

(19) **DANMARK**



Patent- og
Varemærkestyrelsen

(12) Oversættelse af
europæisk patentskrift

(10) **DK/EP 3152012 T3**

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- (51) Int.Cl.: **B 25 J 19/00 (2006.01)** **B 25 J 17/00 (2006.01)**
- (45) Oversættelsen bekendtgjort den: **2018-06-14**
- (80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2018-03-07**
- (86) Europæisk ansøgning nr.: **15726940.8**
- (86) Europæisk indleveringsdag: **2015-06-01**
- (87) Den europæiske ansøgnings publiceringsdag: **2017-04-12**
- (86) International ansøgning nr.: **EP2015062070**
- (87) Internationalt publikationsnr.: **WO2015185474**
- (30) Prioritet: **2014-06-05 FR 1455091**
- (84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**
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- (54) Benævnelse: **ANORDNING TIL FORHÅNDSPOSITIONERING OG AFTAGELIG FASTGØRELSE AF LEDDELTE LEMMER I EN HUMANOID ROBOT**
- (56) Fremdragne publikationer:
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RT-USA: "NASA unveils 6-foot-tall humanoid robot", , 11 décembre 2013 (2013-12-11), XP055163804, Extrait de l'Internet: URL: <http://rt.com/usa/nasa- Valkyrie-texas- robot-076/> [extrait le 2015-01-21]

The invention concerns the field of mobile robotics. It relates to a device for prepositioning and removably fixing articulated limbs of a mobile robot. It also relates to a maintenance method allowing for a simple and rapid replacement of a failing articulated limb with a replacement limb.

Humanoid robotics seeks to combine in one machine the greatest number of characteristics that resemble a human being. The first aim is to approximate the human by the external appearance, the morphology or the movements. The humanoid robot generally comprises several motorised articulations capable of moving, by means of an electric motor, one limb relative to another. The most advanced humanoid robots thus comprise legs, arms or hands. They are capable of walking or of dancing in the manner of a human being. They are capable of manipulating in their hands objects of various forms. Another aim is to approximate the human by its behaviour and its intelligence. The artificial intelligence of robots is increasingly accomplished, allowing for an increasingly complex interaction with a human user.

There are many possible applications of humanoid robots. Applications are envisaged in the industrial field, for example for accessing contaminated zones which present a risk for people. Also envisaged are numerous applications in the health field, for example for assisting people with a disability. Also envisaged is use by a wider public for domestic purposes.

The assumption of large scale deployment intended for the widest possible public is generating new constraints, for example industrial, regulatory or safety constraints. The design of the most recent generations of robots now incorporates a set of constraints for meeting the emerging regulations. For example, the robot intended for the general public must not pose any safety risk, either in normal operation or in the case of a failure. Maintenance operations have to be able to be carried out, by an experienced operator or by a basic user. The aim is to take into account, in the design of the robot, after-sales related constraints, for example to allow easy diagnostics and simple and repairability.

It is already known from the prior art how to replace easily the limbs of an anthropomorphic figure, as shown in document JP 2002 227829 A. However, in this document, the limbs of the figure do not comprise motorised articulations.

To this end, the subject of the invention is a mobile robot comprising a trunk and several limbs removably linked to the trunk, characterised in that it comprises:

- for each of the limbs, means for prepositioning said limb on the trunk, and
- a single flange linked to the trunk and configured to removably fix all the limbs to the trunk.

According to the invention, each of the limbs further comprises a motorised articulation, via which said limb is positioned and fixed onto the trunk, and can be driven in movement relative to the trunk.

Advantageously, the prepositioning means associated with one of the limbs comprise an imprint formed in the trunk configured to receive the motorised articulation of said limb, and means for clipping the motorised articulation in the imprint, so as to position and hold said limb relative to the trunk by exerting a force greater than a force exerted by gravity between the trunk and said limb.

Advantageously, the clipping means of one of the limbs comprise a set of ridges formed in the motorised articulation cooperating with a set of rails formed in the imprint associated with said limb.

Advantageously, the flange is mobile relative to the trunk between an open position making it possible, for each of the limbs, to position and remove the motorised articulation relative to the trunk, and a closed position in which the flange comes to bear against the motorised articulations of all the limbs; the robot comprising removable fixing means for holding the flange in the closed position.

5 Advantageously, the flange is linked to the trunk by a pivot link configured to make it possible to displace the flange in rotation, between the open position and the closed position, and configured so that the flange is held in the open position by the effect of gravity.

Advantageously, the robot comprises, for one of the limbs, a first and a second set of flexible shims, secured respectively to the flange and the imprint associated with said limb, configured to be
10 crushed, ensuring that the motorised articulation is kept positioned and fixed onto the trunk.

Advantageously, the flexible shims are made of an elastomer foam.

Advantageously, the robot comprises, for each of the limbs, removable electronic connection means.

Advantageously, the articulation of one of the limbs is motorised about two or three axes of
15 rotation.

Advantageously, the robot comprises three limbs, one of the limbs articulated about three axes of rotation relative to the trunk being like a head, and two of the limbs articulated about two axes of rotation relative to the trunk and arranged on either side of the trunk being like two arms.

