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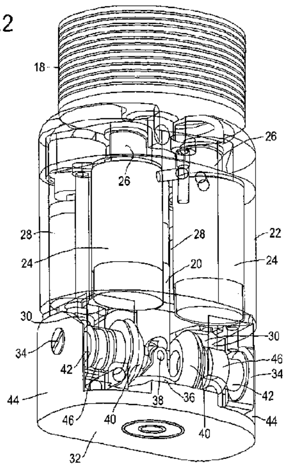
[Continued on next page]

(54) **Title**: PROSTHETIC APPARATUS

Fig.2



(57) **Abstract**: An artificial joint having at least two degrees of freedom of movement and at least two rotary motors arranged to effect movement of the joint in one of those degrees of freedom when the motors operate in respective given senses of rotation and to effect movement of the joint in the other of those at least two degrees of freedom when the sense of rotation of one of the motors is reversed. In this way the actual movement of the joint is dependent upon a balancing of the operation of the said at least two rotary motors, in which those motors are connected to a microprocessor for control thereby. Sensors are provided on the joint to monitor the operation of those motors, the sensors also being connected to the microprocessor to effect a closed loop feedback control in the operation of the motors. Also, a cover for a prosthesis comprising a silicone rubber laminate and a reinforcing liner on the intended underside of the laminate bonded thereto. Also, a prosthetic device comprising a tendon having a portion which engages a movable member of the device, so that movement of the tendon in a given direction urges the said movable member correspondingly. The said portion engages the said movable member by being received in one end of a slot within the movable member. The slot extends from the said end in a direction opposite to the said given direction. Also, a prosthesis comprising at least two parts which are moveable relative to one another, an actuator connected to move one of the parts relative to the other, and a control connected to operate the actuator in dependence upon a signal issued to the control by the user. A movement transducer is connected to the control, and also to the actuator to provide signals to the control indicative of the amount of movement effected by the actuator, and the control operates the actuator in dependence upon the signals it receives from the transducer.

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Prosthetic apparatus

A first aspect of the present invention relates to an artificial joint.

One such joint that has been proposed hitherto comprises a prosthetic wrist in which respective motors control flexing of the wrist and relative rotation of the wrist parts of the joint.

A disadvantage of such a prior construction is the extent to which the operation of the respective motors can be combined.

The first aspect of the present invention seeks to provide a remedy.

Accordingly, the first aspect of the present invention is directed to an artificial joint having at least two degrees of freedom of movement and at least two rotary motors arranged to effect movement of the joint in one of those degrees of freedom when the motors operate in respective given senses of rotation and to effect movement of the joint in the other of those at least two degrees of freedom when the sense of rotation of one of the motors is reversed, so that the actual movement of the joint is dependent upon a balancing of the operation of the said at least two rotary motors, in which those motors are connected to a microprocessor for control thereby, and sensors are provided on the joint to monitor the operation of those motors, the sensors also being connected to the microprocessor to effect a closed loop feedback control in the operation of the motors.

Preferably, the artificial joint comprises a prosthetic wrist.

One of the said at least two degrees of freedom of movement may comprise a flexing of the joint.

The other of the said at least two degrees of freedom of movement may comprise a relative rotation between two parts of the joint.

At least one of the sensors may comprise a device constructed and arranged to monitor the angular position of the rotor of one of the motors.

Alternatively, or in addition, at least one of the sensors may comprise a device which is constructed and arranged to observe movement of one part of the joint relative to another.

One or more of the sensors may comprise a linear encoder, a potentiometer or a Hall effect sensor, for example.

The first aspect of the present invention extends to a prosthesis comprising a prosthetic hand portion and a lower arm portion interconnected by a prosthetic wrist in accordance with the invention.

The second aspect of the present invention relates to a cover for a prosthesis.

Hitherto, covers for prostheses, such as a prosthetic hand have comprised either a relatively strong plastics material which, though hardwearing, is not very lifelike, or have comprised a more lifelike material which is not hardwearing.

The second aspect of the present invention seeks to provide a remedy.

Accordingly, the second aspect of the present invention is directed to a cover for a prosthesis comprising a silicone rubber laminate and a reinforcing liner on the intended underside of the laminate bonded thereto.

Preferably, the silicone rubber laminate comprises from 9 to 12 layers.

Advantageously, one or more outer layers of the laminate comprise a material which gives a good wear resistance and a relatively high tear strength whilst at the same time providing good elasticity.

Each layer of the laminate may be substantially 0.12 mm thick.

One or more layers of the laminate within the outermost layer or layers may comprise a material which gives the cover a softness and high degree of flexibility and also renders the cover lifelike and close in appearance and behaviour to human skin.

Preferably, the reinforcing liner comprises nylon, more preferably woven nylon stocking material.

The bonding between the laminate and the liner may be by means of further silicone material which encapsulates the liner and which is bonded to the laminate. As a result, the portions of the mechanical prosthesis can glide over the inside of the cover to give a relatively low frictional engagement between the cover and the mechanical parts.

The cover is especially useful if it is in the shape of a hand.

Prosthetic nails, for example fingernails, may be formed on the cover. The nails may comprise layers of silicone.

For a lifelike appearance, at least one of the layers of silicone of each nail is coloured pink and at least one of the layers outside the pink layer is clear. The layers of silicone which constitute each nail may collectively be substantially 2 to 3mm thick.

The second aspect of the present invention extends to a method of making a cover for a prosthesis. More especially, such a method may comprise building up successive layers of liquid silicone rubber on the inside of a mould, preferably a mould having a glove-shaped interior, which has been warmed and pretreated with release agent. The laminate cover pre-form may now be removed from the mould, turned inside out, and placed on to a mandrel. A reinforcing layer, such as woven nylon, may now be placed on to the laminate, whereafter one or more further coatings of liquid silicone rubber may be applied to the woven nylon. The strand diameter of the woven nylon may be in the range from 0.1 to 0.5mm. The mandrel with the finished cover may be placed into a hot oven to cure the material of the cover. After heating, the mandrel with cover is removed from the oven and allowed to cool, whereafter the cover may be peeled off from the mandrel.

The third aspect of the present invention relates to a prosthetic device comprising a tendon having a portion which engages a movable member of the device, so that movement of the tendon in a given direction urges the said movable member correspondingly.

A number of such constructions in prosthetic devices which have been proposed hitherto have involved complex and expensive linkages to effect a more lifelike movement of the movable member. However, such constructions have also been susceptible to damage if the prosthetic device is accidentally knocked or forced against an external object.

The third aspect of the present invention seeks to provide a remedy.

Accordingly, the third aspect of the present invention is directed to a prosthetic device having the construction set out in the opening paragraph of the present specification, in which the said portion engages the said movable member by being received in one end of a slot within the movable member, the slot extending from the said end in a direction opposite to the said given direction.

Preferably, the tendon has a further portion spaced from the first-mentioned portion, which further portion is connected to drive means of the device, which drive means may comprise a linear actuator.

The device may be further provided with resilient means to act on the movable member against the action of the tendon when the latter moves in the said given direction.

This provides the advantage that the force of the drive means only needs to be effective in one direction since release of that force enables the resilient means to move the movable member in the opposite sense or direction from that caused by the drive means.

The resilient means may comprise a resilient cover of the prosthetic device.

In one embodiment of the invention, the movable member comprises a phalange.

More especially, the phalange may comprise or be part of a finger connected to a palm of the prosthetic device. In that case the drive means may be secured within the palm of the prosthetic device. Movement of the tendon in the said given direction may effect closure of the finger.

The fourth aspect of the present invention relates to a prosthesis comprising at least two parts which are moveable relative to one another, an actuator connected to move one of the parts relative to the other, and a control connected to operate the actuator in dependence upon a signal issued to the control by the user.

A hand prosthesis having this construction which has already been proposed comprises two parts mechanically linked to move together between a fully open position and a fully closed position, the fully opened position being a known constant. This enables the user to know how to position the hand to ensure that the fully closed position will effect the desired grip.

Increasingly prostheses offering more than one kind of movement are being made available, so that for example one hand prosthesis already proposed can be commanded by the user to selectively effect a first movement following which the hand prosthesis adopts a pointing configuration, or a second movement to effect a pincer grip. Such a prosthesis is so constructed that it positions the moveable parts in a known position, such as a fully open position, before applying appropriate power of movement to the moveable parts to effect the first or the second movement. It needs to start from such a reference configuration to ensure that the end position after the movement is correct. This is important in enabling the user to position the hand prosthesis as a whole to make the movement effective.

A problem encountered with such a prosthesis is that useful energy may be wasted whilst it is first moved into the reference configuration. Furthermore changes in frictional forces between moving parts over time may alter the resulting positions of the parts after a given signal has been issued to the control by the user.

The fourth aspect of the present invention seeks to provide a remedy to one or more of these problems.

Accordingly, the present fourth aspect of the invention is directed to a prosthesis having the construction set out in the opening paragraph of the present specification, in which a movement transducer is connected to the control, and also to the actuator to provide signals to the control indicative of the amount of movement effected by the actuator, and the control operates the actuator in dependence upon the signals it receives from the transducer.

The prosthesis may comprise a hand prosthesis.

The movement transducer may comprise a digital pulse encoder.

The control may be programmed to change the power applied to the actuator in dependence upon the difference between the actual relative position between the relatively moveable parts and a desired relative position stored in the control.

The actuator may comprise an electrical motor.

