position signal to control unit 130.

[0122] The position sensor for the thumb 141 operates too with feedback sensors 140 above described. As shown in Fig. 6, in fact, at joint 121 a housing 141a is arranged in which a magnet 141b is inserted. Such magnet is integral to metacarpal support 111 of mechanical finger 110a and allows Hall-effect sensor 141 detecting the rotation about its axis 121', and then generating the thumb position signal. The sensors above described can be used in combination or as an alternative to each other.

[0123] In the block diagram of Fig. 10 an example is diagrammatically shown of a possible algorithm that can be associated with control unit 130 for analysing the signals detected by the different sensors.

[0124] The signals considered by the algorithm in this example are the myoelectric signal (EMG), the pressure distribution signal (FSR), the spatial position signal (θ), as well as the kinematic signal (θ') and the thumb position signal (PP)

for simplicity, the shown algorithm takes into account only a possible open configuration of the hand.

[0125] More in detail, the algorithm defines a priority sorting of the main input signals, in order to discriminate at each passage any gripping configurations incompatible with the received signals and determine univocally the gripping configuration desired by the patient.

[0126] In particular, when control unit 130 receives a signal EMG and/or a signal FSR (event FSR/EMG), it discriminates, according to this signal, if the patient has given a closure command (positive closure event) or a opening command (negative closure event).

[0127] If the patient has given an opening command, control unit 130 operates actuators 118 in order to bring mechanical fingers 110a-110e to the open configuration of the hand. This is because, as starting hypothesis, there is only one open configuration, and therefore the configuration is univocally predetermined without further controls on the signals.

[0128] In case, instead, the patient has given a closing command, it is possible that control unit 130 has already enough data from the EMG and FSR signals for excluding some gripping configurations that are not compatible with such signals.

[0129] Then, the algorithm proceeds with the following analysis of the signals. The signals θ and θ' are then analysed, relative to the position, the speed and the accelerations of the prosthetic structure. If such signals are compatible with at least one gripping configuration among those that are not excluded in the preliminary step (positive validation of θ and θ'), then the algorithm proceeds with the successive step, excluding possible gripping configurations that are not compatible with the values of the signals θ and θ' detected by control unit 130.

[0130] Alternatively, in case of negative validation of the signals θ and θ', i.e. in case no gripping configurations are found compatible with the values of the signals θ and θ' detected by control unit 130, the algorithm returns to the starting step and control unit 130 does not give any actuation command.

[0131] Similar situations occur in the successive step, concerning the validation of the thumb position signal PP.

[0132] The principles of the algorithm can be then extended at any signal that the control unit can receive, in order to select gradually the range of possible gripping configurations.

[0133] After having validated the all signals, the algorithm can identify in an univocal way the gripping configuration desired by the patient. In any case, to avoid errors to the prosthesis, a final step of the algorithm (not shown in Fig. 10) can be provided that operates the actuation only when a gripping configuration has been univocally predetermined. In case, instead, more than one gripping configuration has been found compatible, then the algorithm returns to the starting step, and control unit 130 does not give any actuation command.

[0134] In Fig. 11 an example is shown of a 3D vector space generated by the signals transmitted from the sensors to control unit 130.

[0135] More in general, the signals transmitted from the sensors to control unit 130 generates a vector space with N dimensions, where each Nth dimension corresponds to a parameter detected by the sensors or to a quantity deriving from this parameter.

[0136] In this vector space a plurality of subspaces is detected, each of which corresponds to a particular gripping configuration. In particular, each gripping configuration is defined by a combination of N coordinates, each Nth coordinate corresponding to a range of values of the parameter corresponding to the Nth dimensions vector.

[0137] In the example of Fig. 11, the vector space is generated using 3 parameters and defines then a volumetric space. In this space, two volumes an and B are shown, corresponding to two particular gripping configurations and defined by a combination of three ranges of values.

[0138] In this case, the algorithm of Fig. 10 should carry out 3 steps of validation, one for each parameter.

[0139] In a first step the algorithm is configured to exclude all the gripping configurations whose range of values of the first parameter does not comprise the value of the parameter detected by the sensor.

[0140] In a second step the algorithm is configured to test the compatibility of the value of the second parameter detected with the residue gripping configurations deriving from the previous step. If this value is comprised in the range of values of the second parameter of at least one of such residue gripping configurations, then the algorithm passes through the third step, where the same procedure is repeated.

[0141] If the vector subspaces defining the different gripping configurations do not have intersections with each other, then certainly each combination of values of the parameters defines univocally a gripping configuration, and the control unit can give the actuation command.

[0142] Graphically, the lines 20 define the trajectories obtained from the subsets of three parameters during the use of the prosthesis. When a trajectory crosses a volume associated with a gripping configuration, the prosthesis performs such gripping configuration. In Figs. 12A to 12E some of the possible gripping configurations are shown obtainable from the above described prosthetic structure.

[0143] In particular, Fig. 12A shows a grip with the index finger, Fig. 12B shows a hook-like grip, Fig. 12C shows a cylindrical palm grip with thumb in opposition, Fig. 12D shows a cylindrical palm grip on objects of big diameter, Fig. 12F shows a key grip and Fig. 12E shows a grip on cylinders of small size.

[0144] The foregoing description of specific exemplary embodiments will so fully reveal the invention according to the conceptual point of view, so that others, by applying current knowledge, will be able to modify and/or adapt in various applications the specific exemplary embodiments without further research and without parting from the invention, and, accordingly, it is meant that such adaptations and modifications will have to be considered as equivalent to the specific embodiments. The means and the materials to realise the different functions described herein could have a different nature without, for this reason, departing from the field of the invention. It is to be understood that the phraseology or terminology that is employed herein is for the purpose of description and not of limitation.

Claims

1. A prosthetic hand structure (100), said structure comprising:

- at least one mechanical finger (110a-110e) comprising:
    - a metacarpal support (111);
    - a proximal stiff link (112) connected to said metacarpal support (111) by a proximal cylindrical joint (113), said proximal stiff link (112) arranged to carry out a rotation of predetermined amplitude (φ) with respect to said metacarpal support (111) about an axis (113') of said proximal cylindrical joint (113);
    - a transmission member (116, 117) connected to said proximal stiff link (112), said transmission member (116, 117) arranged to actuate said proximal stiff link (112) in order to cause said rotation of predetermined amplitude (φ);
    - an actuator (118) arranged to operate said transmission member (116, 117);

said prosthetic hand structure (100) **characterized in that**
said transmission member (116, 117) comprises:

- a worm screw (116) having a thread profile, said worm screw (116) being integral to said proximal stiff link (112) and arranged to carry out a rotation about a longitudinal axis (116') of said worm screw (116);
- a flexible rack (117) having a first end portion (117a), which is pivotally connected to said metacarpal support (111), and a second end portion (117b), which is arranged to engage with said thread profile of said worm screw (116) at an engagement zone (P) of said flexible rack (117);

and in that said actuator (118) is mounted to said mechanical finger (110a-110e), said actuator arranged to actuate said worm screw (116), obtaining said rotation about said rotation axis (116'), in such a way that, when said actuator (118) moves said worm screw (116), a moving away/approaching movement of said engagement zone (P) is obtained from/to said first end portion (117a), causing said rotation of predetermined amplitude (φ), in a direction of rotation, or in the opposite direction of said proximal stiff link (112) about said axis (113') of said proximal cylindrical joint (113), said rotation of predetermined amplitude (φ) corresponding to the extension/flexion movement of the mechanical finger (110a-110e) .

2. Prosthetic hand structure (100), according to claim 1, wherein said worm screw (116) is adapted to carry out a rotation about a rotation axis (116'), said rotation axis (116') of said worm screw (116) arranged in a plane (n) substantially orthogonal to said axis (113') of said proximal cylindrical joint (113).

3. Prosthetic hand structure (100), according to any of the previous claims, wherein said, or each, mechanical finger (110a-110e) also comprises a distal stiff link (114) connected to said proximal stiff link (112) by a distal cylindrical joint (115), said distal stiff link (114) arranged for carrying out a rotation of predetermined amplitude (ω) with respect to said proximal stiff link (112) about an axis (115') of said distal cylindrical joint (115).

4. Prosthetic hand structure (100), according to claim 3, wherein said distal cylindrical joint (115) is underactuated by a mechanical reduction gear comprising a couple of gears or a belt that is wound/unwound in guiding grooves.

5. Prosthetic hand structure (100), according to claim 3, wherein said distal cylindrical joint (115) is rigidly connected to said proximal stiff link (112), in such a way that the mechanical finger is substantially a mono-phalangeous finger.

6. Prosthetic hand structure (100), according to claim 1, comprising:

- a plurality of mechanical fingers (110a-110e) comprising a mechanical finger for the thumb (110a);
- a metacarpal base (120) connected to said metacarpal support (111) of each mechanical finger (110a-110e) of said plurality, said metacarpal base (120) being connected to said mechanical finger for the thumb (110a) by a rotational joint (121) for a rotation about a longitudinal axis (121') of the rotational joint (121), in order to provide to said mechanical finger for the thumb (110a) an abduction/adduction degree of freedom.

7. Prosthetic hand structure (100), according to any of claims from 1 to 6, wherein at least one feedback position sensor (140) is further provided and associated with said, or each, mechanical finger (110a-110e), said feedback position sensor (140) configured to measure the position of said proximal stiff link (112) with respect to said metacarpal support (111), and then to determine in real time the amplitude (φ) of said rotation, said feedback position sensor (140) configured also to generate instantly a corresponding feedback signal and to transmit said feedback signal to a control unit (130), said control unit (130) configured to analyse said feedback signal and to operate said actuator (118) for actuating said worm screw (116) until said amplitude (φ) determined in real time meets a predetermined amplitude (φ).

8. Prosthetic hand structure (100), according to claim 7, wherein said feedback position sensor (140) is a Hall-effect sensor.