The invention also relates to a method for replacing a failing limb of a robot having the features
20 described previously with a non-failing limb, in particular the imprint and the removable fixing means, the method comprising steps consisting in:

- removing the removable fixing means,
- displacing the flange to the open position,
- removing the failing limb,
- 25 • prepositioning the non-failing limb in the imprint (32) associated with the failing limb,
- displacing the flange to the closed position,
- refitting the fixing means.

Advantageously, the method further comprises steps consisting respectively in disconnecting and connecting the electronic connection means between the robot and respectively the failing limb and the non-
30 failing limb.

The invention will be better understood and other advantages will become apparent on reading the detailed description of an embodiment given by way of example in the following figures.

Figures 1a and 1b show two examples of humanoid robots that can be equipped with a prepositioning and fixing device according to the invention,

35 Figures 2a, 2b and 2c show an example of a robot according to the invention comprising a trunk and several articulated limbs fixed to the trunk by means of a flange shown in three distinct positions,

Figures 3a and 3b show, in two perspective views, the trunk and the flange in the open position,

Figures 4a and 4b show means for prepositioning and fixing articulated limbs to the trunk of the robot.

For the sake of clarity, the same elements will bear the same references in the different figures.

Figures 1a and 1b show two examples of humanoid robots developed by the Company
5 ALDEBARAN ROBOTICS™. The humanoid robot 10 shown in Figure 1a comprises a head 1, a torso 2, two arms 3, two hands 4, two legs 5 and two feet 6. The humanoid robot 10' shown in Figure 1b comprises a head 1, a torso 2, two arms 3, two hands 4 and a skirt 7. These two robots comprise several articulations allowing the relative movement of the different limbs of the robot in order to reproduce the human morphology and the movements thereof. The robots 10 and 10' comprise, for example, an articulation 11
10 between the torso 2 and each of the arms 3. The articulation 11 is motorised about two axes of rotation to make it possible to move the arm 3 relative to the torso 2 in the manner of the movements that are possible for a shoulder of a human being.

The humanoid robot 10 also comprises several articulations for moving the legs of the robot and reproducing the walking movement, in particular articulations that can be likened to a hip, between the torso
15 and the thigh, to a knee, between the thigh and the leg, and to an ankle between the leg and the foot. Several forms of motorised articulations are implemented, moving one of the limbs about one or more degrees of freedom in rotation.

The humanoid robot 10' has a different architecture. To improve the stability and lower the centre of gravity of the robot, the robot does not comprise legs but a skirt 7 comprising, in its base, a tripod
20 capable of moving the robot around. The skirt also comprises a first articulation 12 like a knee, between a leg 7a and a thigh 7b. A second articulation 13 like a hip is mounted between the torso 2 and the thigh 7b. These two articulations 12 and 13 are pivot links motorised about an axis of rotation. The axis of rotation Xa of the articulation 12 and the axis of rotation Xb of the articulation 13 are substantially parallel to an axis linking the two shoulders of the robot, making it possible to tilt the robot forward or backward.

25 The general idea of the present invention consists in linking several limbs to the torso of the robot removably, by means a device making it possible to preposition each of the limbs and to fix the limbs using a single flange. The opening of the flange makes it possible to access rapidly the articulations of the limbs. The device allows for an easy replacement of a failing limb.

The invention is described below for a humanoid robot comprising two arms articulated about two
30 axes of rotation relative to the torso and a head articulated about three axes of rotation. Obviously, the invention is not limited to this particular example. More generally, the device according to the invention can be applied to a robot comprising several limbs articulated relative to a trunk. The robot can be a humanoid-type robot or an animal-type robot, generally referred to as mobile robots. The articulated limbs are, in general, mechanical subassemblies that are required to move relative to one another or relative to a trunk. A
35 "limb" should be understood below to be a mechanical sub-assembly of the robot like, for example, a leg, a thigh, a torso, a head, an arm, a hand, or a combination thereof. It should also be noted that, if the following figures detail a particular example of an articulation motorised about two or three degrees of freedom, it is understood that the invention applies in principle to any type of articulation, for example an articulation with one, two or three degrees of freedom in rotation, or even an articulation with one or more degrees of
40 freedom in translation. The motor is preferentially an electric motor. Other motors can be envisaged without

departing from the scope of the invention, for example a thermal, hydraulic, or compressed air motor. In the example, the device makes it possible to preposition and fix three limbs, like two arms and a head. The device does not include any lower limbs such as legs or a skirt. This selection of three limbs is a particular case and the invention covers any selection of several limbs of a robot.

5 Figures 2a, 2b and 2c show an example of a robot according to the invention comprising a torso and several articulated limbs fixed to the trunk by means of a flange shown in three distinct positions. In the description that follows, the trunk is called torso by analogy with human morphology. The robot 20 comprises a torso 11 and three limbs 12, 13 and 14. Each of the limbs is linked to the torso 11 respectively via a motorised articulation 22, 23 and 24. To simplify the reading of the drawings, only the motorised
10 articulation of the limbs is shown. An illustration of the possible form of the limbs can be deduced from Figures 1a and 1b already described. In Figures 2a to 2c, the robot is shown from the back and in a standing position. By their location and their movements relative to the torso, the limbs 12, 13 and 14 are respectively like a left arm, a right arm and a head. The robot can also comprise one or more of the lower limbs not shown in Figures 2a to 2c, which can be similar to those shown in Figures 1a and 1b.