The hand prosthesis may comprise a plurality of digits each moveable relative to a main support of the prosthesis, the digits being provided with respective actuators having respective transducers, the control operating the actuators in dependence upon the signals it receives from the transducers in accordance with a signal issued by the user.

The control may be programmed to effect movement of the hand prosthesis to any selected one of a number of different configurations. The latter may comprise a point configuration, a key grip configuration and a precision grip configuration.

Examples of prosthetic apparatus embodying the different aspects of the present invention will now be described in greater detail with reference to the accompanying drawings, in which:

Figure 1 shows a front view of a prosthesis having an artificial joint embodying the first aspect of the present invention;

Figure 2 shows a perspective side partially see-through view of the joint of Figure 1, inverted relative to the orientation it has in Figure 1;

Figure 3 shows a circuit diagram of simple electrical circuitry of the artificial joint shown in Figures 1 and 2;

Figure 4 shows a flow chart of a programme in accordance with which the artificial joint is operated;

Figure 5 shows a perspective rear view of a mould for a cover for a prosthesis hand;

Figure 6 shows a perspective front view of a mandrel bearing a cover made from the mandrel shown in Figure 5;

Figure 7 shows a perspective rear view of a cover made in accordance with the second aspect of the present invention with the mould and the mandrel shown in Figures 5 and 6;

Figure 7a shows a cross-sectional diagram on a very much larger scale of the material of the cover shown in Figure 7;

Figure 8 shows a side view of a device embodying the third aspect of the present invention with the parts thereof having first relative positions;

Figure 9 shows a further side view of the device shown in Figure 8, but with the parts thereof having second relative positions;

Figure 10 shows a side view of the prosthetic device shown in Figures 8 and 9 with the parts thereof having yet further different relative positions;

Figure 11 shows a diagram of a hand prosthesis embodying the fourth aspect of the present invention from its front, including electrical circuitry thereof;

Figure 12 shows a flow chart of a software program by which a control of the prosthesis shown in Figure 11 is programmed to operate;

Figure 13 shows a flow chart of a further software program by which a control of the prosthesis shown in Figure 11 is programmed to operate; and

Figures 14 to 16 show respective front views of the prosthesis shown in Figure 11 after it has been moved into different respective selectable configurations.

The prosthesis 10 shown in Figure 1 comprises a forearm portion 12, a prosthetic hand portion 14 and a wrist joint interconnecting the forearm portion 12 with the hand portion 14, the joint being covered by a flexible covering 13 which also overlaps a lower part of the hand portion 14 and an upper part of the forearm portion 12.

The wrist joint mechanism is shown in greater detail in Figure 2. It comprises a cylindrical attachment part 18, the cylindrical surface of which is grooved to facilitate bonding to the distal end of the forearm portion 12. From the face of the part 18 which is intended to be directed away from the forearm portion 12 extends a rod 20. The rod 20 is thus fixed relative to the part 18. A cylindrical drive housing 22 houses two electrical motors 24. The axis of the housing 22 coincides with that of the rod 20 and the axes of the motors 24 are generally parallel to the rod 20. Respective adjacent ends of the motors 24 are provided with respective drive spindles 26 connected by way of belt drives (not shown) to drive respective gear boxes 28. The latter have respective axes of rotation also generally parallel to the rod 20. The ends of the gear boxes 28 which are further from the part 18 are provided with worm drives 30. The axis of rotation of the motors 24 and the gear boxes are angularly spaced apart around the rod 20. The housing 22, motors 24, and gear boxes 28 are all in a fixed position relative to one another, and together are rotatable around the rod 20.

An articulated part 32 is pivotally connected to the housing 22 by way of pivots 34. It is to this articulated part 32 that the hand portion 14 is attached. The articulated part 32 is able to pivot about the common axis of the pivots 34. A bevelled gearwheel 36 is fixed centrally to the floor of the articulated part 32. The side of the gearwheel 36 nearer to the part 18 is fixed to the distal end of the rod 20 by way of a universal coupling 38.

Two further bevelled gearwheels 40 are arranged with their axes of rotation coincident with one another and so as to engage the wheel 36 at diametrically opposite positions thereof. The gearwheels 40 are mounted on respective axles 42 which extend inwardly from respective sides 44 of the articulated part 32, with their axes in alignment with the pivots 34. The gearwheels 40 therefore have axes of rotation which are at right angles to the axis of rotation of the gearwheel 36. The gearwheels 40 are fixed relative to respective worm wheels 46 engaged to be driven respectively by the worm drives 30.

The electrical circuitry of the prosthetic wrist shown in Figure 2 is shown in Figure 3. It comprises a microprocessor 50 connected to each of the motors 24 via respective drive control lines. The motors 24 are equipped with respective sensors 51 indicative of the angular positions of each rotor of the motor 40. The sensors 51 are also connected to the microprocessor 50 to enable closed loop feedback control of the motors 24 by the microprocessor 50. Respective user inputs 52 are also connected to the microprocessor 50 to enable the user to effect a flexing or rotation of the wrist prosthesis respectively, or a combination of flexing and rotation. Such inputs may be connected to motor nerves of the user.

Operation of the prosthesis 10 shown in Figures 1 to 3 is illustrated by the flow chart shown in Figure 4.

Thus, from the start position 60 at the top of the flow chart shown in Figure 4, the microprocessor 50 is programmed to await, at step 62 in the flow chart shown in Figure 4, an input signal from the user to rotate the two portions 12 and 14 connected at the prosthetic wrist relative to one another or to flex those two parts or to execute a combination of both of these degrees of freedom of movement. This is effected by input signals to the microprocessor 50 via the user inputs 52.

At step 64 in the flow chart shown in Figure 3, the microprocessor 50 obtains readings from the respective sensors 51 to determine the starting positions of the motors 24. Depending upon the input to the microprocessor 50 from the user inputs 52, the programme executed by the microprocessor 50 determines the speed and direction for each motor to effect the movement required by the user at step 66.

For example, if an input signal to the microprocessor 50 requires a rotation only of the hand portion 14 relative to the arm portion 12 about the longitudinal axis thereof, the motors 24 rotate their respective gearwheels 40 in opposite senses about their common axis of rotation. This will cause the wheels 40 to track around the wheel 36, causing both the articulated part 32 and with it the housing and its contents 22 to rotate about the axis of the rod 20. As a result the lower forearm portion 12 and the hand 14 rotate relative to one another.

If, on the other hand, an input signal to the microprocessor 50 by the input 52 is a command to flex the wrist joint mechanism, the gearwheels 40 are rotated in the same sense. This will cause the gearwheel 36 to move around the common axis of the pivots 30 and consequently the articulated part 32 to be pivoted about the pivots 30, such a flexing being accommodated by the universal coupling 38. This is so regardless of the relative angular position of the articulated part 32 relative to the attachment part 18 about the axis of the rod 20. As a result the lower forearm portion 12 and the hand 14 flex relative to one another.

A combination of these two movements may be effected by the user creating mixed input signals to the microprocessor 50 via the input signals 52. The relative amounts of these two movements are in proportion to these signals.

At step 68 in the flow chart shown in Figure 4, the programme executed by the microprocessor 50 checks the position of the motors 50 via the inputs the microprocessor receives from the sensors 51. Any discrepancy between the values thus obtained and the desired position according to the input signals to the microprocessor 50 causes the microprocessor 50 to make a corresponding adjustment to the speed and/or sense of rotation of one or both motors 24.

This process continues until step 70 of the programme as shown in Figure 4, at which stage the input signals to the microprocessor 50 have been removed or an end stop of movement of the wrist joint mechanism has been reached or one or both motors have reached their current limit indicative of a jamming or end stop of the wrist joint mechanism. Both motors 24 are then shut down at step 72 and this routine in the programme by which operation of the microprocessor 50 is determined reaches its end 74.

Numerous variations and modifications to the illustrated prosthesis may occur to the reader without taking it outside the scope of the present invention. Thus, for example, the joint shown in Figure 1 may be adapted to operate as an elbow joint so that the portions 12 and 14 are respectively ends of upper and lower arm portions.

The bevelled gearwheel 36 may be of larger diameter, and the slant of its bevelling reversed to be inward instead of outward relative to that wheel, and the axles 42 could be mounted on blocks immediately adjacent to and on opposite sides of the universal coupling 38 so that those axles 42 extend outwardly from those blocks as with the gearwheels 40 so that they engage the larger diameter gearwheel 36 at positions thereof diametrically opposite one another. The gearing ratios of the gear boxes 28 and/or the diameter of the gearwheels 40 may correspondingly be altered to take into account the larger diameter of the gearwheel 36.

Furthermore, it will be appreciated that although what is shown in Figures 1 to 4 comprises a wrist prosthesis, it may equally be an artificial wrist for a robot.

The mould 110 shown in Figure 5 is hollow and has the shape of a glove so that its interior has the shape of a hand. It is open at a position corresponding to the wrist 112. The mould 110 is pre-warmed and pretreated on its interior surface with a release agent. A liquid silicone rubber mixed with solvent is poured into the mould 110, and the mould 110 is plugged at the wrist 112. The silicone is one which gives good wear resistance and a relatively high tear strength whilst at the same time providing good elasticity. The mould is inserted into a motion machine which will not be described in detail as readers familiar with the art will be fully aware of the construction of such a machine. The machine moves the mould 110 to evenly distribute the liquid silicone rubber over the interior of the mould. The amount of liquid poured into the mould 110 is such as to provide a layer of thickness of the silicone rubber of about 0.12mm.