9. Prosthetic hand structure (100), according to any of claims from 1 to 8, wherein the following are further provided:

- at least one myoelectric sensor (150) arranged, in use, in contact with the stump of the patient, said or each myoelectric sensor (150) configured to measure a voltage associated with activation of an agonist and/or antagonist muscle of the stump of the patient and to generate a relative myoelectric signal;
- a plurality of force sensors (160) arranged, in use, in contact with the stump of the patient and distributed on a predetermined surface of the stump, said plurality of force sensors (160) configured to measure a plurality of pressure data corresponding to a predetermined muscle configuration achieved by the patient and to generate at least one corresponding pressure distribution signal on the stump;
- a control unit (130) configured to analyse said, or each, myoelectric signal and said, or each, pressure distribution signal and to carry out a selection of a predetermined working configuration among a plurality of possible predetermined working configurations, said control unit (130) arranged to operate said, or each, actuator (118), in such a way to obtain said selected working configuration.

10. Prosthetic hand structure (100), according to claim 9, wherein said control unit (130) is arranged to perform said selection among said plurality of possible predetermined working configurations by comparing said myoelectric signal and said pressure distribution signal generated by said sensors (150, 160) with a plurality of signals associated with predetermined working configurations.

11. Prosthetic hand structure (100), according to claim 10, wherein at least one inertial sensor (170, 171) is further provided selected from the group consisting of:

- an inertial sensor (170) configured to measure the spatial orientation of the prosthetic structure (100) with respect to a predetermined direction (x), to generate a corresponding spatial position signal, and to transmit said spatial position signal to said control unit (130);
- an inertial sensor (171, 172) configured to measure at least one linear and/or angular speed and/or acceleration of said prosthetic structure (100), to generate a corresponding kinematic signal, and to transmit said kinematic signal to said control unit (130);
- a combination thereof;

said control unit (130) arranged, in this case, to carry out said selection of possible working configurations also on the basis of said spatial position signal and/or said kinematic signal.

12. Prosthetic hand structure (100), according to claim 9 or 11, wherein the following are further provided:

- a first inertial sensor (171) configured to measure at least one linear and/or angular speed and/or acceleration, of said prosthetic structure (100), to generate a corresponding kinematic signal, and to transmit said kinematic signal to said control unit (130);
- a second inertial sensor (172), which is located on the forearm, if said first inertial sensor (171) is located on the hand, or on the hand if said first inertial sensor (171) is located on the forearm, said second inertial sensor (172) arranged for:
    - measuring at least one linear and/or angular speed and/or acceleration, respectively, of the forearm or the hand;
    - generating a corresponding reference spatial position signal, and
    - transmitting said reference spatial position signal to said control unit (130);

said control unit (130) arranged to compare said spatial position signal with said reference position signal, obtaining a value of relative position between hand and forearm, said control unit (130) for carrying out said selection of possible gripping configurations also on the basis of said relative position value between hand and forearm.

13. Prosthetic hand structure (100), according to claims 6 and 9, wherein at least one position sensor for the thumb (141) is further provided, configured to measure the direction of the mechanical finger for the thumb (110a) with respect to said metacarpal base (120), to generate a corresponding thumb position signal, and to transmit said thumb position signal to said control unit (130), said control unit (130) arranged, in this case, to carry out said selection of possible gripping configurations also on the basis of said thumb position signal.

14. Prosthetic hand structure (100), according to claim 13, wherein said position sensor for the thumb (141) is a Hall-effect sensor.

15. Prosthetic hand structure (100), according to any one of claims 1, 7 or 9, where a source of electric current is also provided and arranged to provide electric energy for feeding said sensors and/or said actuator.

Patentansprüche

1. Handprothesenstruktur (100), wobei die Struktur Folgendes umfasst:

- mindestens einen mechanischen Finger (110a-110e) umfassend:
    - eine Mittelhandstütze (111);
    - ein proximales steifes Verbindungsglied (112), das mit der Mittelhandstütze (111) durch ein proximales zylindrisches Gelenk (113) verbunden ist, wobei das proximale steife Verbindungsglied (112) ausgelegt ist, um eine Rotation von vorbestimmter Amplitude (φ) in Bezug auf die Mittelhandstütze (111) um eine Achse (113') des proximalen zylindrischen Gelenks (113) durchzuführen;

ein Übertragungselement (116, 117), das mit dem proximalen steifen Verbindungsglied (112) verbunden ist, wobei das Übertragungs element (116, 117) ausgelegt ist, um das proximale steife Verbindungsglied (112) anzutreiben, um die Rotation von vorbestimmter Amplitude (φ) herbeizuführen;
ein Stellorgan (118), das ausgelegt ist, um das Übertragungselement (116, 117) zu betreiben;
wobei die Handprothesenstruktur (100) **dadurch gekennzeichnet ist, dass** das Übertragungselement (116, 117) Folgendes umfasst:

eine Schneckenschraube (116) aufweisend ein Gewindeprofil, wobei die Schneckenschraube (116) einstückig mit dem proximalen steifen Verbindungsglied (112) ausgebildet ist und ausgelegt ist, um eine Rotation um eine Längsachse (116') der Schneckenschraube (116) durchzuführen;
eine flexible Zahnstange (117) aufweisend einen ersten Endabschnitt (117a), welches schwenkbar mit der Mittelhandstütze (111) verbunden ist, und einen zweiten Endabschnitt (117b), welches ausgelegt ist, um mit dem Gewindeprofil der Schneckenschraube (116) an einem Eingriffsbereich (P) der flexiblen Zahnstange (117) in Eingriff zu stehen;
und dass das Stellorgan (118) am mechanischen Finger (110a-110e) montiert ist, wobei das Stellorgan ausgelegt ist, um die Schraubenschnecke (116) anzutreiben, wobei die Rotation um die Rotationsachse (116') so erreicht wird, dass, wenn das Stellorgan (118) die Schneckenschraube (116) bewegt, eine Auseinander-/Annäherungsbewegung des Eingriffsbereichs (P) von/zu dem ersten Endabschnitt (117a) erreicht wird, wobei die Rotation von vorbestimmter Amplitude (φ), in einer Rotationsrichtung,

oder in der entgegengesetzten Richtung des proximalen steifen Verbindungsglieds (112) um die Achse (113') des proximalen zylindrischen Gelenks (113) herbeigeführt wird, wobei die Rotation von vorbestimmter Amplitude (φ) der Extensions-/Flexions-Bewegung des mechanischen Fingers (110a-110e) entspricht.

2. Handprothesenstruktur (100) nach Anspruch 1, wobei die Schneckenschraube (116) angepasst ist, um eine Rotation um eine Rotationsachse (116') durchzuführen, wobei die Rotationsachse (116') der Schneckenschraube (116) in einer Ebene (π) angeordnet ist, die im Wesentlichen rechtwinklig zur Achse (113') des proximalen zylindrischen Gelenks (113) ist.

3. Handprothesenstruktur (100) nach einem der vorhergehenden Ansprüche, wobei der oder jeder mechanische Finger (110a-110e) auch ein distales steifes Verbindungsglied (114) umfasst, das mit dem proximalen steifen Verbindungsglied (112) durch ein distales zylindrisches Gelenk (115) verbunden ist, wobei das distale steife Verbindungsglied (114) ausgelegt ist, um eine Rotation von vorbestimmter Amplitude (ω) in Bezug auf das proximale steife Verbindungsglied (112) um eine Achse (115') des distalen zylindrischen Gelenks (115) durchzuführen.

4. Handprothesenstruktur (100) nach Anspruch 3, wobei das distale zylindrische Gelenk (115) durch ein mechanisches Untersetzungsgetriebe umfassend ein paar Zahnräder oder einen Riemen, der in Führungsrillen aufgewickelt/abgewickelt wird, unteraktuiert wird.

5. Handprothesenstruktur (100) nach Anspruch 3, wobei das distale zylindrische Gelenk (115) mit dem proximalen steifen Verbindungsglied (112) so starrverbunden ist, dass der mechanische Finger im Wesentlichen ein einzelgliedriger Finger ist.

6. Handprothesenstruktur (100) nach Anspruch 1, umfassend:

eine Vielzahl mechanischer Finger (110a-110e) umfassend einen mechanischen Finger für den Daumen (110a);
eine Mittelhandbasis (120), die mit der Mittelhandstütze (111) von jedem mechanischen Finger (110a-110e) der Vielzahl verbunden ist, wobei die Mittelhandbasis (120) mit dem mechanischen Finger für den Daumen (110a) durch ein Drehgelenk (121) für eine Rotation um eine Längsachse (121') des Drehgelenks (121) verbunden ist, um den mechanischen Finger für den Daumen (110a) mit einem Abduktions-/Adduktions-Freiheitsgrad zu versehen.

7. Handprothesenstruktur (100) nach einem der Ansprüche von 1 bis 6, wobei mindestens ein Rückmeldungspositionssensor (140) ferner bereitgestellt und dem oder jedem mechanischen Finger (110a-110e) zugeordnet ist, wobei der Rückmeldungspositionssensor (140) gestaltet ist, um die Position des proximalen steifen Verbindungsglieds (112) in Bezug zur Mittelhandstütze (111) zu messen und danach in Echtzeit die Amplitude (φ) der Rotation zu ermitteln, wobei der Rückmeldungspositionssensor (140) auch gestaltet ist, um augenblicklich ein entsprechende Rückmeldungssignal zu erzeugen und das Rückmeldungssignal an eine Steuereinheit (130) zu übertragen, wobei die Steuereinheit (130) gestaltet ist, um das Rückmeldungssignal zu analysieren und das Stellorgan (118) zu betreiben, um die Schneckenschraube (116) laufen zu lassen bis die in Echtzeit ermittelte Amplitude (φ) der vorbestimmten Amplitude (φ) entspricht.