15 The torso 11 of the robot 20 comprises a cellular supporting structure 11a and an outer shell 11b. The supporting structure 11a is preferably made of a rigid thermoplastic material. Various equipment items can be fixed to the structure 11a such as, for example, electronic modules or storage batteries.

 The articulations 22 and 23 of the arms 12 and 13 are two links motorised about two axes of rotation. The motorised articulation 22 comprises a fixed part 22a intended to be fixed to the torso 11, and a
20 mobile part 22b moving the arm 12 relative to the torso. Similarly, the motorised articulation 23 comprises a fixed part 23a fixed to the torso 11, and a mobile part 23b moving the arm 13. The articulation 24 of the head 14 is a link motorised about three axes of rotation. The articulation 24 comprises a fixed part 24a and a mobile part 24b.

 According to one aspect of the invention, the robot comprises a device for prepositioning and
25 removably fixing the limbs 12, 13 and 14 to the torso 11. The device comprises:

- for each of the limbs 12, 13 and 14, means for prepositioning said limb on the trunk 11, and
- a single flange 25 linked to the trunk 11 and configured to removably fix all the limbs to the trunk 11.

30 The flange 25 is mobile relative to the torso 11 between an open position shown in Figure 2a and a closed position shown in Figure 2c. Figure 2b shows the flange in a position that is intermediate to the open position and to the closed position. The flange 25 is linked to the torso 11 by means of a pivot link 26 with a horizontal axis. The pivot link 26 is arranged in the lower part of the flange and configured such that the open position of the flange is held stable by the effect of gravity, or, in other words, such that the flange
35 is kept in the open position by the effect of gravity. The open position of the flange shown in Figure 2a is configured to allow an operator of the robot to access the articulations of the limbs, and to mount and dismantle each of the limbs.

 The flange can be kept in the closed position by removable fixing means. In the example that is shown, holding in the closed position is ensured by four screws (not shown) passing through an upper part
40 of the flange and cooperating with four nuts 27, provided on the torso, and distributed along a horizontal

axis. In the closed position shown in Figure 2c, the flange 25 comes to bear against the motorised articulations, so as to simultaneously ensure the fixing of all the limbs relative to the torso.

Advantageously, the flange comprises a cellular structure made of a rigid thermoplastic material similar to that of the supporting structure of the torso.

5 It should be noted that Figure 2c shows an outer shell 11b partially covering the torso 11. An outer shell entirely covering the torso 11 is envisaged. Covering the flange 25 with an outer shell is also envisaged. The outer shells advantageously comprise a surface treatment giving the trunk of the robot an aesthetic appearance.

Figures 3a and 3b show, in two perspective views, the trunk and the flange in the open position.
10 The device ensures the prepositioning and the fixing of the limbs via their motorised articulation. Each of the limbs 12, 13 and 14 has an associated imprint formed in the torso 11, respectively referenced 32, 33 and 34. Each of the imprints is configured to receive the motorised articulation of the associated limb. Thus, the imprint 32 of substantially semi-tubular form is configured to receive the fixed part 22b of substantially cylindrical form of the motorised articulation 22.

15 Similarly, an imprint associated with each of the limbs is formed in the flange. The flange 25 comprises three imprints 42, 43 and 44 associated respectively with the limbs 12, 13 and 14. Each of the imprints, of substantially semi-tubular form, is intended to closely follow, when the flange is in the closed position, the substantially cylindrical form of the fixed part of the articulations of each of the limbs.

The prepositioning and removable fixing device also comprises a first set of flexible shims 28
20 secured to the torso and positioned in the imprints 32, 33 and 34 of the torso so as to be inserted between the rigid supporting structure and the fixed part of the motorised articulation of the limbs. The device also comprises a second set of flexible shims 29 secured to the flange, positioned notably in the imprints 42, 43 and 44 of the flange so as to be inserted, when the flange is in the closed position, between the flange and the fixed part of the motorised articulation of the limbs.

25 In a preferred implementation of the invention, the flexible shims 28 and 29 are made of an elastomer foam material. Thus, the flexible shims are advantageously configured to be partially crushed when the flange is in the closed position so as to ensure a balanced and non-hyperstatic holding of the motorised articulation of each of the limbs relative to the torso.

Figures 4a and 4b detail the means for prepositioning and removably fixing the articulated limbs to
30 the trunk of the robot. According to an advantageous aspect of the invention, the device comprises prepositioning means associated with each of the limbs and removable fixing means capable of fixing, by means of a single flange, all the limbs. For each of the limbs, the prepositioning means comprise, on the one hand, the imprint formed in the torso associated with said limb, as previously described by means of the references 32, 33 and 34. They also comprise means for clipping the motorised articulation in the imprint so
35 as to position and hold said limb relative to the trunk. Various embodiments of the clipping means can be envisaged without departing from the scope of the invention. In the example shown in the figures, the clipping is done by means of a set of longitudinal ridges 36 formed on the cylindrical fixed part of the articulation, intended to come into contact with a set of rails 37 formed in the structure of the torso in proximity to the imprint. When the articulation is mounted, the fixed part is first of all placed facing the
40 imprint, then it is clipped by pressing the fixed part against the imprint of the torso. The force exerted by an

operator on the fixed part makes it possible, by elastic deformation of the structure of the torso, to displace the rails 37 until they allow the passage of the ridges 36. After the ridge has passed, the rail reverts into position. The fixed part is then held in the imprint of the torso, bearing against the flexible shims, by the set of ridges and of rails. When the articulation is dismantled, an operator exerts a force against one of the rails 37 so as to make it possible to extract the articulation from the imprint of the torso. The prepositioning means can advantageously be configured so as to exert a force, between the articulation and the torso, greater than the force exerted by simple gravity between the torso and the limb. Thus, the clipping means make it possible to position and temporarily hold the limb relative to the torso without the limb being able to leave its housing and drop by the effect of gravity, without deliberate outside intervention from the operator.