Such moulding is known as rotational or slush moulding.

The mould is then removed from the motion machine, unplugged and orientated so that excess silicone is allowed to drain away.

One or more further layers of the silicone mixed with solvent are deposited in the interior of the mould 110 in this way by repeating this procedure.

A number of layers of a second silicone mixed with solvent are then built up on the interior of the mould 110, onto the layers of the first silicone, so that there are in all a total of twelve layers of silicone built up on the interior of the mould 110. The second silicone is one which gives the finished article a softness and a high degree of flexibility and also renders the cover lifelike and close in appearance and behaviour to human skin. It will be appreciated that the number of layers may be fewer or greater than twelve.

The mould with these layers is then placed into an oven to cure the silicone.

The mould is then removed from the oven, allowed to cool and the cover pre-form 114 is then extracted from the mould interior.

The cover pre-form 114 is then turned inside out and then placed on an appropriately shaped mandrel or former 116, as shown in Figure 6. A pre-formed reinforcing glove shaped woven nylon matrix or mesh is then placed over the cover pre-form 114. The strand diameter of the nylon mesh is substantially 0.3mm. A blend of liquid silicone, rubber and solvent is now applied by roller or brush to the cover pre-form 114. This technique impregnates the matrix or mesh, encapsulates it, and glues it to the silicone laminate. A second application of such a blend may be applied to the matrix or mesh so as to uniformly coat the cover pre-form. The mandrel with cover is now placed in an oven to cure the further applied silicone.

After curing the mandrel with cover is removed from the oven and allowed to cool to room temperature, whereupon the finished cover 114 is peeled off from the mandrel 116. The finished cover 120 for a prosthetic hand is shown in Figure 7. It will be seen that prosthetic fingernails 122 have been attached by depositing and curing further layers of silicone on to the cover 120 at the fingertips thereof, comprising at least one layer of pink silicone covered by at least one layer of clear silicone, to a thickness of substantially 2.5mm.

A section through a portion of the cover 120 is now as shown in Figure 7a. The outermost layers 124 of silicone comprise the first silicone and the middle layers 126 of silicone comprise the second silicone. Within the innermost layer of silicone 128 there is embedded the nylon mesh 130.

Numerous variations and modifications to the illustrated method of manufacturing the prosthetic cover, as well as the prosthetic cover itself may occur to the skilled reader without taking the resulting construction outside the scope of the present invention. For example, there may be fewer layers of silicone, or more layers of silicone, in the finished cover 120.

The prosthetic device 210 shown in Figures 8 to 10 is constituted by a myoelectric prosthetic hand device and comprises a base part 212 constituting a palm of the prosthetic device in which is housed a linear actuator drive motor 214. A lower end 216 of a tendon 218 is secured to this linear actuator drive motor 214. A spigot 220 is provided on and fixed to the opposite end 222 of the tendon 218 and engages a lower end 224 of a slightly arcuate slot 226 formed in the lower half of a first or proximal phalange 228 of a finger 230 of the prosthetic device 210.

A lower end 232 of the first phalange 228 is pivoted at a pivot 234 to a mount 236 which constitutes a knuckle of the prosthesis and which is fixed to the base 212 rearwardly and above the linear actuator drive motor 214.

The slightly arcuate slot 226 has its concave side closer to the amount 236.

A further pivot 238, provided on the mount 236, is set rearwardly and above the pivot 234.

A rearward end 240 of a second phalange 242 is pivoted to an upper end 244 of the first phalange 228 by way of a pivot 246. The rearward end 240 of the phalange 242 is provided with a second pivot 248 positioned, in the setting shown in Figure 8 in which the finger 230 is in an open position, below and forwardly of the pivot 246. A ligament 250 extends between and is pivoted to the mount 236 and the second phalange 242 at the pivots 238 and 248 respectively by respective through-pins.

When the linear actuator drive motor 214 is operated, it retracts the tendon 218 into the base or palm 212 so that the spigot 222 is lowered when the prosthetic device is orientated as shown in Figure 8. This causes the first phalange 228 to pivot in an anti-clockwise sense, viewing it as in Figure 8, about the pivot 234. At the same time, because the spacing between the pivots 238 and 248 is fixed by the ligament 250, the second phalange 242 pivots about the pivot 246 towards the first phalange 228. This results in the closure of the finger 230 towards the base or palm 212, so that the parts of the prosthetic device have the relative positioning shown in Figure 9.

Release of the retracting force on the tendon 218 enables the finger 213 to be restored to the position it has in Figure 8. This may be effected by means of an elastic covering or glove (not shown) or by means of internal springs (not shown) of the prosthetic device.

In the event that an external force should be applied to for example the said second phalange 242, causing inward deflection thereof so as to urge it towards the base or palm 212, without operation of the linear actuator drive motor 214, the likelihood of damage is reduced by virtue of the slot 228 enabling the spigot 220 to ride up away from the end 224 of the slot 226 towards the opposite end thereof, so that the tendon 218 and the motor 214 and/or other parts of the prosthetic device, are not damaged, the parts of the prosthetic device then adopting the relative positioning shown in Figure 10, or any positioning intermediate between that shown in Figure 8 and that shown in Figure 9.

Numerous modifications and variations to the illustrated prosthetic device may occur to the reader without taking the resulting construction outside the scope of the present invention. For example, there may be a plurality of fingers 230 with respective tendons 218 and motors 214 arranged side by side on the base or palm 212, imitating the four fingers of a hand. A similarly constructed thumb may also be provided on the prosthetic device.

At the same time, it will be appreciated that the present invention is not limited to prosthetic devices which imitate a hand, so that the protective slot construction, which may be considered to be an over-travel feature, may be embodied in a foot prosthetic device or in for example an arm prosthetic device or a leg prosthetic device.

Figure 11 shows a hand prosthesis 310 comprises a wrist portion 312 from which extends a main support or palm portion 314. From this extends a thumb digit 316, and index finger digit 318, and three further finger digits 320, each being jointed so that it can be curled up or straightened up as with an actual hand. Respective actuators 322 are provided for the digits, the actuators having respective ligaments 324 to enable them to effect such curling up and/or straightening.

Each actuator 322 is also provided with a movement transducer in the form of a digital pulse encoder 325. Each actuator 322 is connected to a control processor 326 to be controlled thereby, and each transducer 325 is connected to the control to deliver signals thereto indicative of the movement effected by its associated actuator 322, both in amount and direction. An input 328 to the processor 326 enables the user to initiate movement of the digits, for example by movement of a selected muscle of the user.

The manner in which signals issued by the transducers 325 are used by the processor 326 to effect movement of the digits of the prosthesis 310 is shown by the flow chart of Figure 12.

Thus the program is commenced by a command signal at the input 328 recognised by the control processor 326, indicated by step 330 in Figure 12. The current actual positions of the digits held in memory locations within the processor 326, as constantly updated by the transducers 325, are read by the control at steps 332. If both the thumb and the finger digits are already in the correct positions for the selected movement, as determined at steps 334, the program moves to step 336 at which a check is made whether the power applied is proportional to that selected by the user at step 330. If it is, the control removes the application of power to the actuators 322 at step 337 since this is indicative of the required grip having been achieved. Otherwise the program is advanced to steps 338 in which the required power is applied to the digit actuators. There follows the interrogation at step 340 as to whether power consumption is greater than that required for movement of the digit. If it is that is indicative that the grip has been closed and the program is forwarded to step 336. Otherwise it is returned to the steps 334. If the digits are nonetheless in the correct position, the program is advanced to step 336. If not, the control processor calculates the required speed to move the digit or digits at steps 341 by comparing the actual position of each digit with the desired position stored in the control processor 326.

These steps result in constant movement rates for the digits.

Figure 13 shows how the grip is maintained at the desired level. Once the desired grip is achieved, the grip maintenance program shown in this Figure is initiated. With the grip at the required level power is removed from the or each actuator at step 342. At step 344 the digit position is read. The query as to whether that position is changing is raised at step 346. If it is, power is applied to increase the grip or move the digit to the required grip position at step 348. If the applied power is proportional to the original input signal determined at step 350, the program returns to step 342. Otherwise it returns to step 348. A slip sensing function is thereby achieved.

Any selected one of a number of different programs stored in the control processor may be effected by a corresponding signal applied by the user to the input 328, to effect movement of the prosthesis into respective different configurations shown in Figures 14, 15 and 16, being point, key grip and precision grip configurations respectively.

Numerous variations and modifications to the illustrated prosthesis may occur to the reader without taking it outside the scope of the present invention. To give one example only, the three further finger digits may be controlled by one and the same actuator.

Claims:

1. An artificial joint having at least two degrees of freedom of movement and at least two rotary motors arranged to effect movement of the joint in one of those degrees of freedom when the motors operate in respective given senses of rotation and to effect movement of the joint in the other of those at least two degrees of freedom when the sense of rotation of one of the motors is reversed, so that the actual movement of the joint is dependent upon a balancing of the operation of the said at least two rotary motors, in which those motors are connected to a microprocessor for control thereby, and sensors are provided on the joint to monitor the operation of those motors, the sensors also being connected to the microprocessor to effect a closed loop feedback control in the operation of the motors.

2. An artificial joint according to claim 1, in which the artificial joint comprises a prosthetic wrist.

3. An artificial joint according to claim 1 or claim 2, in which one of the said at least two degrees of freedom of movement comprises a flexing of the joint.