8. Handprothesenstruktur (100) nach Anspruch 7, wobei der Rückmeldungspositionssensor (140) ein Hall-Effekt-Sensor ist.

9. Handprothesenstruktur (100) nach einem der Ansprüche von 1 bis 8, wobei Folgendes ferner bereitgestellt ist:

mindestens einen myoelektrischen Sensor (150), der, bei Benutzung, in Berührung mit dem Stumpf des Patienten angeordnet ist, wobei der oder jeder myoelektrische Sensor (150) gestaltet ist, um eine mit Aktivierung eines agonistischen und/oder antagonistischen Muskels des Stumpfes des Patienten verbundene Spannung zu messen und ein relatives myoelektrisches Signal zu erzeugen;
eine Vielzahl von Kraftsensoren (160), die, bei Benutzung, in Berührung mit dem Stumpf des Patienten angeordnet sind und auf einer vorbestimmten Oberfläche des Stumpfes verteilt sind, wobei die Vielzahl von Kraftsensoren (160) gestaltet sind, um eine Vielzahl von Druckdaten zu messen, die einer vorbestimmten vom Patienten erzielten Muskelkonfiguration entsprechen, und um mindestens ein entsprechendes Druckverteilungssignal am Stumpf zu erzeugen;
eine Steuereinheit (130), die gestaltet ist, um das oder jedes myoelektrische Signal und das oder jedes Druckverteilungssignal zu analysieren und um eine Auswahl einer vorbestimmten Arbeitskonfiguration unter einer Vielzahl von möglichen vorbestimmten Arbeitskonfigurationen durchzuführen, wobei die Steuereinheit (130) ausgelegt ist, um das oder jedes Stellor-

gan (118) so zu betreiben, dass die ausgewählte Arbeitskonfiguration erreicht wird.

10. Handprothesenstruktur (100) nach Anspruch 9, wobei die Steuereinheit (130) ausgelegt ist, um die Auswahl unter der Vielzahl von möglichen vorbestimmten Arbeitskonfigurationen durch Vergleich des myoelektrischen Signals und des Druckverteilungssignals, die von den Sensoren (150,160) erzeugt werden, mit einer Vielzahl von mit vorbestimmten Arbeitskonfigurationen verbundenen Signalen auszuführen.

11. Handprothesenstruktur (100) nach Anspruch 10, wobei mindestens ein Trägheitssensor (170, 171) ferner bereitgestellt ist, ausgewählt aus der Gruppe bestehend aus:

einem Trägheitssensor (170), der gestaltet ist, um die räumliche Orientierung der Prothesenstruktur (100) in Bezug auf eine vorbestimmte Richtung (x) zu messen, um ein entsprechendes Raumpositionssignal zu erzeugen, und um das Raumpositionssignal an die Steuereinheit (130) zu übertragen;
einem Trägheitssensor (171,172) der gestaltet ist, um mindestens eine Linear- und/oder Winkelgeschwindigkeit und/oder Beschleunigung der Prothesenstruktur (100) zu messen, um ein entsprechendes kinematisches Signal zu erzeugen, und um das kinematische Signal an die Steuereinheit (130) zu übertragen;
einer Kombination davon,
wobei die Steuereinheit (130) in diesem Fall ausgelegt ist, um die Auswahl von möglichen Arbeitskombinationen auch auf der Basis des Raumpositionssignals und/oder des kinematischen Signals durchzuführen.

12. Handprothesenstruktur (100) nach Anspruch 9 oder 11, wobei Folgendes ferner bereitgestellt ist:

ein erster Trägheitssensor (171) der gestaltet ist, um mindestens eine Linear- und/oder Winkelgeschwindigkeit und/oder Beschleunigung der Prothesenstruktur (100) zu messen, um ein entsprechendes kinematisches Signal zu erzeugen, und um das kinematische Signal an die Steuereinheit (130) zu übertragen;
ein zweiter Trägheitssensor (172), welcher sich am Unterarm, wenn sich der erste Trägheitssensor (171) an der Hand befindet, oder sich an der Hand, wenn sich der erste Trägheitssensor (171) am Unterarm befindet, befindet, wobei der zweite Trägheitssensor (172) ausgelegt ist, um:

- mindestens eine Linear- bzw./oder Winkelgeschwindigkeit bzw./oder Beschleunigung des Unterarms oder der Hand zu messen;
- ein entsprechendes Referenz-Raumpositionssignal zu erzeugen und
- das Referenz-Raumpositionssignal an die Steuereinheit (130) zu übertragen;

wobei die Steuereinheit (130) ausgelegt ist, um das Raumpositionssignal mit dem Referenzpositionssignal zu vergleichen, wobei ein Wert relativer Position zwischen Hand und Unterarm erhalten wird, wobei die Steuereinheit (130) gestaltet ist, um die Auswahl von möglichen Greifkonfigurationen auch auf der Basis des relativen Positionswertes zwischen Hand und Unterarm durchzuführen.

13. Handprothesenstruktur (100) nach Anspruch 6 und 9, wobei mindestens ein Positionssensor für den Daumen (141) ferner bereitgestellt ist, der gestaltet ist, um die Richtung des mechanischen Fingers für den Daumen (110a) in Bezug auf die Mittelhandbasis (120) zu messen, um ein entsprechendes Daumenpositionssignal zu erzeugen, und um das Daumenpositionssignal an die Steuereinheit (130) zu übertragen, wobei die Steuereinheit (130) in diesem Fall ausgelegt ist, um die Auswahl von möglichen Greifkonfigurationen auch auf der Basis des Daumenpositionssignals durchzuführen.

14. Handprothesenstruktur (100) nach Anspruch 13, wobei der Positionssensor für den Daumen (141) ein Hall-Effekt-Sensor ist.

15. Handprothesenstruktur (100) nach einem der Ansprüche 1, 7 oder 9, in der eine Quelle elektrischen Stroms auch bereitgestellt und ausgelegt ist, um elektrische Energie zum Speisen der Sensoren und/oder des Stellorgans bereitzustellen.

Revendications

1. Structure de main prothétique (100), ladite structure comprenant :

- au moins un doigt mécanique (110a à 110e)

comprenant :

- un support métacarpien (111) ;
- un élément de liaison rigide proximal (112) relié audit support métacarpien (111) par une articulation cylindrique proximale (113), ledit élément de liaison rigide proximal (112) étant agencé pour effectuer une rotation d'amplitude prédéfinie (φ) par rapport audit support métacarpien (111) autour d'un axe (113') de ladite articulation

cylindrique proximale (113) ;

- un élément de transmission (116, 117) relié audit élément de liaison rigide proximal (112), ledit élément de transmission (116, 117) étant agencé pour actionner ledit élément de liaison rigide proximal (112) afin de provoquer ladite rotation d'amplitude prédéfinie (φ) ;
- un actionneur (118) agencé pour actionner ledit élément de transmission (116, 117) ; ladite structure de main prothétique (100) étant **caractérisée en ce que** ledit élément de transmission (116, 117) comprend :
- une vis sans fin (116) possédant un profil de filetage, ladite vis sans fin (116) étant partie intégrante dudit élément de liaison rigide proximal (112) et agencée pour effectuer une rotation autour d'un axe longitudinal (116') de ladite vis sans fin (116) ;
- une crémaillère souple (117) possédant une première partie d'extrémité (117a), qui est reliée pivotante audit support métacarpien (111), et une seconde partie d'extrémité (117b), qui est agencée pour venir en prise avec ledit profil de filetage de ladite vis sans fin (116) au niveau d'une zone d'engrènement (P) de ladite crémaillère souple (117) ;

et **en ce que** ledit actionneur (118) est monté sur ledit doigt mécanique (110a à 110e), ledit actionneur étant agencé pour actionner ladite vis sans fin (116), de manière à le faire tourner autour de l'axe de rotation (116'), d'une façon telle que lorsque ledit actionneur (118) déplace ladite vis sans fin (116), ladite zone d'engrènement (P) s'éloigne ou se rapproche de ladite première partie d'extrémité (117a) entraînant ladite rotation d'amplitude prédéfinie (φ), dans le sens de rotation, ou dans le sens opposé, dudit élément de liaison rigide proximal (112) autour dudit axe (113') de ladite articulation cylindrique proximale (113), ladite rotation d'amplitude prédéfinie (φ) correspondant au mouvement d'extension/de flexion du doigt mécanique (110a à 110e).

2. Structure de main prothétique (100) selon la revendication 1, ladite vis sans fin (116) étant conçue pour tourner autour d'un axe de rotation (116'), ledit axe de rotation (116') de ladite vis sans fin (116) étant agencé dans un plan (Π) sensiblement orthogonal audit axe (113') de ladite articulation cylindrique proximale (113).

3. Structure de main prothétique (100) selon l'une quelconque des revendications précédentes, ledit ou chaque doigt mécanique (110a à 110e) comprenant également un élément de liaison rigide distal (114) relié à l'élément de liaison rigide proximal (112) par une articulation cylindrique distale (115), ledit élément de liaison rigide distal (114) étant agencé pour effectuer une rotation d'amplitude prédéfinie (ω) par rapport à l'élément de liaison rigide proximal (112) autour d'un axe (115') de ladite articulation cylindrique distale (115).

4. Structure de main prothétique (100) selon la revendication 3, ladite articulation cylindrique distale (115) étant sous-actionnée par un réducteur mécanique comprenant une paire d'engrenages ou une courroie qui est enroulée/déroulée dans des rainures de guidage.

5. Structure de main prothétique (100) selon la revendication 3, ladite articulation cylindrique distale (115) est reliée rigidement audit élément de liaison rigide proximal (112), d'une façon telle que le doigt mécanique est sensiblement un doigt à une phalange.

6. Structure de main prothétique (100) selon la revendication 1, comprenant :

- une pluralité de doigts mécaniques (110a à 110e) comprenant un doigt mécanique pour le pouce (110a) ;
- une base métacarpienne (120) reliée audit support métacarpien (111) de chaque doigt mécanique (110a à 110e) de ladite pluralité, ladite base métacarpienne (120) étant reliée audit doigt mécanique pour le pouce (110a) par une articulation rotative (121) pour une rotation autour d'un axe longitudinal (121') de l'articulation rotative (121) afin de conférer audit doigt mécanique pour le pouce (110a) un degré de liberté d'abduction/adduction.

7. Structure de main prothétique (100) selon l'une quelconque des revendications 1 à 6, au moins un capteur de position à rétroaction (140) étant fourni en plus et associé audit, ou à chaque, doigt mécanique (110a à 110e), ledit capteur de position à rétroaction (140) étant conçu pour mesurer la position dudit élément de liaison rigide proximal (112) par rapport audit support métacarpien (111), et pour ensuite déterminer en temps réel l'amplitude (φ) de ladite rotation, ledit capteur de position à rétroaction (140) étant conçu également pour générer instantanément un signal de rétroaction correspondant et pour transmettre ledit signal de rétroaction à une unité de commande (130), ladite unité de commande (130) étant conçue pour analyser ledit signal de rétroaction et actionner ledit actionneur (118) permettant d'actionner ladite vis sans fin (116) jusqu'à ce que ladite amplitude (φ) déterminée en temps réel corresponde à une amplitude prédéfinie (φ).