The device can also comprise removable electronic connection means between the torso and at least one limb. In the example that is shown, the device comprises removable connection means between the torso and each of the limbs. The electronic connection means are configured to allow for the electrical powering and electronic driving of the motorised articulation and/or of other electrical devices, such as sensors, (microphone, optical sensor, etc.) or actuators (articulations of the elbow, of the hand, etc.). Advantageously, the device may be configured such that the clipping of the limb makes it possible to preposition the limb and connect the limb to the torso simultaneously. The unclipping of the limb also ensures the disconnection of the removable electronic connection means. Removable electronic connection means 48 are shown in Figure 4a.

The invention relates to the device for prepositioning and removably fixing limbs relative to the trunk of the robot. It also relates to a robot equipped with such a prepositioning and fixing device. The invention also relates to the method for mounting and dismantling limbs of such a robot. The operation for mounting a limb of a robot provided with the prepositioning and fixing device then comprises steps consisting in:

- prepositioning the limb relative to the torso using the prepositioning means; this step comprising sub-steps consisting in:

introducing the fixed part of the articulation of the limb into the torso and placing it facing the associated imprint in the torso,

clipping the fixed part in the imprint on the torso so as to preposition the limb relative to the torso,

- fixing the limb to the torso using the removable fixing means; this step comprising sub-steps consisting in:

displacing the flange from the open position to the closed position,

fixing the flange to the torso using the removable fixing means; the fixed part of the articulation being held in position relative to the torso by means of the flange partially crushing the flexible shims fixed to the torso and to the flange.

By a reverse method, the operation for dismantling a limb of a robot provided with the prepositioning and fixing device comprises steps consisting in:

- removing the fixing means from the flange,

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- displacing the flange from the closed position to the open position,
- unclipping the fixed part of the motorised articulation of said limb by imposing a force greater than the clipping force,
- removing the fixed part of the motorised articulation from the imprint of the torso.

5 The invention relates finally to a maintenance method for a robot, or more specifically to a method for replacing a failing limb of a robot provided with a prepositioning and removable fixing device with a non-failing limb. The replacement method comprises steps consisting in:

- removing the removable fixing means,
- displacing the flange from the closed position to the open position,
- 10 • removing said failing limb,
- prepositioning said non-failing limb in the imprint associated with the limb to be replaced,
- displacing the flange to the closed position,
- refitting the fixing means.

It should be noted that when the device comprises removable electronic connection means, the
15 method for replacing a failing limb further comprises a step consisting in disconnecting the removable electronic connection means, between the torso and the failing limb - this step being performed before or simultaneously with the step of removal of the failing limb - and a step consisting in connecting the removable electronic connection means, between the torso and the non-failing limb - this step being performed before or simultaneously with the step of prepositioning of the non-failing limb.

20

ANORDNING TIL FORHÅNDSPOSITIONERING OG AFTAGELIG FASTGØRELSE AF LEDDELTE
LEMMER I EN HUMANOID ROBOT

PATENTKRAV

1. Mobil robot, der omfatter en krop (11) og flere lemmer (12, 13, 14), der er aftageligt forbundet
5 med kroppen (11), kendetegnet ved, at den omfatter:
 - for hvert lem (12) midler (32, 28, 36, 37) til forhåndspostionering af lemmet (12) på kroppen (11) og
 - en enkelt flange (25), der er forbundet med kroppen (11) og konfigureret til aftageligt at fastgøre enheden af lemmer (12, 13, 14) til kroppen (11)
 - 10 • og ved, at hvert af lemmerne (12, 13, 14) omfatter en motoriseret leddeling (22, 23, 24), ved hjælp af hvilken lemmet (12, 13, 14) positioneres og befæstes på kroppen (11) og kan bringes i bevægelse i forhold til kroppen (11).
2. Robot ifølge det foregående krav, hvor forhåndspostioneringsmidlerne (32, 28, 36, 37), der er forbundet med ét af lemmerne (12), omfatter et aftryk (32), der er tilvejebragt i kroppen (11), og som er
15 konfigureret til at modtage lemmets (12) motoriserede leddeling (22a), og midler (36, 37) til fastklemning af den motoriserede leddeling (22a) i aftrykket (32), således at lemmet (12) positioneres og fastholdes i forhold til kroppen (11), ved at udøve en kraft, der er større end tyngdekraften, mellem kroppen (11) og lemmet (12).
3. Robot ifølge krav 2, hvis midler til fastklemning (32, 28, 36, 37) af ét af lemmerne (12) omfatter
20 en enhed af riller (36), der er tilvejebragt i den motoriserede leddeling (22a), som samvirker med en enhed af skinner (37), der er tilvejebragt i aftrykket (32), der er forbundet med lemmet (12).
4. Robot ifølge krav 2 eller 3, hvis flange (25) er bevægelig i forhold til kroppen (11) mellem en åben position, der gør det muligt for hvert af lemmerne (12, 13, 14) at positionere og fjerne den motoriserede leddeling (22, 23, 24) i forhold til kroppen (11), og en lukket position, hvori flangen (25) ligger an mod de
25 motoriserede leddelinger (22, 23, 24) af samtlige lemmer (12, 13, 14); hvor robotten omfatter aftagelige fastgørelsesmidler (27) til at bevare flangen (25) i lukket position.
5. Robot ifølge krav 4, hvis flange (25) er forbundet med kroppen (11) af en drejeforbindelse (26), der er konfigureret til at tillade forskydning af flangen (11) i rotation, mellem den åbne position og den lukkede position, og er konfigureret således, at flangen (25) holdes i den åbne position ved hjælp af
30 tyngdekraft.
6. Robot ifølge krav 4 eller 5, der omfatter for ét af lemmerne (12) en første og en anden enhed af smidige kilder (29, 28), der henholdsvis er forbundet med flangen (25) og aftrykket (32), der er forbundet med lemmet (12), der er konfigureret til at blive knust, hvorved der sikres bevaring af den motoriserede leddeling (22) positioneret og fastgjort på kroppen (11).
- 35 7. Robot ifølge krav 6, hvis fleksible kiler (28, 29) består af et elastomerskum.
8. Robot ifølge et af de foregående krav, der omfatter for hvert af lemmerne (12, 13, 14) midler til aftagelige elektronisk forbindelse (48).
9. Robot ifølge et af de foregående krav, hvor leddelingen (22) af ét af lemmerne (12) er motoriseret omkring to eller tre rotationsakser.