4. An artificial joint according to claim 3, in which the other of the said at least two degrees of freedom of movement comprises a relative rotation between two parts of the joint.

5. An artificial joint according to any preceding claim, in which at least one of the sensors comprises a device constructed and arranged to monitor the angular position of the rotor of one of the motors.

6. An artificial joint according to any preceding claim, in which at least one of the sensors comprises a device which is constructed and arranged to observe movement of one part of the joint relative to another.

7. An artificial joint according to any preceding claim, in which one or more of the sensors comprises a linear encoder.

8. An artificial joint according to any one of claims 1 to 6, in which one or more of the sensors comprises a potentiometer.

9. An artificial joint according to any one of claims 1 to 6, in which one or more of the sensors comprises a Hall effect sensor.

10. A prosthesis comprising a prosthetic hand portion and a lower arm portion interconnected by a

prosthetic wrist as claimed in claim 2 or any one of claims 3 to 9 read as appended to claim 2.

11. A cover for a prosthesis comprising a silicone rubber laminate and a reinforcing liner on the intended underside of the laminate bonded thereto.

12. A cover according to claim 11, in which the silicone rubber laminate comprises from 9 to 12 layers.

13. A cover according to claim 12, in which one or more outer layers of the laminate comprise a material which gives a good wear resistance and a relatively high tear strength whilst at the same time providing good elasticity.

14. A cover according to any one of claims 11 to 13, in which each layer of the laminate is substantially 0.12 mm thick.

15. A cover according to any one of claims 11 to 14, in which one or more layers of the laminate within the outermost layer or layers comprises a material which gives the cover a softness and high degree of flexibility and also renders the cover lifelike and close in appearance and behaviour to human skin.

16. A cover according to any one of claims 11 to 15, in which the reinforcing liner comprises nylon.

17. A cover according to claim 16, in which the reinforcing liner comprises woven nylon stocking material.

18. A cover according to any one of claims 11 to 17, in which the bonding between the laminate and the liner is by means of further silicone material which encapsulates the liner and which is bonded to the laminate.

19. A cover according to any one of claims 11 to 18, in which the cover is in the shape of a hand.

20. A cover according to any one of claims 11 to 19, in which prosthetic nails, for example fingernails, are formed on the cover.

21. A cover according to claim 20, in which the nails comprise layers of silicone.

22. A cover according to claim 21, in which, for a lifelike appearance, at least one of the layers of silicone of each nail is coloured pink and at least one of the layers outside the pink layer is clear.

23. A cover according to claim 21 or claim 22, in which the layers of silicone which constitute each

nail collectively are substantially 2 to 3mm thick.

24. A method of making a cover for a prosthesis, the cover being as claimed in any one of claims 11 to 23.

25. A method according to claim 24, in which the method comprises building up successive layers of liquid silicone rubber on the inside of a mould, which has been warmed and pretreated with release agent, removing the cover pre-form from the mould, turning it inside out, placing it on to a mandrel, placing a reinforcing layer, such as woven nylon, on to the laminate, and thereafter applying one or more further coatings of liquid silicone rubber to the woven nylon.

26. A method according to claim 25, in which the strand diameter of the woven nylon is in the range from 0.1 to 0.5mm.

27. A method according to claim 25 or claim 26, in which the mandrel with the finished cover is placed into a hot oven to cure the material of the cover.

28. A method according to claim 27, in which after heating, the mandrel with cover is removed from the oven and allowed to cool, whereafter the cover is peeled off from the mandrel.

29. A prosthetic device comprising a tendon having a portion which engages a movable member of the device, so that movement of the tendon in a given direction urges the said movable member correspondingly, in which the said portion engages the said movable member by being received in one end of a slot within the movable member, the slot extending from the said end in a direction opposite to the said given direction.

30. A prosthetic device according to claim 29, in which the tendon has a further portion spaced from the first-mentioned portion, which further portion is connected to drive means of the device.

31. A prosthetic device according to claim 30, in which the drive means comprises a linear actuator.

32. A prosthetic device according to any one of claims 29 to 31, in which the device is further provided with resilient means to act on the movable member against the action of the tendon when the latter moves in the said given direction.

33. A prosthetic device according to claim 32, in which the resilient means comprises a resilient cover of the prosthetic device.

34. A prosthetic device according to any one of claims 29 to 33, in which the movable member comprises a phalange.

35. A prosthetic device according to claim 34, in which the phalange comprises or is part of a finger connected to a palm of the prosthetic device.

36. A prosthetic device according to claim 35, in which the drive means is secured within the palm of the prosthetic device.

37. A prosthetic device according to claim 35 or claim 36, in which movement of the tendon in the said given direction effects closure of the finger.

38. A prosthesis comprising at least two parts which are moveable relative to one another, an actuator connected to move one of the parts relative to the other, and a control connected to operate the actuator in dependence upon a signal issued to the control by the user, in which a movement transducer is connected to the control, and also to the actuator to provide signals to the control indicative of the amount of movement effected by the actuator, and the control operates the actuator in dependence upon the signals it receives from the transducer.

39. A prosthesis according to claim 38, in which the prosthesis comprises a hand prosthesis.

40. A prosthesis according to claim 38 or claim 39, in which the movement transducer comprises a digital pulse encoder.

41. A prosthesis according to any one of claims 38 to 40, in which the control is programmed to change the power applied to the actuator in dependence upon the difference between the actual relative position between the relatively moveable parts and a desired relative position stored in the control.

42. A prosthesis according to any one of claims 38 to 41, in which the actuator comprises an electrical motor.

43. A prosthesis according to claim 39 or to any one of claims 40 to 42 read as appended to claim 39, in which the hand prosthesis comprises a plurality of digits each moveable relative to a main support of the prosthesis, the digits being provided with respective actuators having respective transducers, the control operating the actuators in dependence upon the signals it receives from the transducers in accordance with a signal issued by the user.

44. A prosthesis according to claim 43, or to claim 39, or to any one of claims 40 to 42 read as appended to claim 39, in which the control is programmed to effect movement of the hand prosthesis to any selected one of a number of different configurations.

45. A prosthesis according to claim 44, in which the different configurations comprise a point configuration, a key grip configuration and a precision grip configuration.