8. Structure de main prothétique (100) selon la revendication 7, ledit capteur de position à rétroaction (140) étant un capteur à effet Hall.

9. Structure de main prothétique (100) selon l'une quelconque des revendications 1 à 8, les éléments suivants étant également fournis :

- au moins un capteur myoélectrique (150) agencé, lors de l'utilisation, de manière à être en contact avec le moignon du patient, ledit ou chaque capteur myoélectrique (150) étant conçu pour mesurer une tension associée à l'activation d'un muscle agoniste et/ou antagoniste du moignon du patient et pour générer un signal myoélectrique relatif ;
- une pluralité de capteurs de force (160) agencés, lors de l'utilisation, de manière à être en contact avec le moignon du patient et répartis sur une surface prédéfinie du moignon, ladite pluralité de capteurs de force (160) étant conçue pour mesurer une pluralité de données de pression correspondant à une configuration du muscle prédéfinie atteinte par le patient et pour générer au moins un signal de distribution de pression correspondant sur le moignon ;
- une unité de commande (130) conçue pour analyser ledit, ou chaque, signal myoélectrique et ledit, ou chaque, signal de distribution de pression et pour sélectionner une configuration de travail prédéfinie parmi une pluralité de configurations de travail prédéfinies possibles, ladite unité de commande (130) étant agencée pour actionner ledit, ou chaque, actionneur (118), de manière à obtenir ladite configuration de travail sélectionnée.

10. Structure de main prothétique (100) selon la revendication 9,
ladite unité de commande (130) étant agencée pour réaliser ladite sélection parmi ladite pluralité de configurations de travail prédéfinies possibles en comparant ledit signal myoélectrique et ledit signal de distribution de pression générée par lesdits capteurs (150, 160) avec une pluralité de signaux associés à des configurations de travail prédéfinies.

11. Structure de main prothétique (100) selon la revendication 10, au moins un capteur inertiel (170, 171) étant fourni également, choisi dans le groupe constitué par :

- un capteur inertiel (170) conçu pour mesurer l'orientation spatiale de la structure prothétique (100) par rapport à une direction prédéfinie (x), pour générer un signal de position spatiale correspondant et pour transmettre ledit signal de position spatiale à ladite unité de commande (130) ;
- un capteur inertiel (171, 172) conçu pour mesurer au moins une accélération et/ou une vitesse linéaire et/ou angulaire de ladite structure prothétique (100), pour générer un signal cinématique correspondant et pour transmettre ledit signal cinématique à ladite unité de commande (130) ;
- une combinaison de ceux-ci ;

ladite unité de commande (130) étant agencée, dans ce cas, pour réaliser ladite sélection des configurations de travail possibles sur la base également dudit signal de position spatiale et/ou dudit signal cinématique.

12. Structure de main prothétique (100) selon la revendication 9 ou 11, les éléments suivants étant également fournis :

- un premier capteur inertiel (171) conçu pour mesurer au moins une accélération et/ou une vitesse linéaire et/ou angulaire de ladite structure prothétique (100) pour générer un signal cinématique correspondant et pour transmettre ledit signal cinématique à ladite unité de commande (130) ;
- un second capteur inertiel (172) situé sur l'avant-bras, si ledit premier capteur inertiel (171) se situe sur la main, ou sur la main si ledit premier capteur inertiel (171) se situe sur l'avant-bras, ledit second capteur inertiel (172) étant agencé pour :
    - mesurer au moins une accélération et/ou une vitesse linéaire et/ou angulaire, respectivement, de l'avant-bras ou de la main ;
    - générer un signal de position spatiale de référence correspondant, et
    - transmettre ledit signal de position spatiale de référence à ladite unité de commande (130) ; ladite unité de commande (130) étant agencée pour comparer ledit signal de position spatiale avec ledit signal de position de référence, obtenant une valeur de position relative entre la main et l'avant-bras, ladite unité de commande (130) permettant d'effectuer ladite sélection de configurations de préhension possibles sur la base également de ladite valeur de position relative entre la main et l'avant-bras.

13. Structure de main prothétique (100), selon les revendications 6 et 9, au moins un capteur de position pour le pouce (141) étant fourni également, conçu pour mesurer la direction du doigt mécanique pour le pouce (110a) par rapport à ladite base métacarpienne (120), pour générer un signal de position de pouce correspondant, et pour transmettre ledit signal de position de pouce à ladite unité de commande (130), ladite unité de commande (130) étant agencée, dans ce cas, pour réaliser ladite sélection de configurations de préhension possibles sur la base également dudit signal de position de pouce.

14. Structure de main prothétique (100) selon la revendication 13, ledit capteur de position pour le pouce (141) étant un capteur à effet Hall.

15. Structure de main prothétique (100) selon l'une quelconque des revendications 1, 7 ou 9, une source de courant électrique étant également fournie et agencée pour fournir de l'énergie électrique permettant l'alimentation desdits capteurs et/ou dudit actionneur.