Fig.1

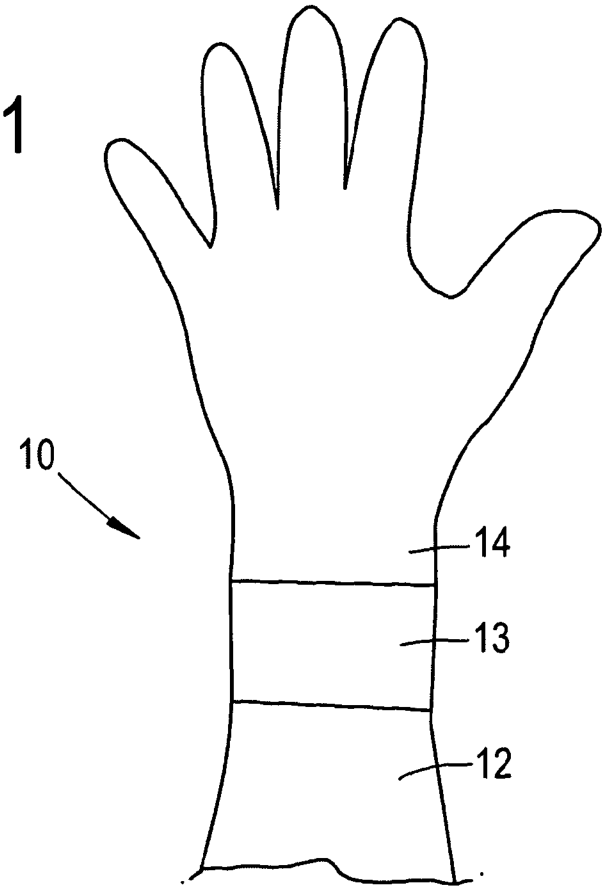


Fig.3

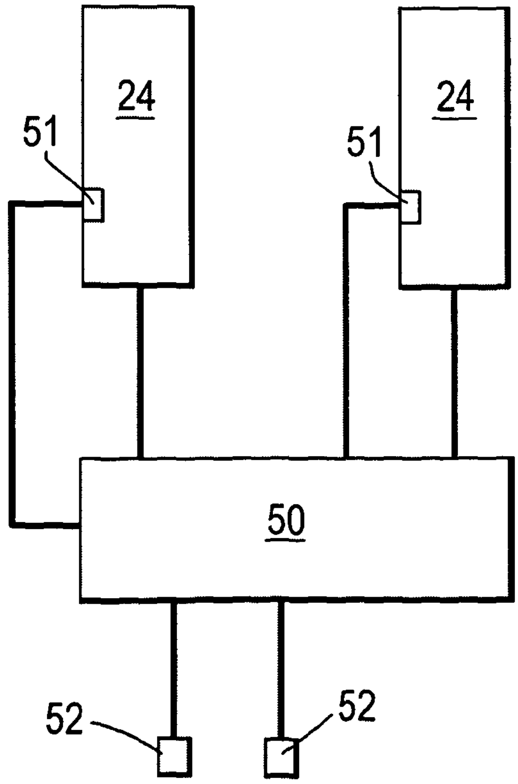


Fig.2

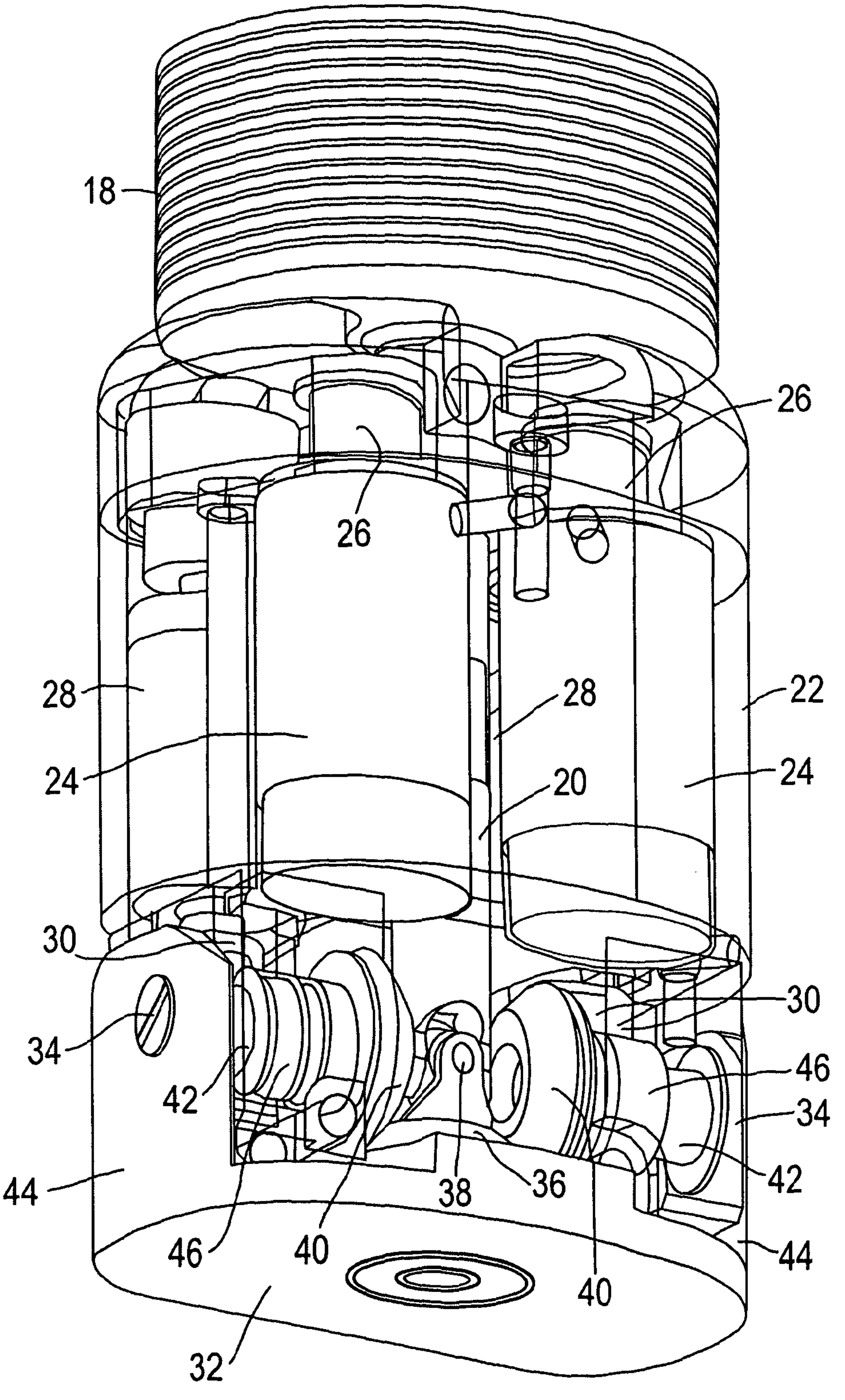
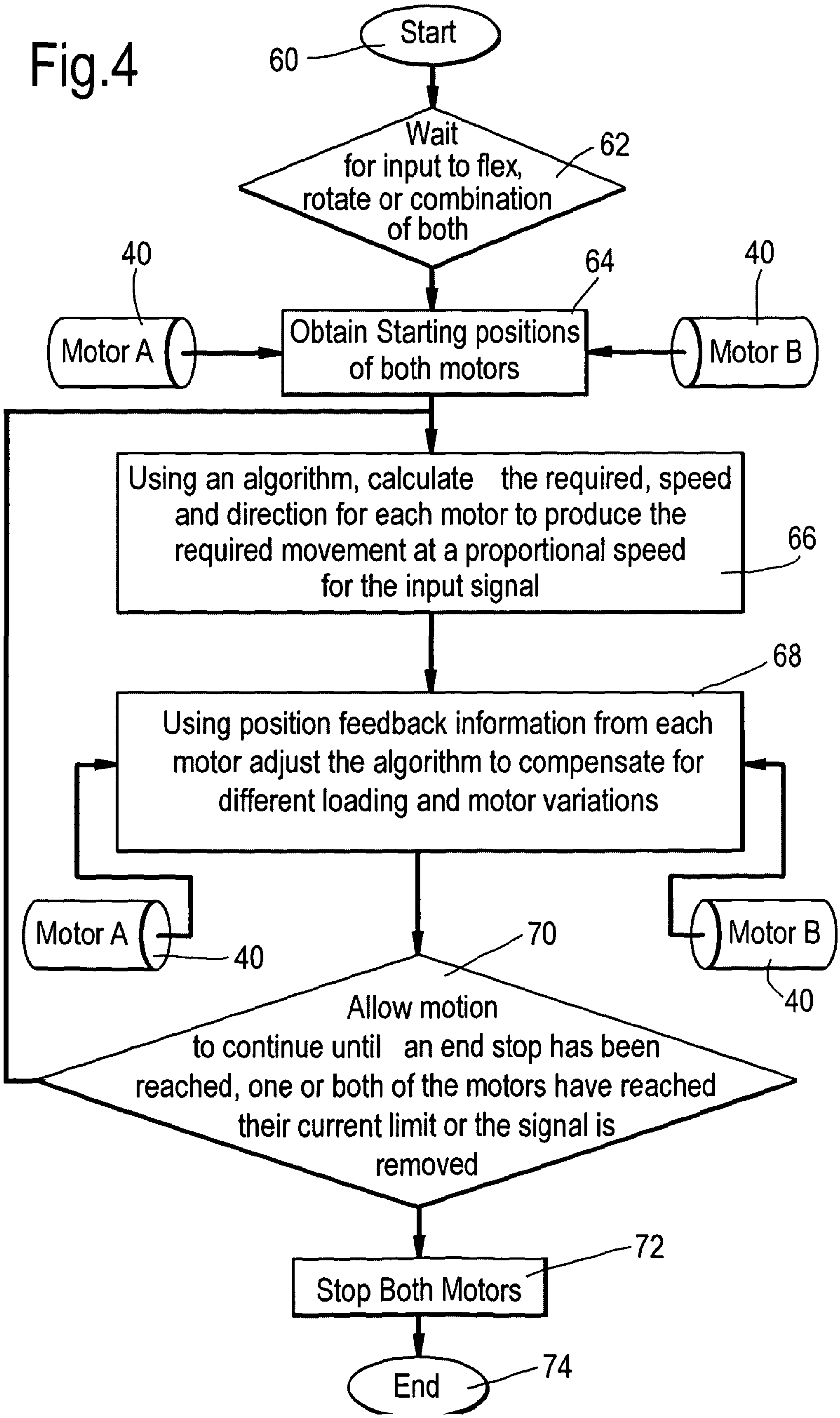


Fig.4


Start
60
Wait
for input to flex,
rotate or combination
of both
62
40
64
40
Motor A
Obtain Starting positions
of both motors
Motor B
Using an algorithm, calculate the required, speed
and direction for each motor to produce the
required movement at a proportional speed
for the input signal
66
68
Using position feedback information from each
motor adjust the algorithm to compensate for
different loading and motor variations
Motor A
40
70
Motor B
40
Allow motion
to continue until an end stop has been
reached, one or both of the motors have reached
their current limit or the signal is
removed
72
Stop Both Motors
End
74

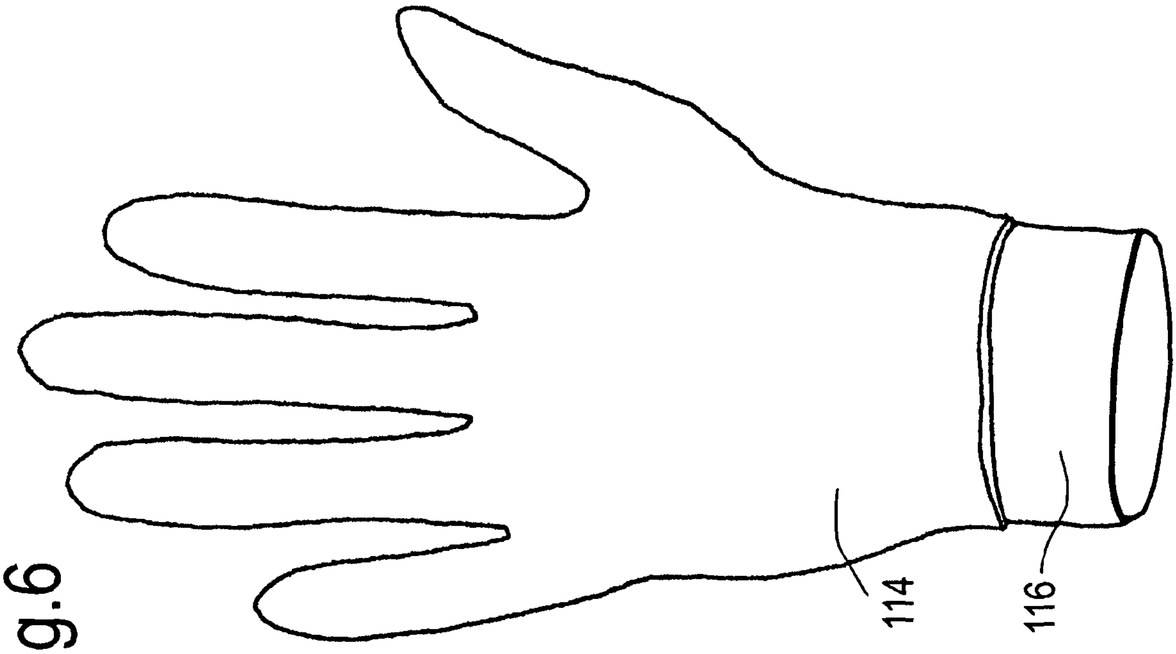


Fig.6

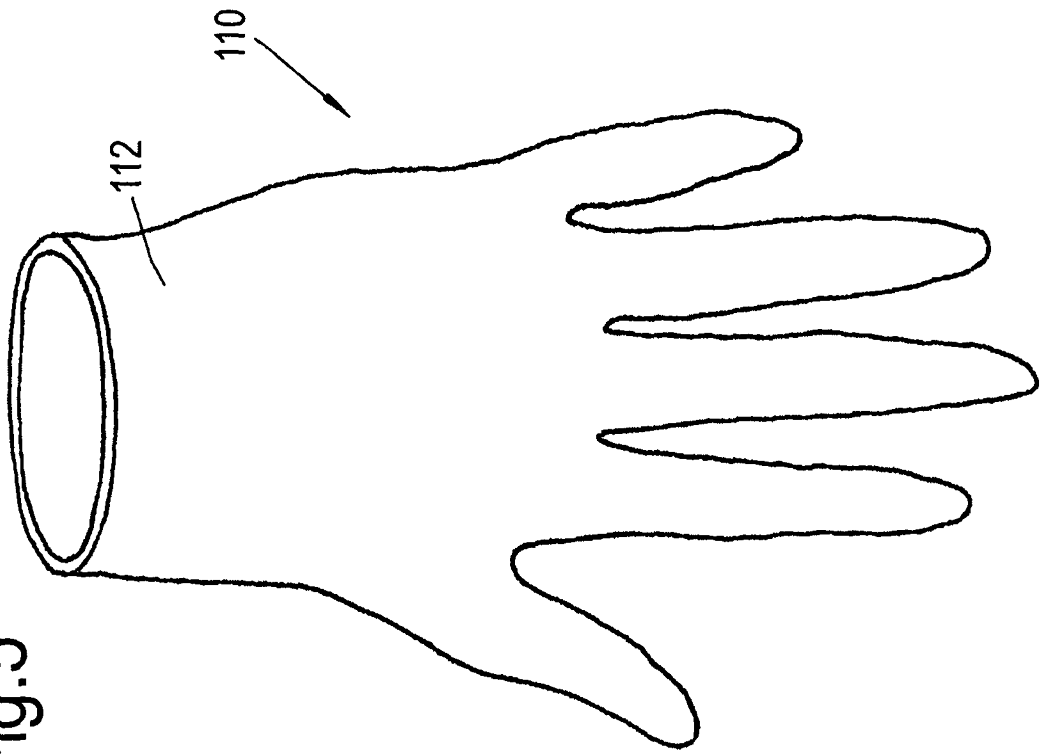


Fig.5

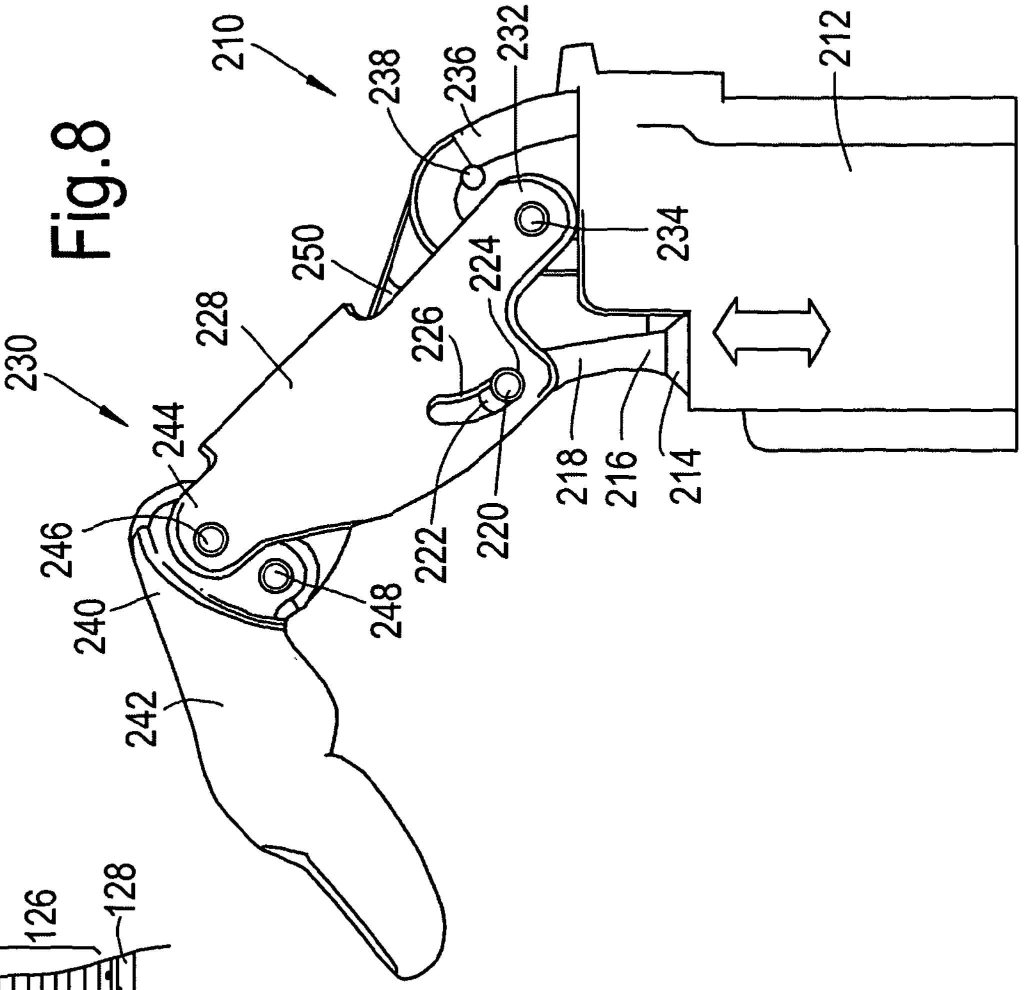


Fig.8

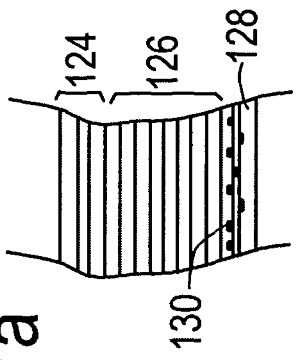


Fig.7a

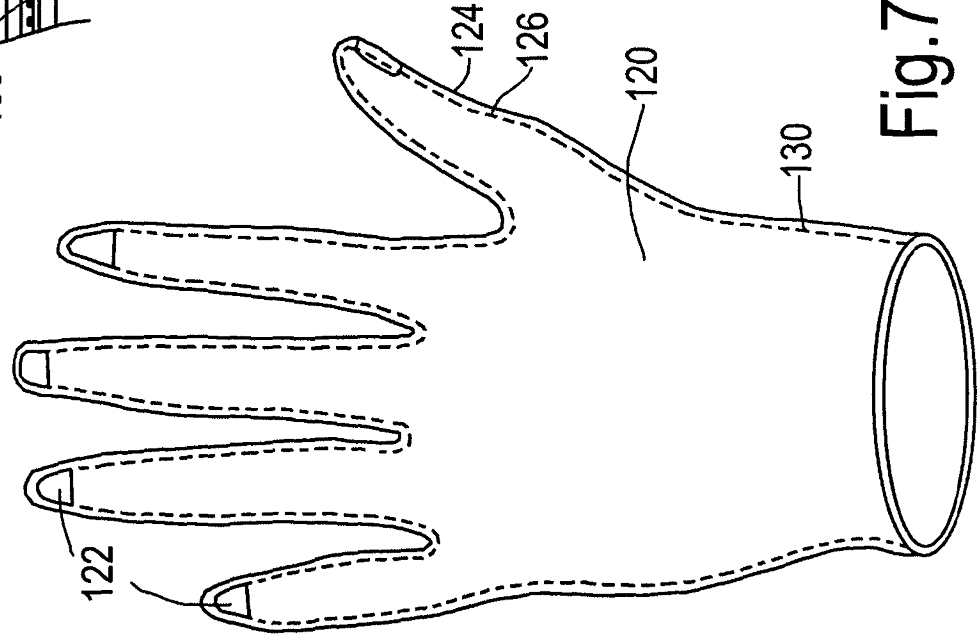


Fig.7

Fig.9

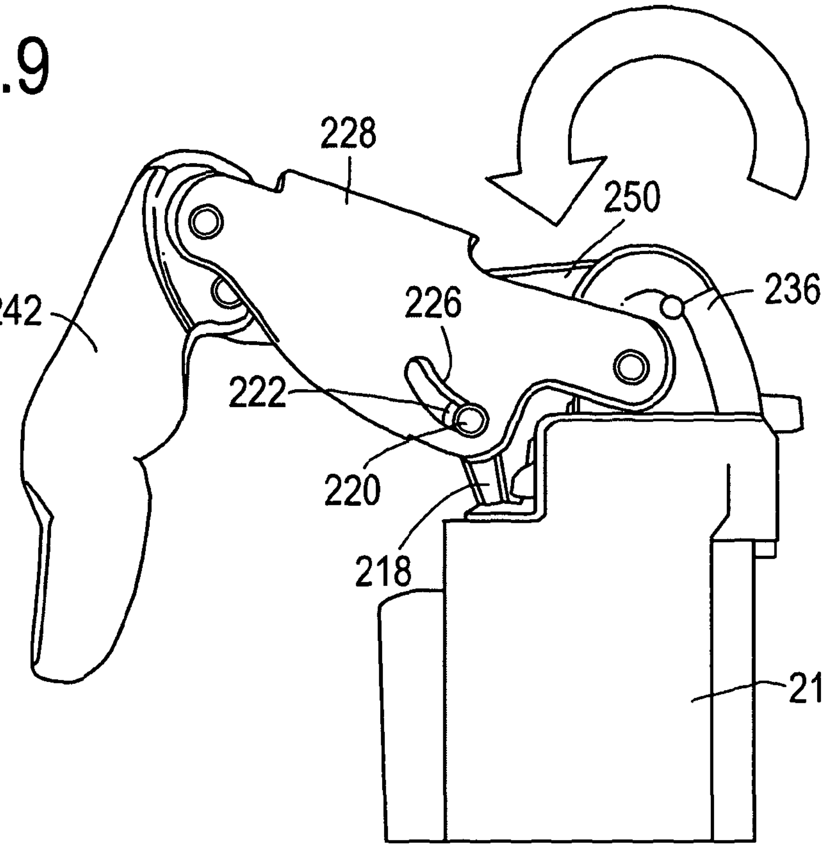

228
250
210
236
242
226
222
220
218
212

Fig.10

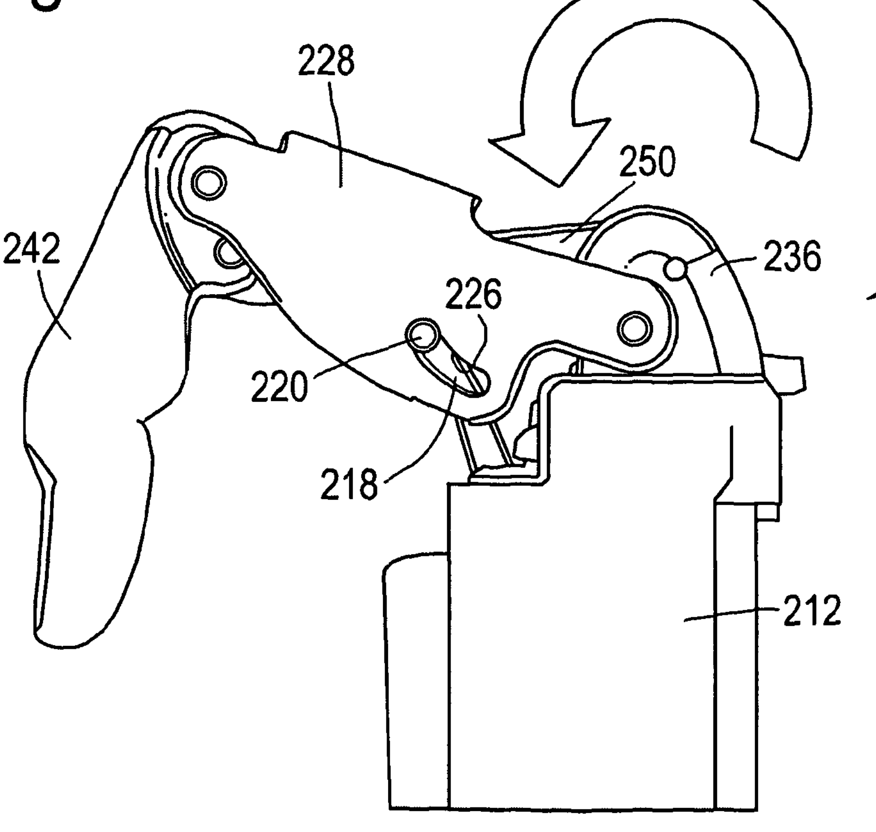

228
250
210
242
236
226
220
218
212