Fig. 1

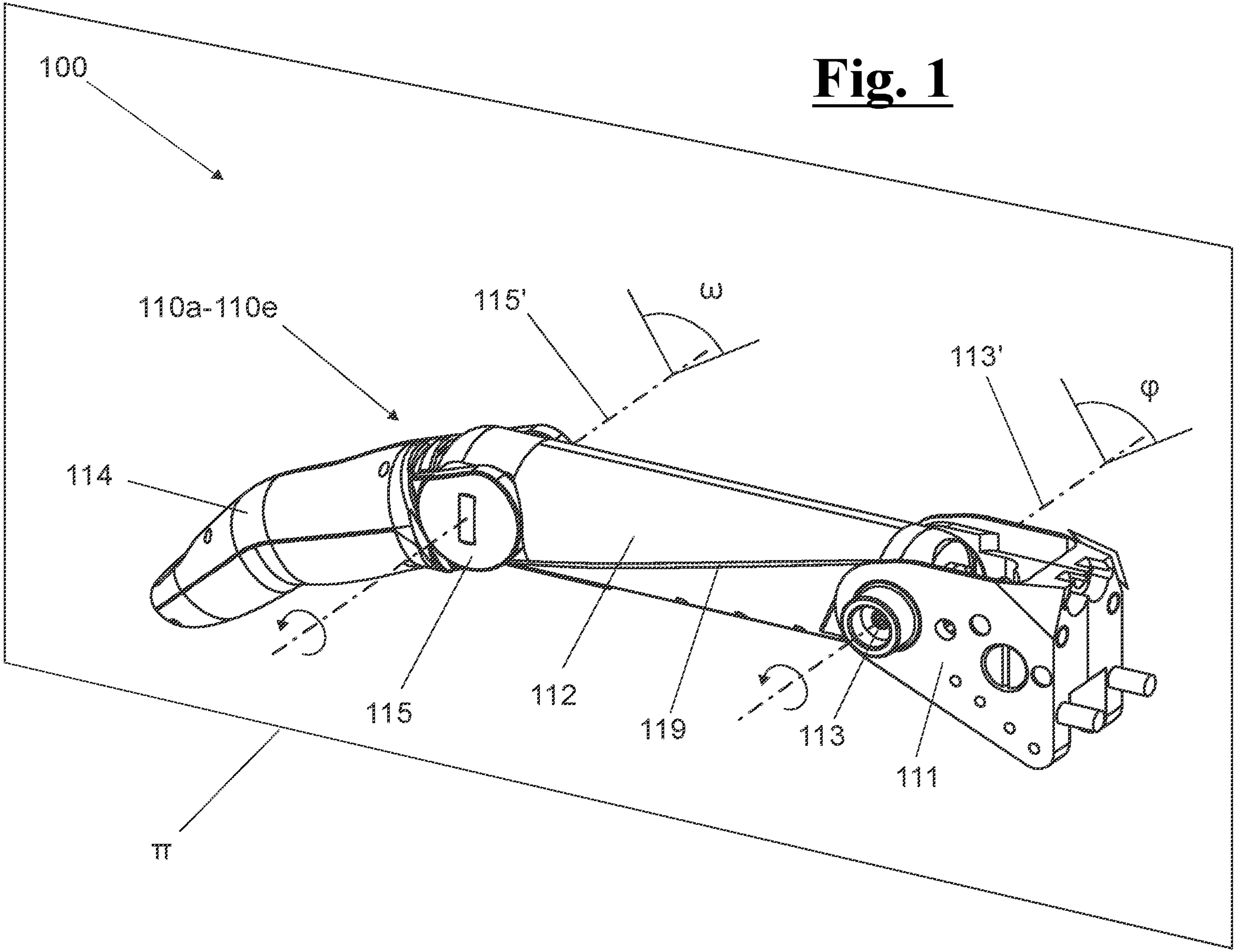


Fig. 2

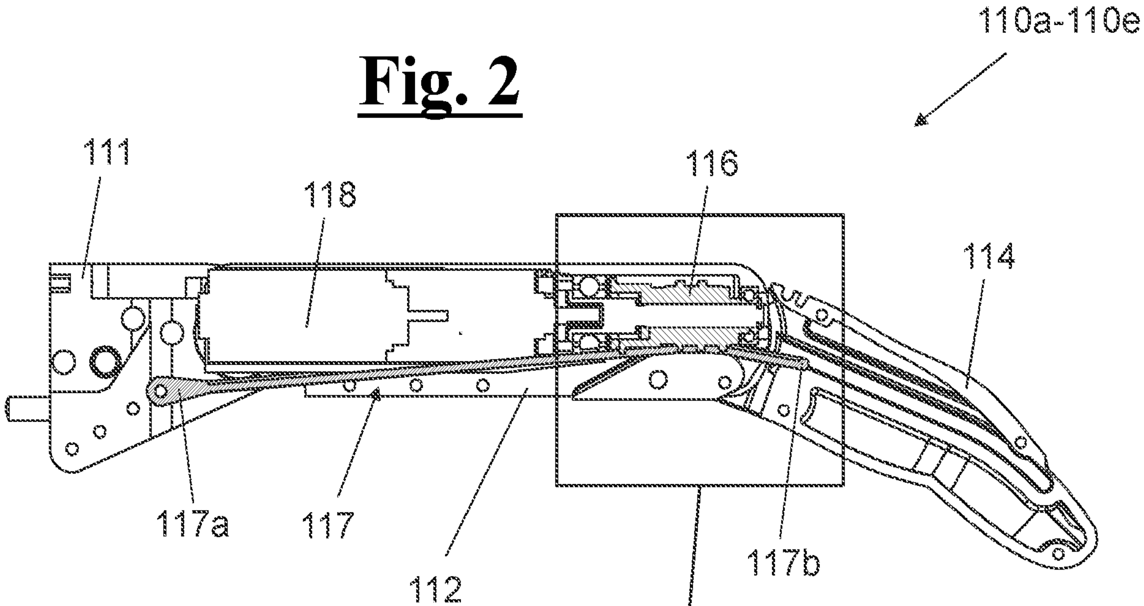


Fig. 2A

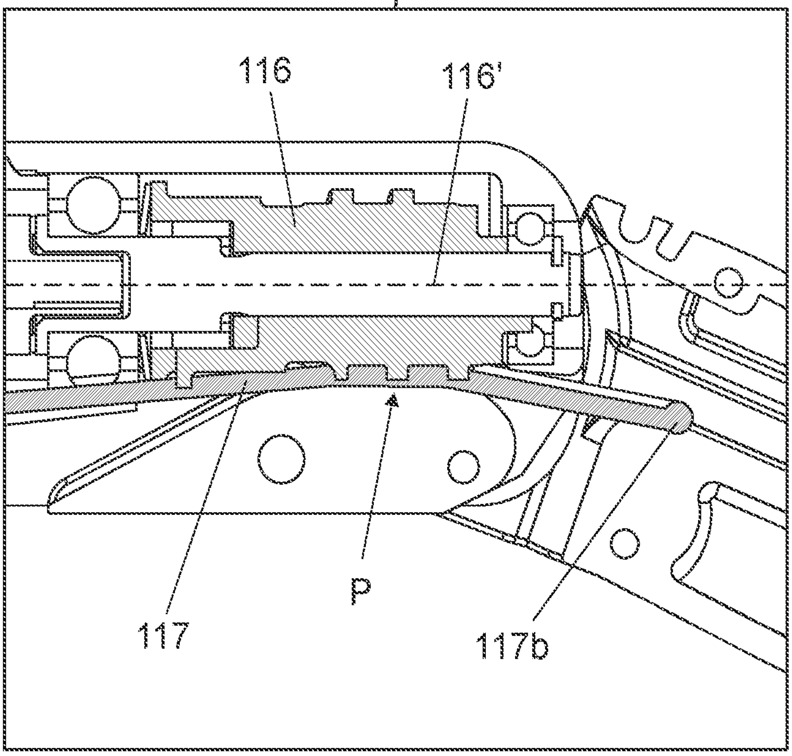


Fig. 3A

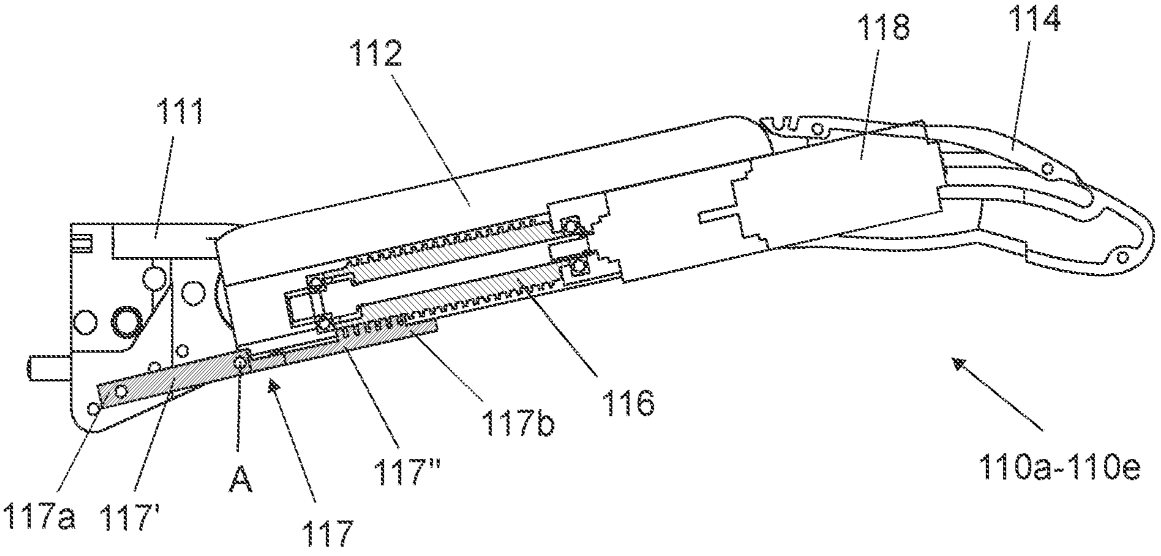
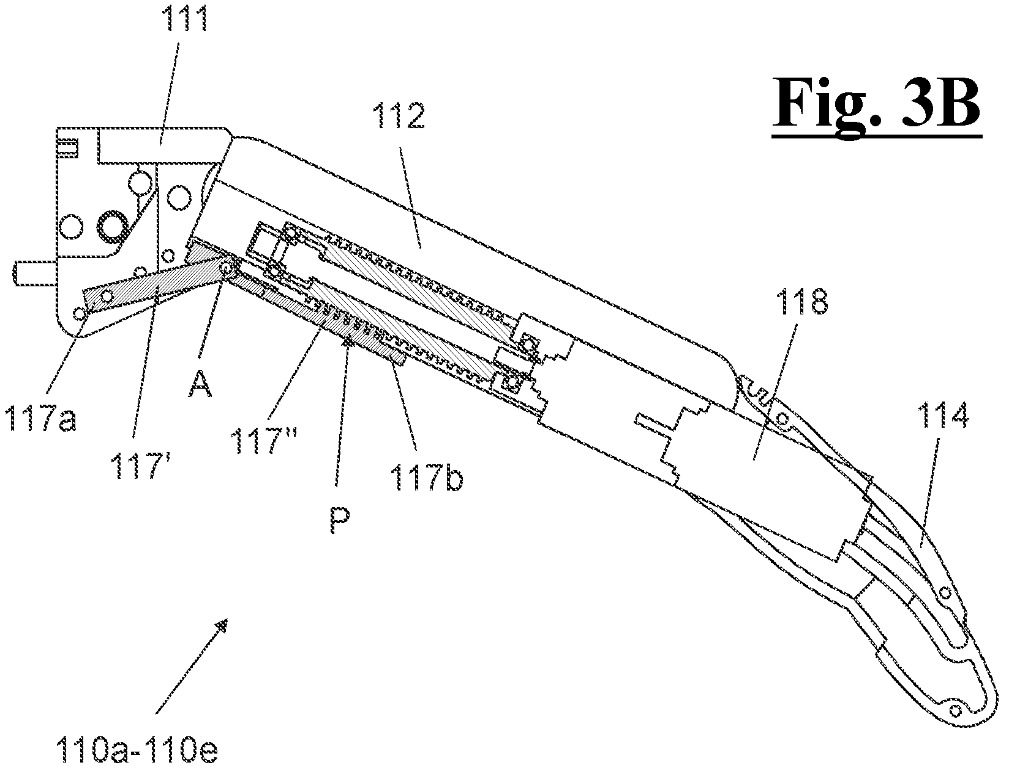

112
111
118
114
116
117b
117''
A
117
117a
117'
110a-110e

Fig. 3B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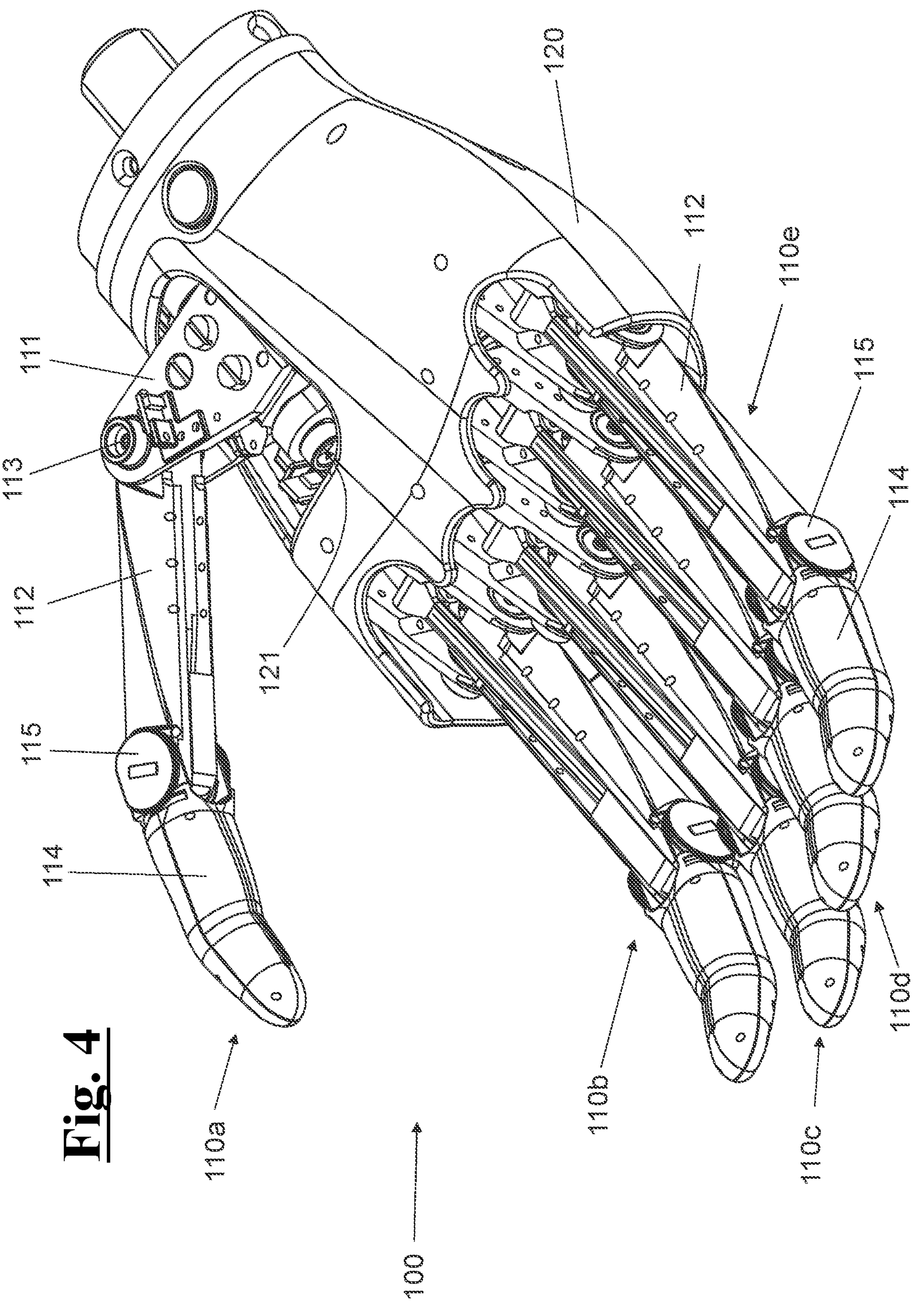
118
114
117a
A
117'
117''
117b
P
110a-110e


111
113
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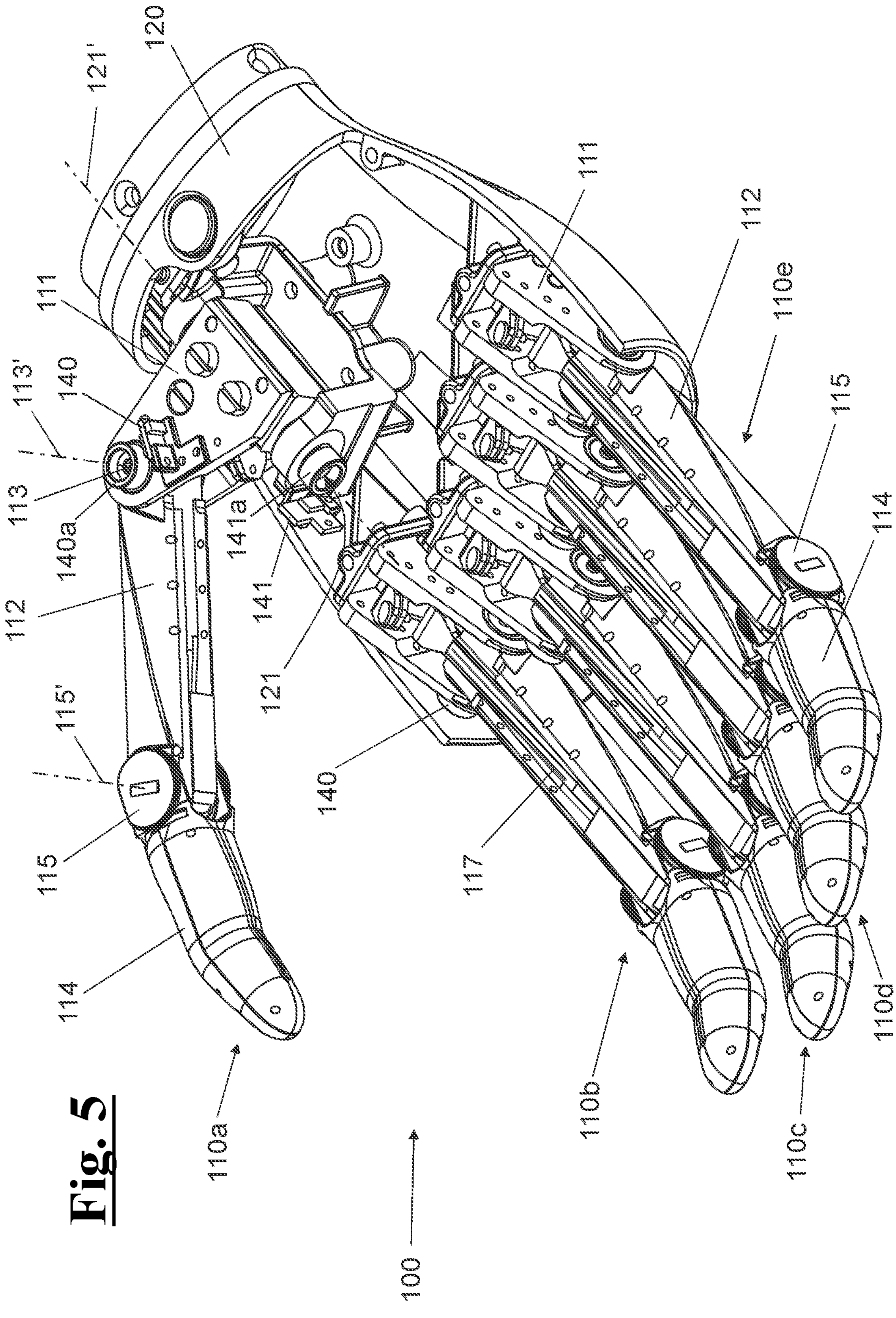
115
114
121
120
112
112
110e
115
114
110a
100
110b
110c
110d

Fig. 4


120
121'
111
140
113'
113
140a
141a
141
112
121
115'
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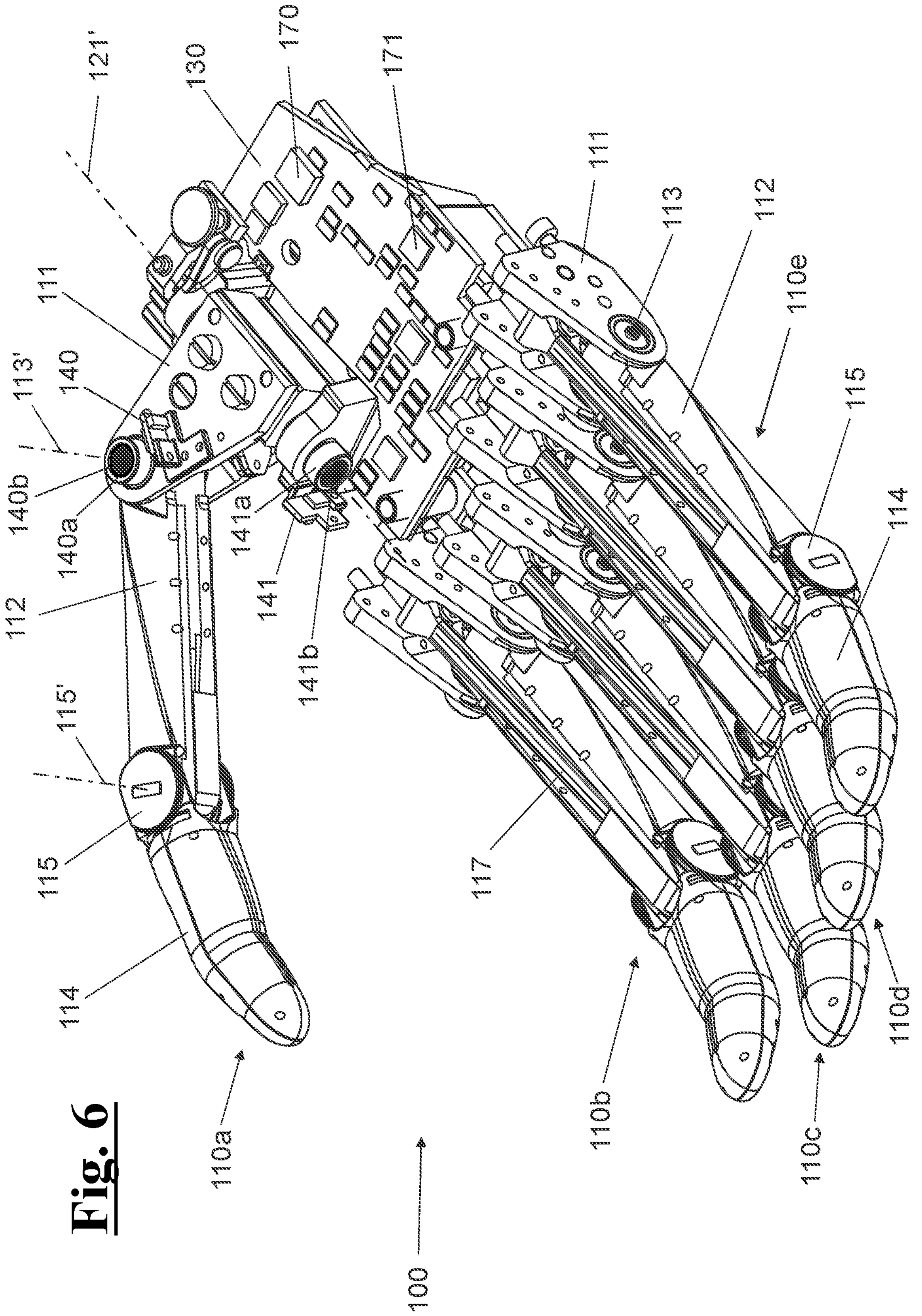
114
140
117
111
112
110e
115
114
110a
100
110b
110c
110d