Fig.11

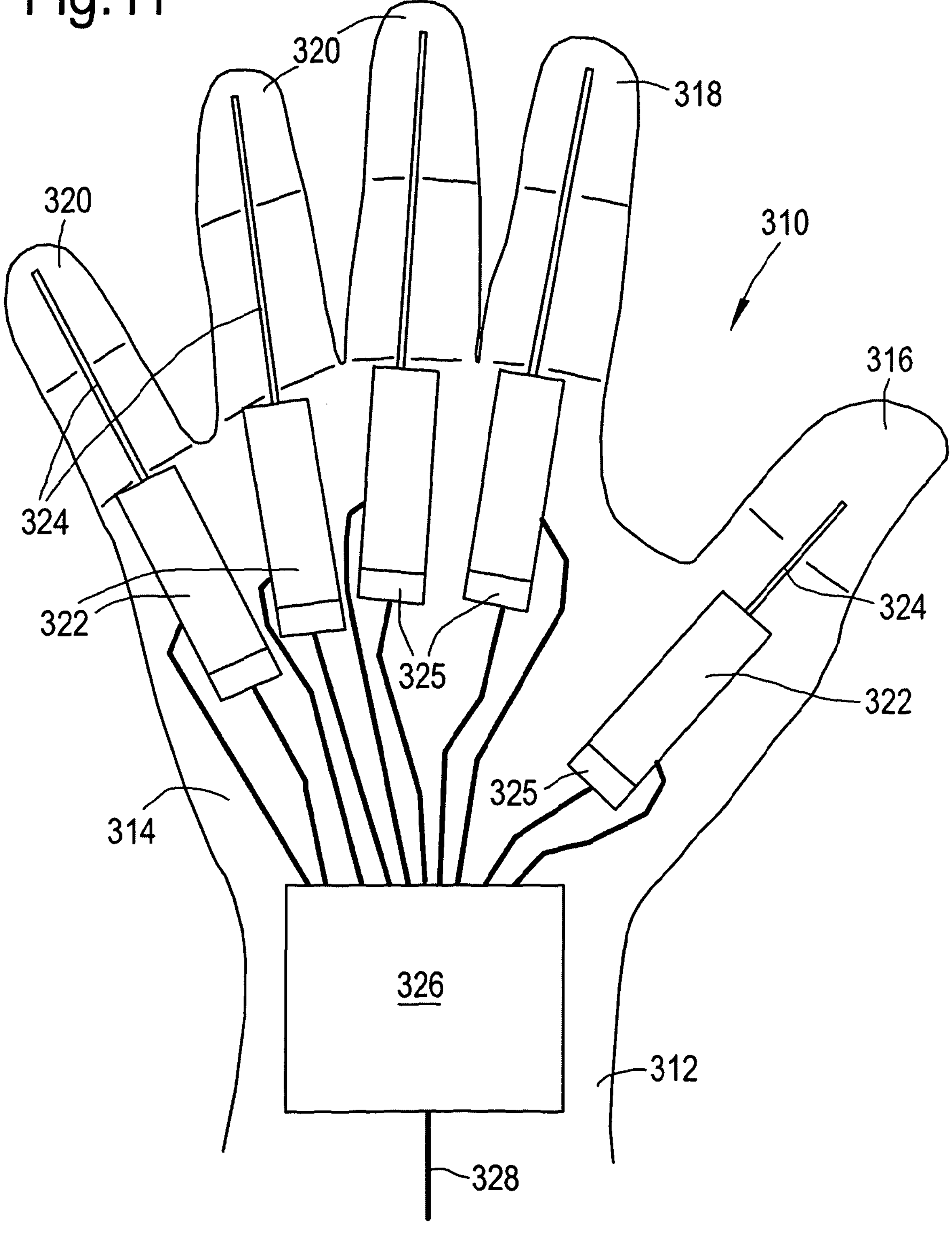


Fig.12

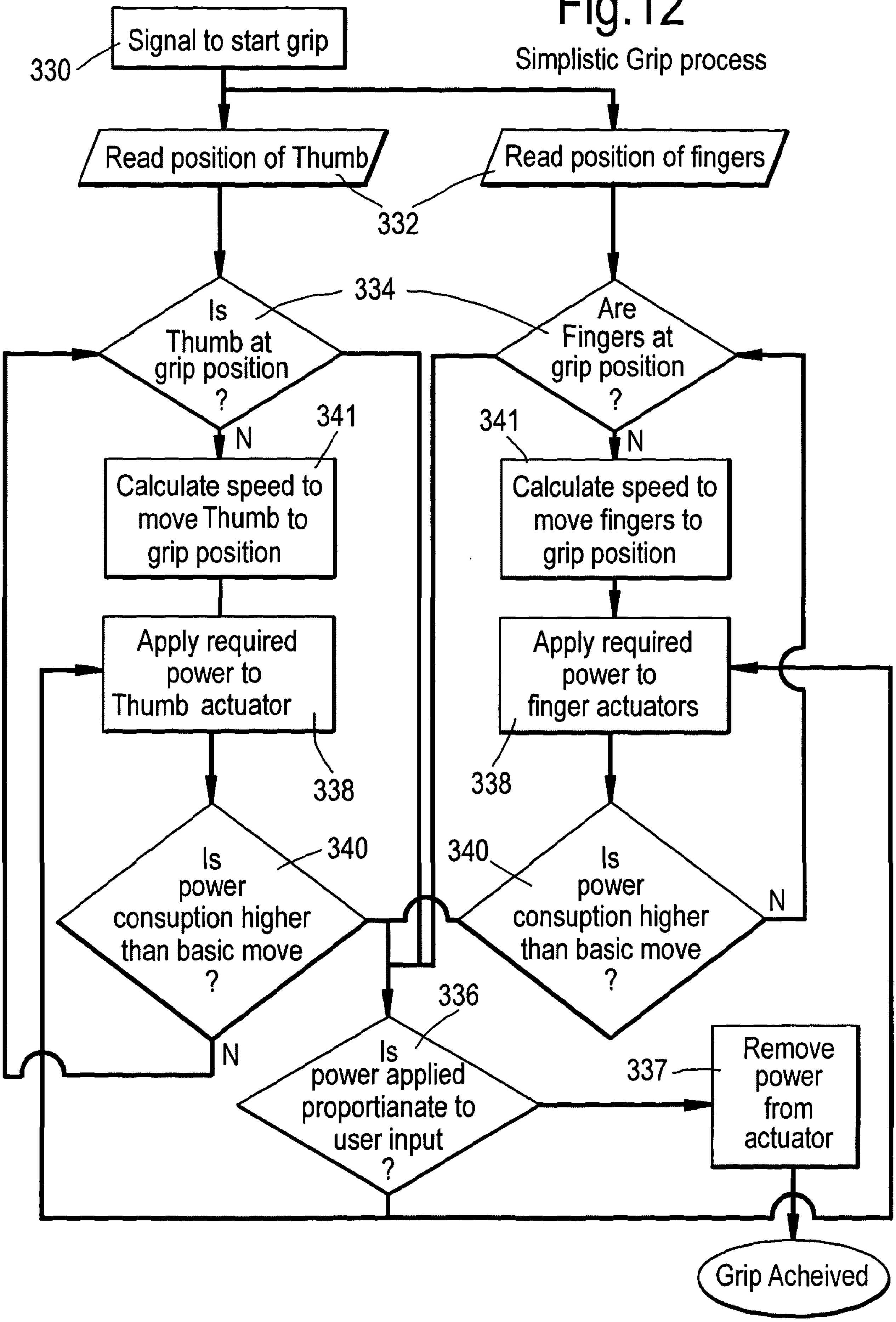

Simplistic Grip process
Signal to start grip
330
Read position of Thumb
Read position of fingers
332
334
Is Thumb at grip position ?
Are Fingers at grip position ?
N
N
341
341
Calculate speed to move Thumb to grip position
Calculate speed to move fingers to grip position
Apply required power to Thumb actuator
Apply required power to finger actuators