Fig. 5


121'
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171
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114
113'
140
140b
140a
141a
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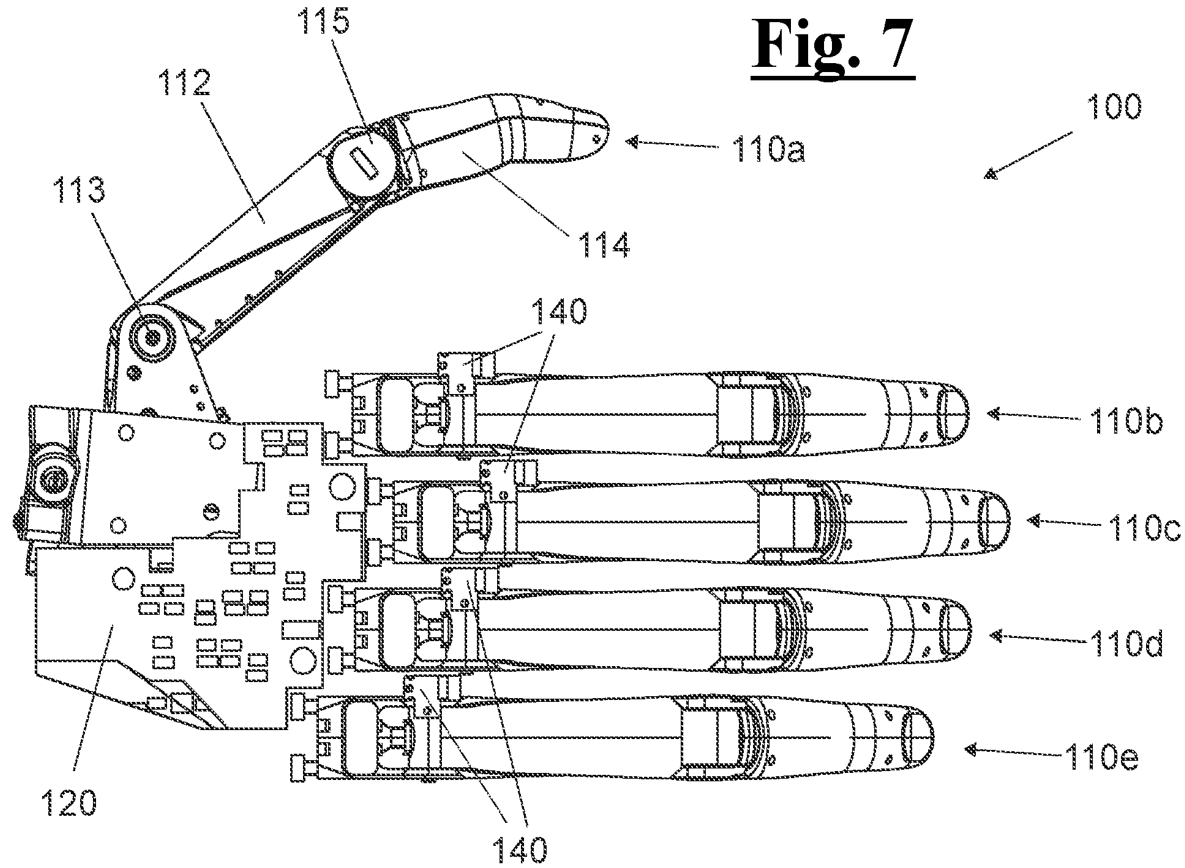
141b
112
115'
115
114
110a
117
110b
110c
110d
100

Fig. 6

Fig. 7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110a
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110b
110c
110d
110e
120
140

Fig. 8

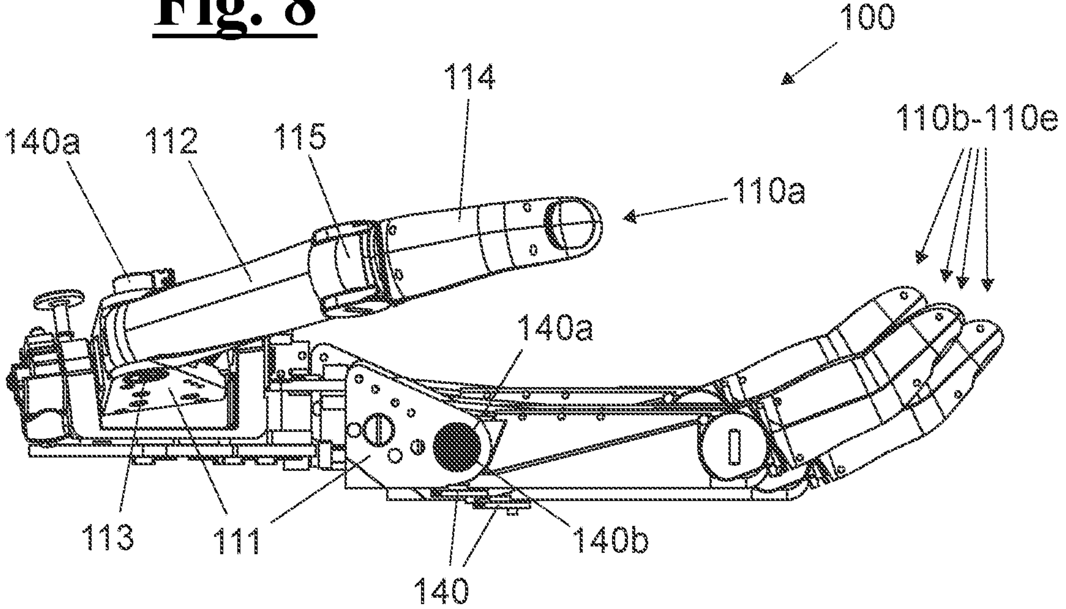
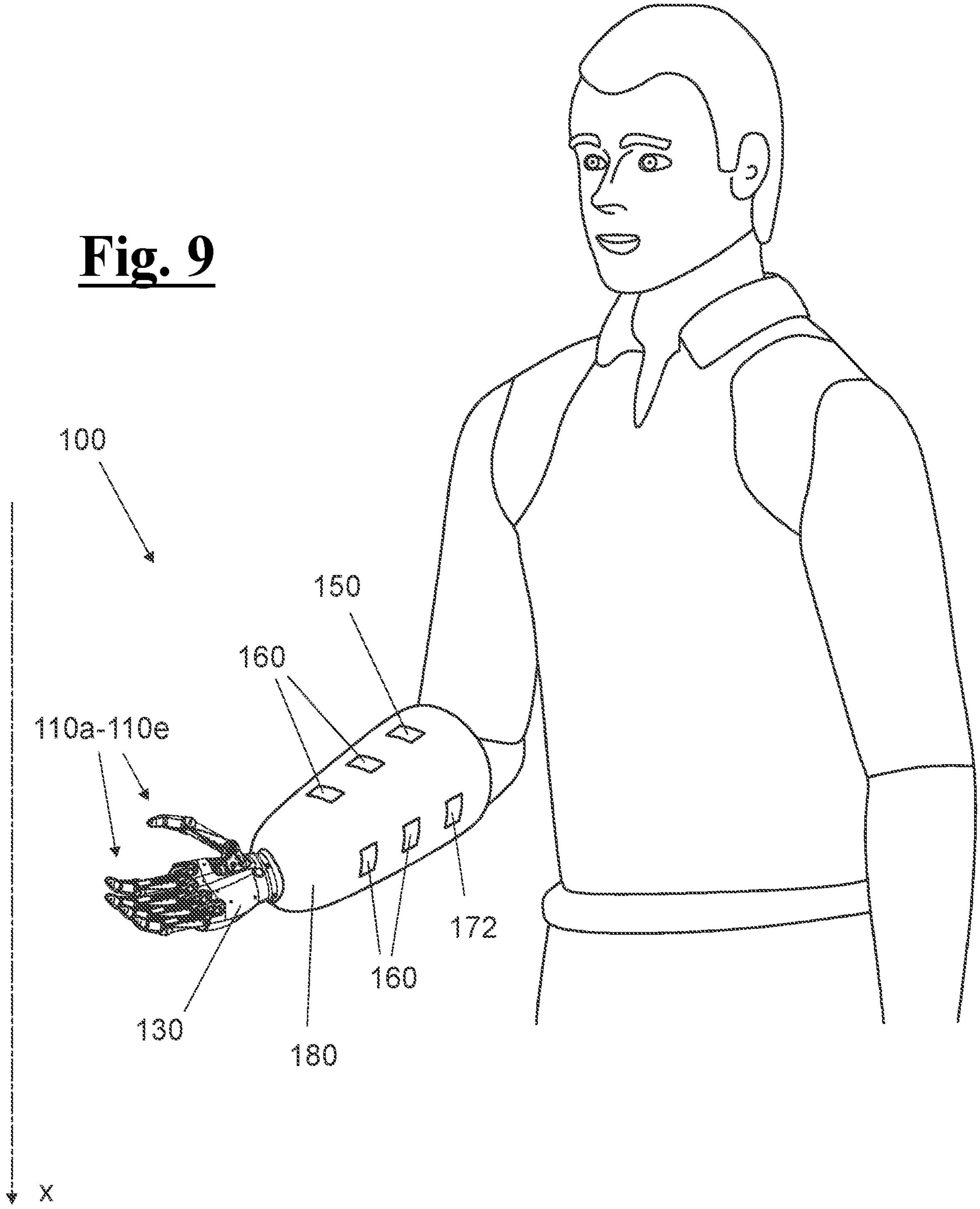
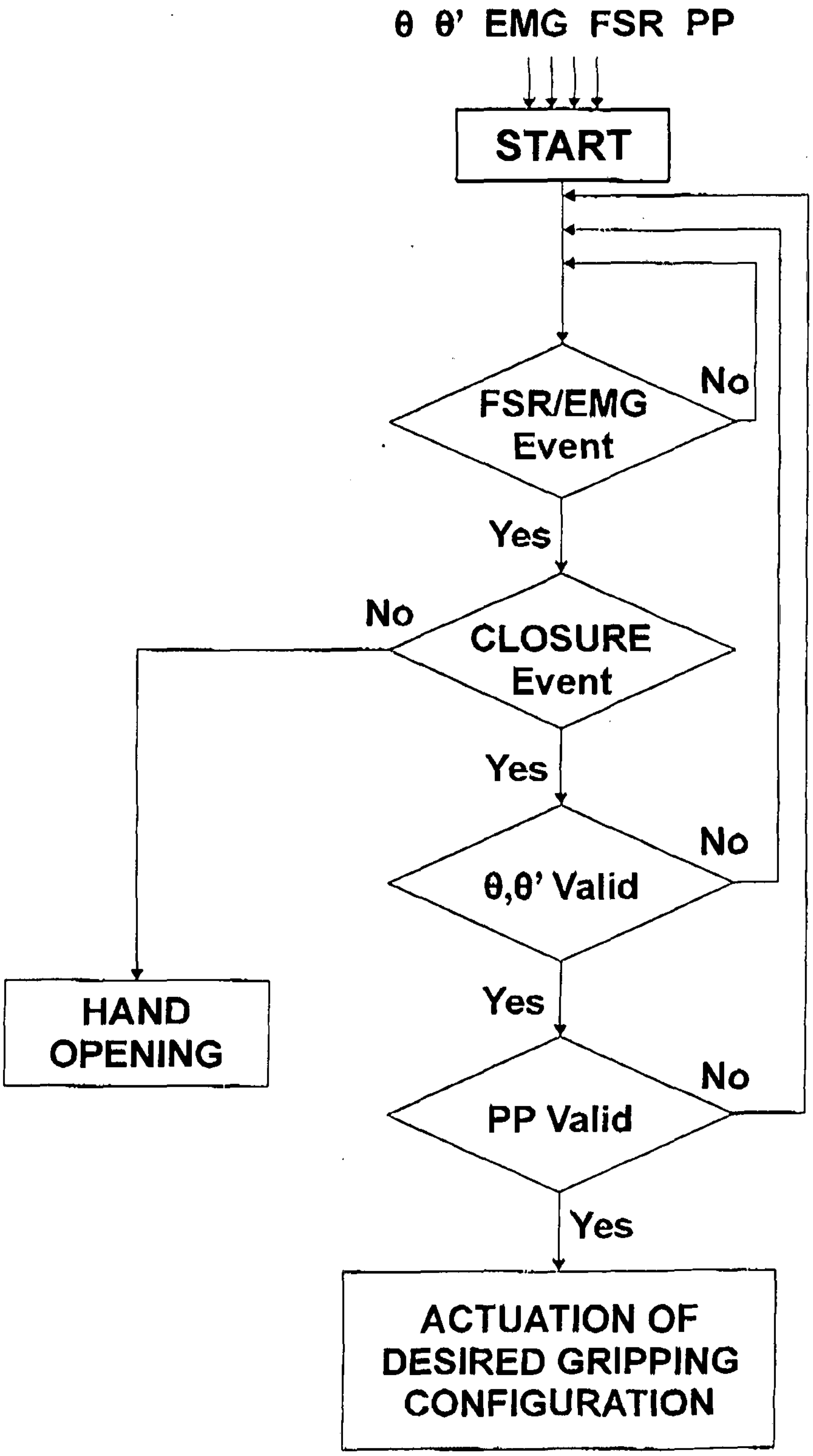