338
338
340
340
Is power consuption higher than basic move ?
Is power consuption higher than basic move ?
N
N
336
Is power applied proportianate to user input ?
337
Remove power from actuator
Grip Acheived

Fig.13

Basic grip maintenance

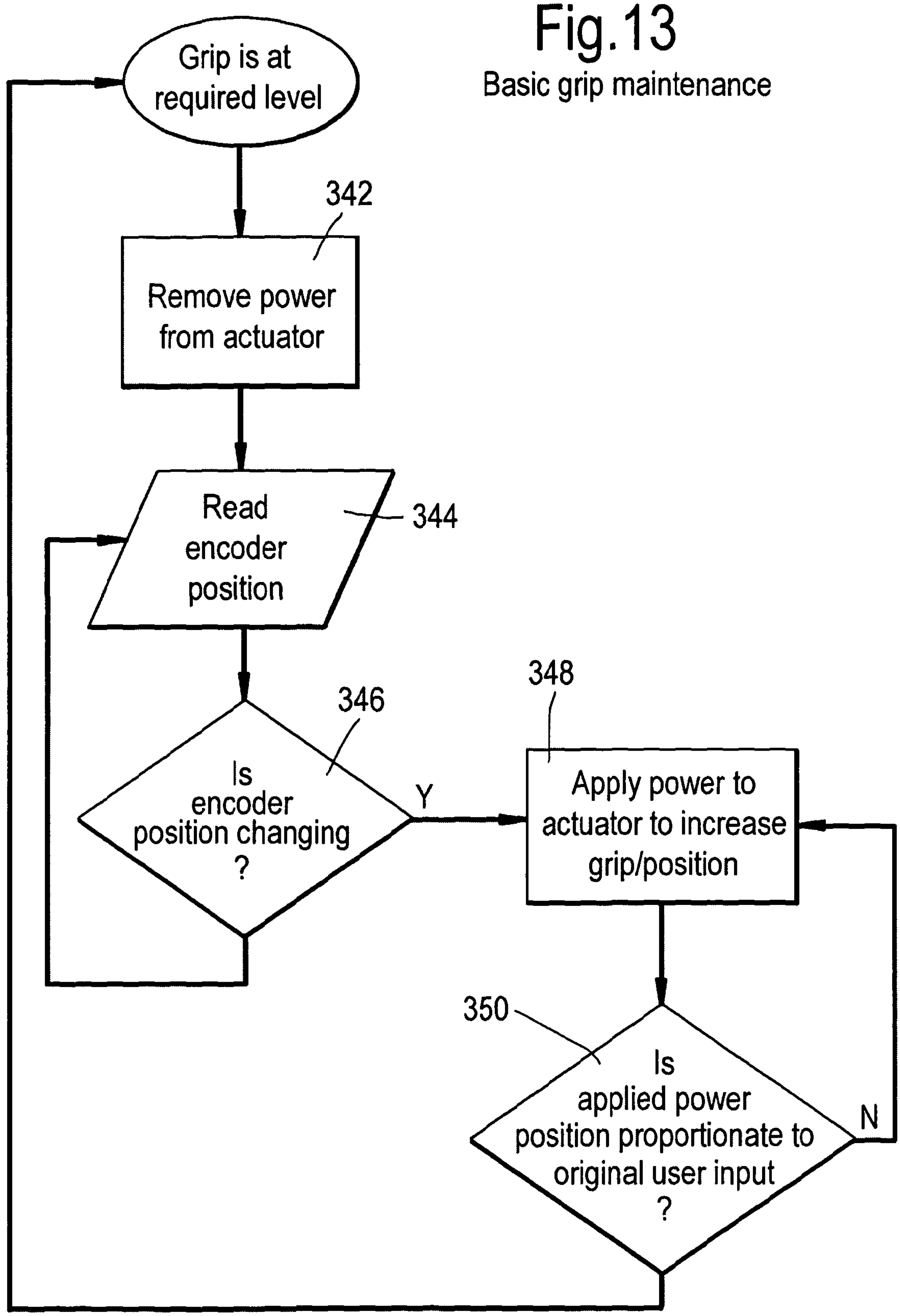
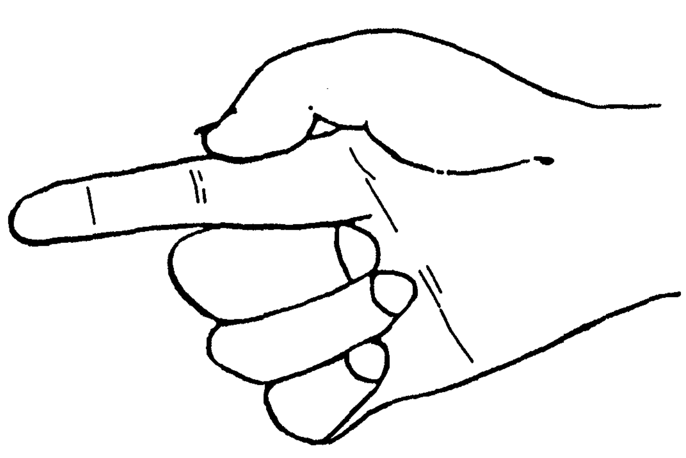
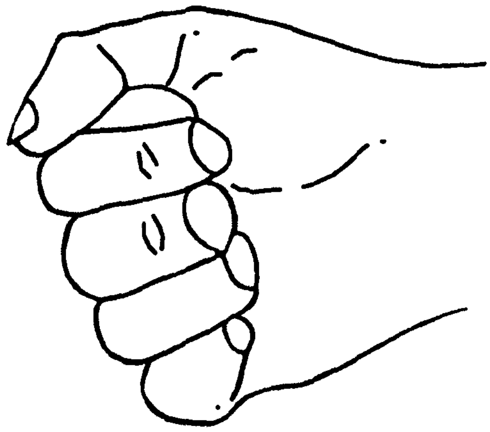


Fig.14



Point

Fig.15



Key

Fig.16

Precision