100
114
140a
112
115
110b-110e
110a
140a
113
111
140b
140

Fig. 9

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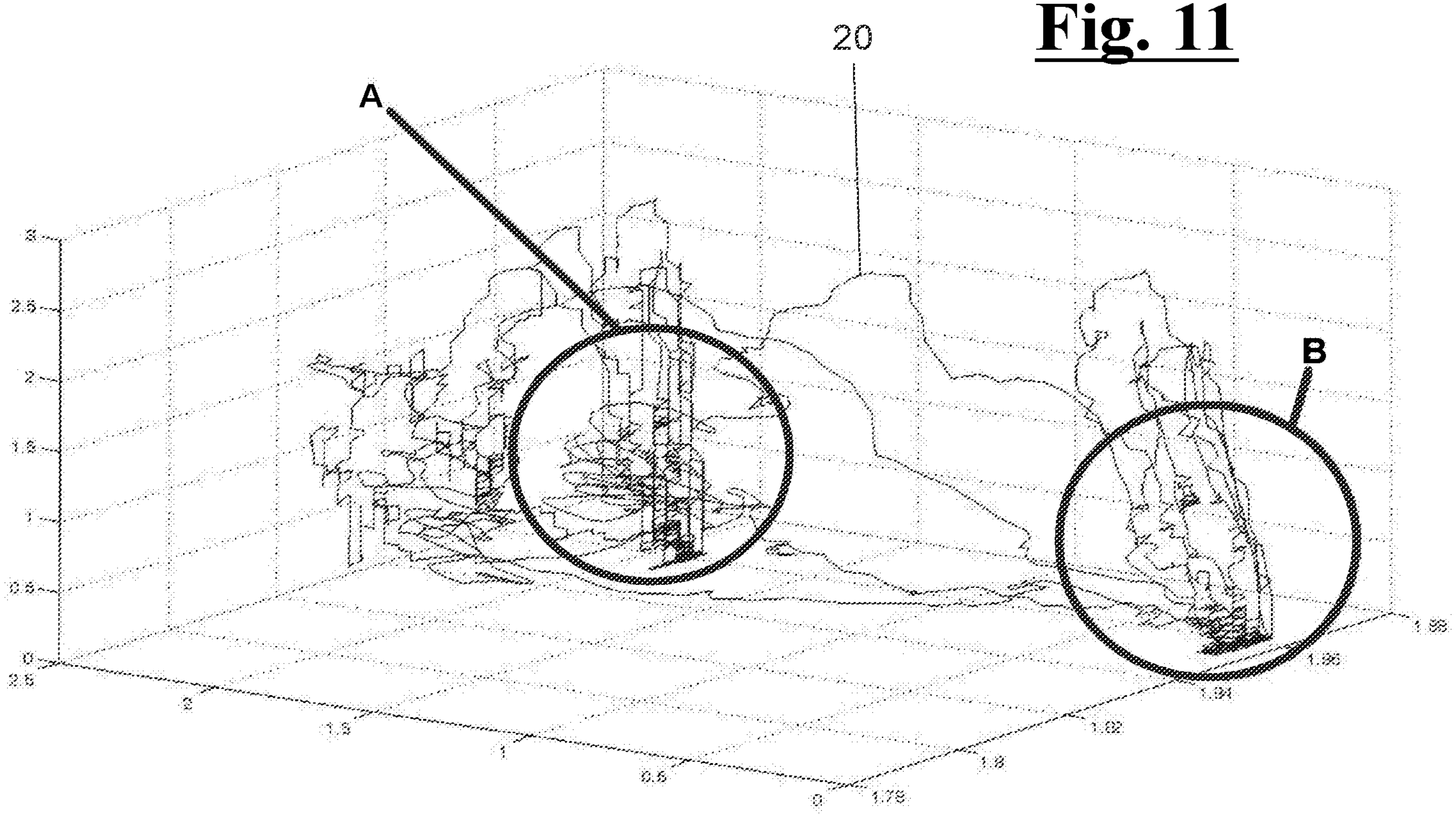
START
FSR/EMG Event
No
Yes
CLOSURE Event
No
Yes
θ,θ' Valid
No
Yes
PP Valid
No
Yes
HAND OPENING
ACTUATION OF DESIRED GRIPPING CONFIGURATION

Fig. 10

Fig. 11



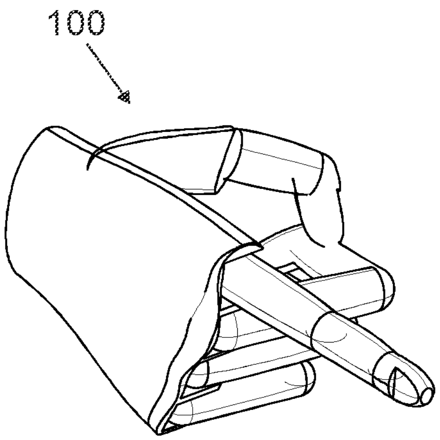


Fig. 12A

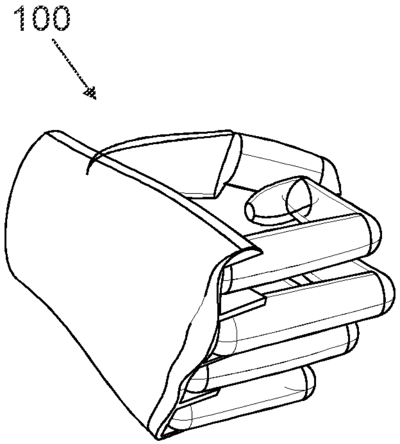


Fig. 12B

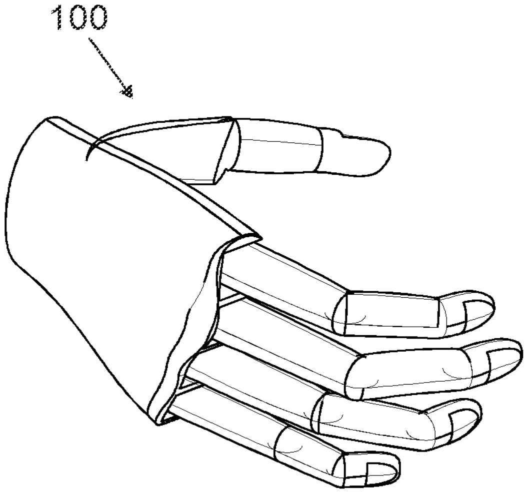


Fig. 12C

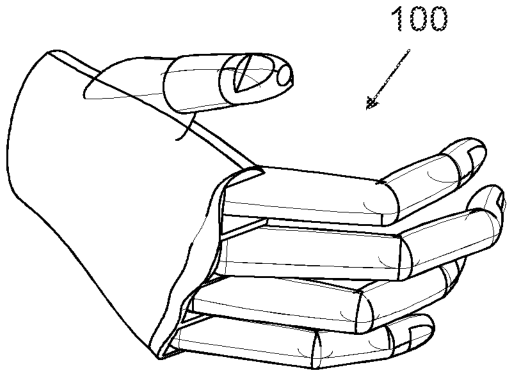


Fig. 12D

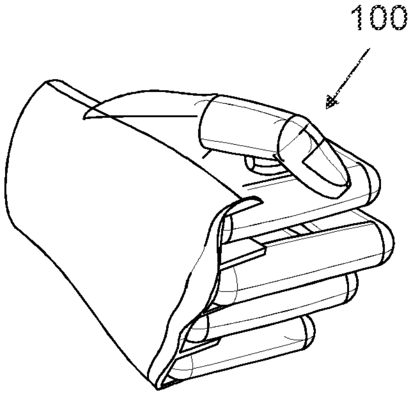


Fig. 12F

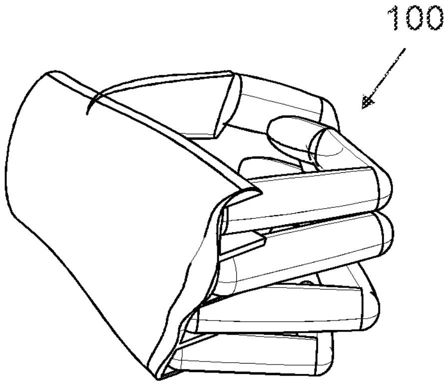


Fig. 12E

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- EP 1195151 A **[0026]**
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