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10. Robot ifølge et af de foregående krav, der omfatter tre lemmer (12, 13, 14), hvoraf ét af lemmerne (14), der er ledforbundet omkring tre rotationsakser i forhold til kroppen (11), er som et hoved, og to af lemmerne (12, 13), der er ledforbundet omkring to rotationsakser i forhold til kroppen (11) og anbragt på begge sider af kroppen (11), er som to arme.
- 5 11. Fremgangsmåde til udskiftning af et defekt lem på en robot ifølge krav 4 med et ikke-defekt lem, kendetegnet ved, at den omfatter trinnene, der består i at:
- fjerne de aftagelige fastgørelsesmidler (27),
 - forskyde flangen (25) til åben position,
 - fjerne det defekte lem,
 - 10 - forhåndspositionere det ikke-defekte lem i aftrykket (32), der er forbundet med det defekte lem,
 - forskyde flangen (25) til lukket position,
 - genmontere fastgørelsesmidlerne (27).
12. Fremgangsmåde ifølge krav 11 til en robot ifølge krav 8, der endvidere omfatter trinnene, der
- 15 består i henholdsvis at frakoble og tilkoble de elektroniske forbindelsesmidler (48) mellem henholdsvis robotten og det defekte lem og det ikke-defekte lem.

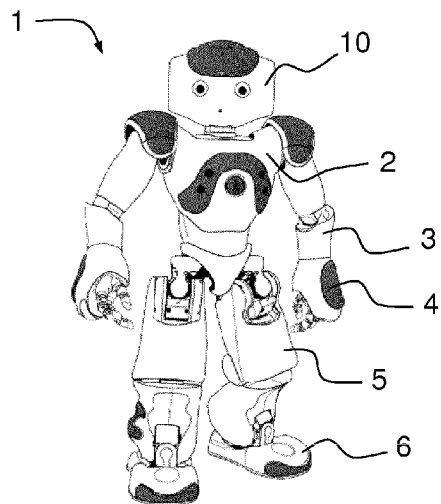


FIG. 1a

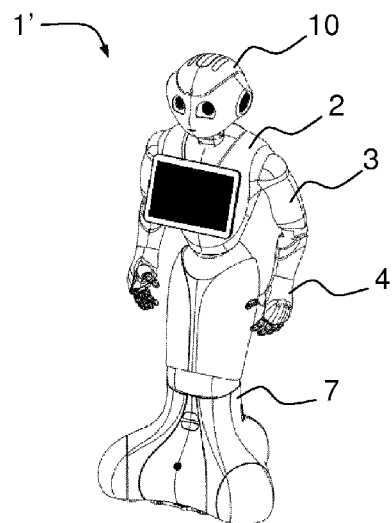


FIG. 1b

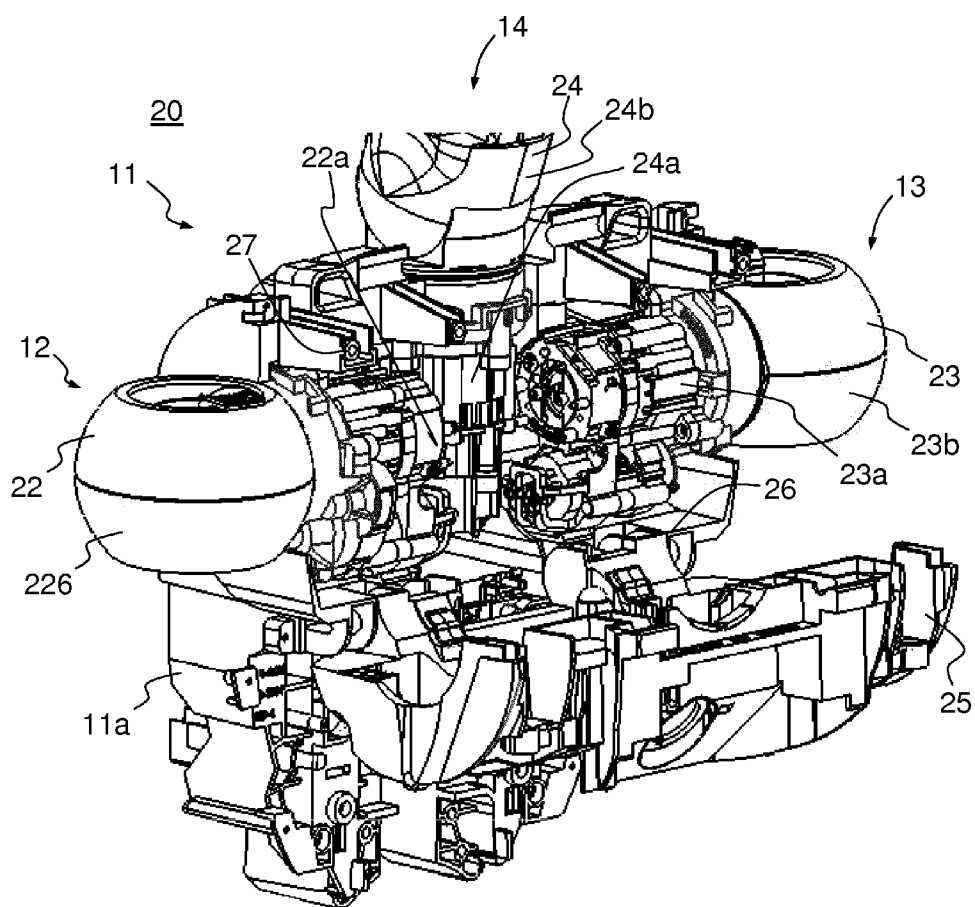


FIG.2a

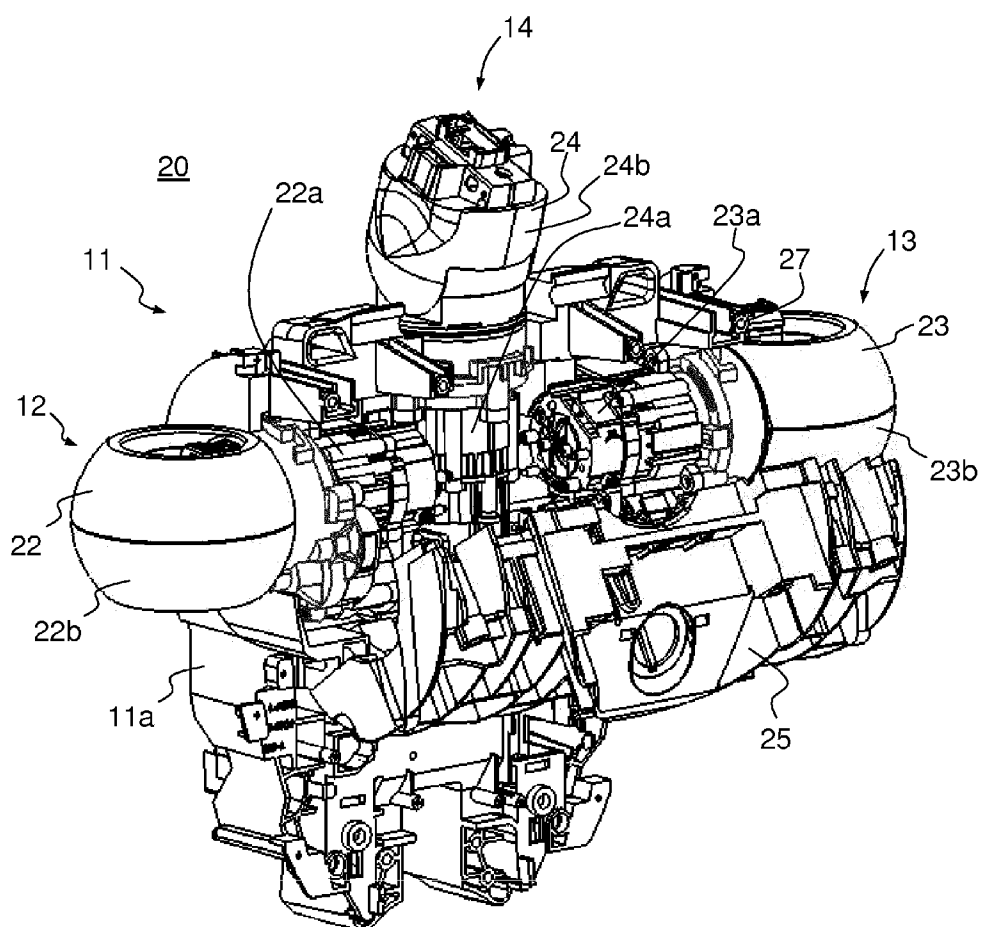


FIG.2b

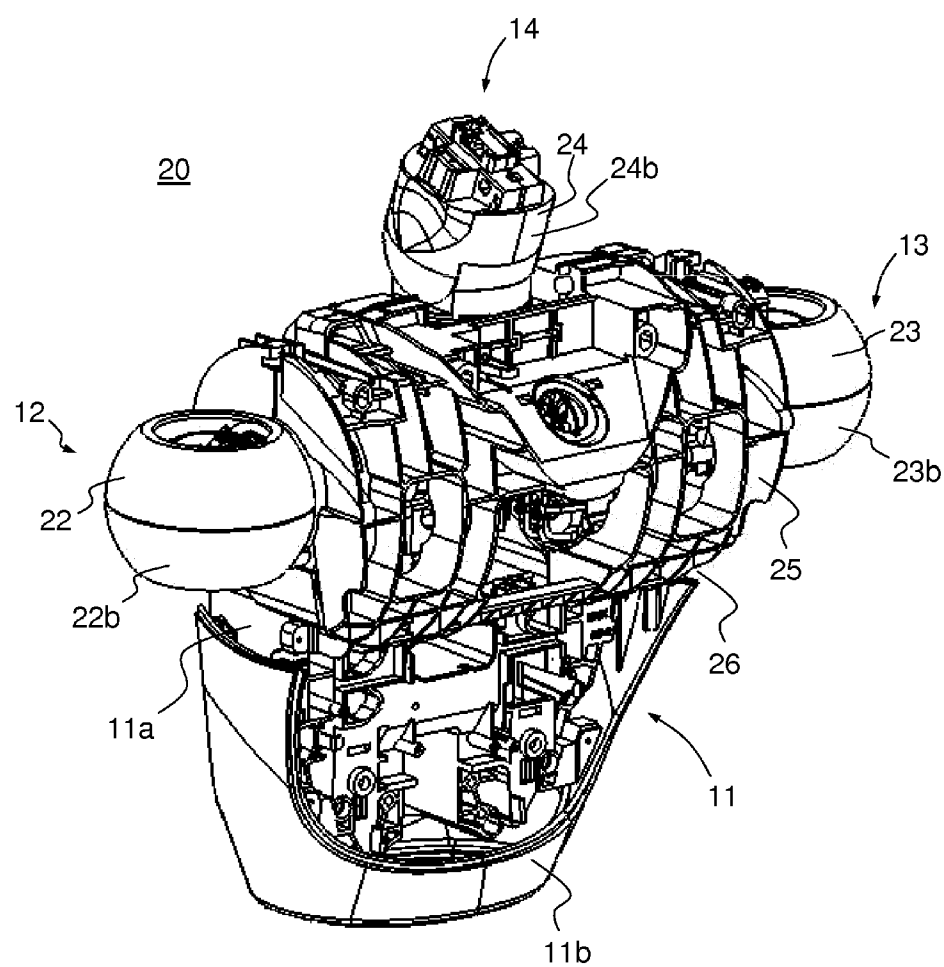


FIG.2c

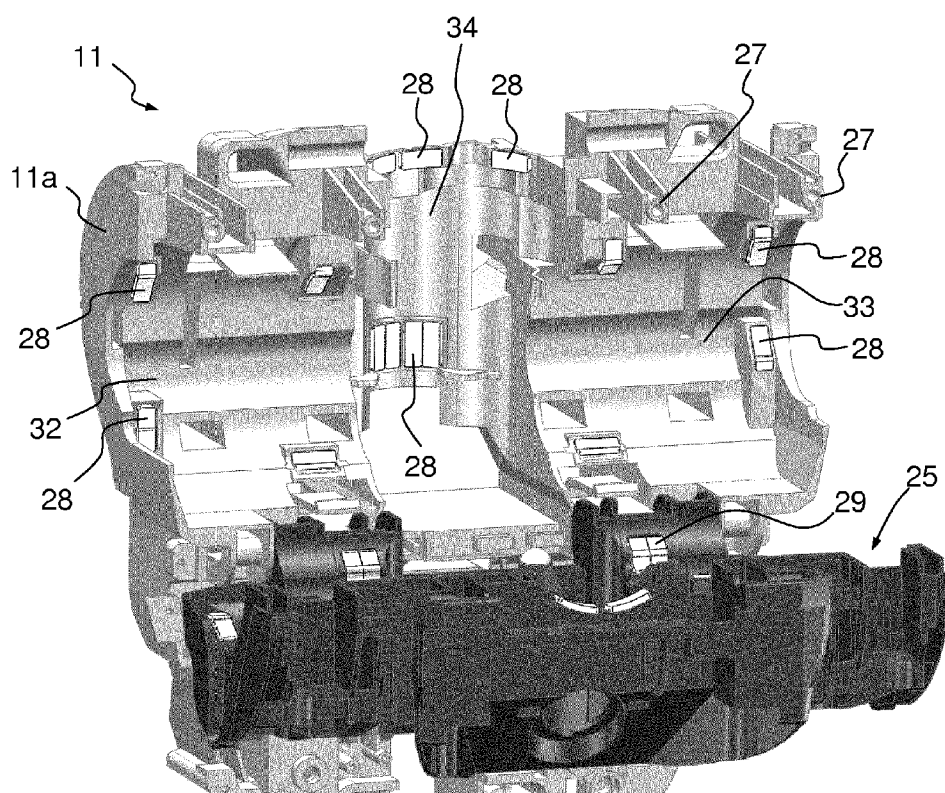


FIG.3a

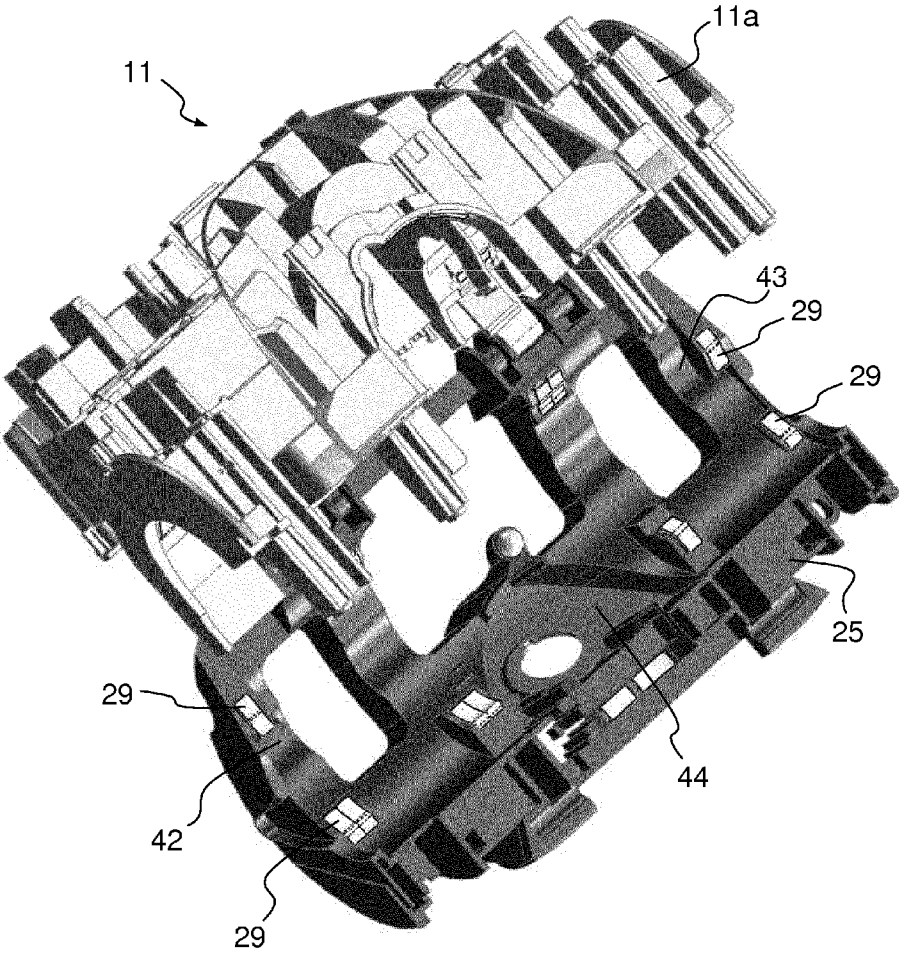


FIG.3b

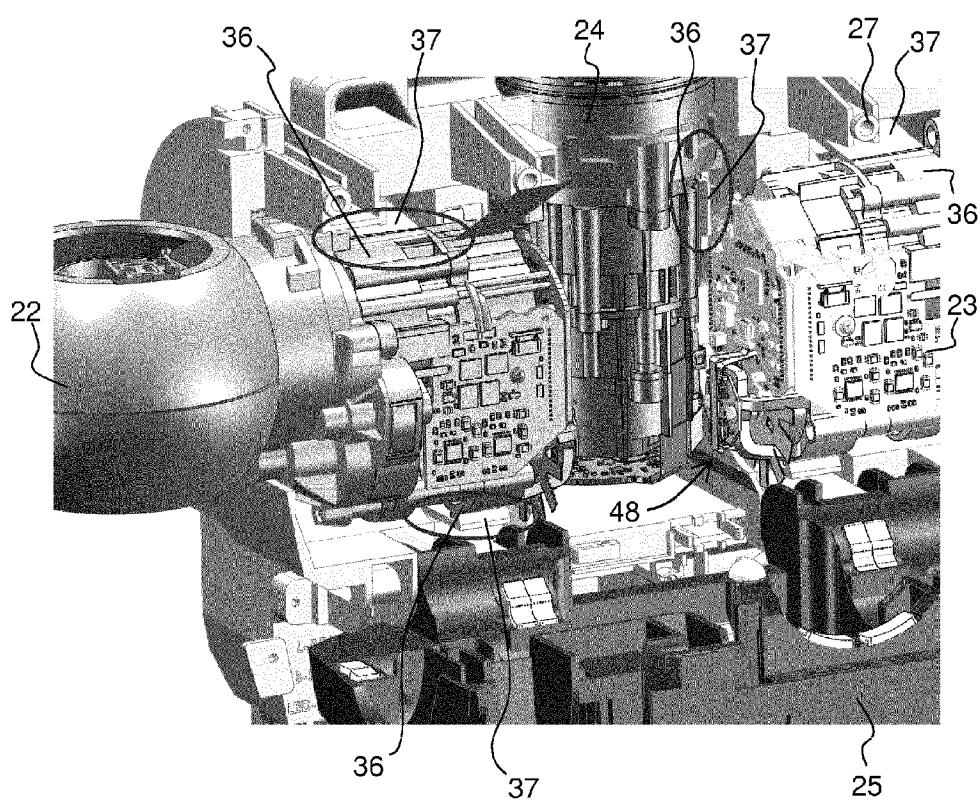


FIG.4a

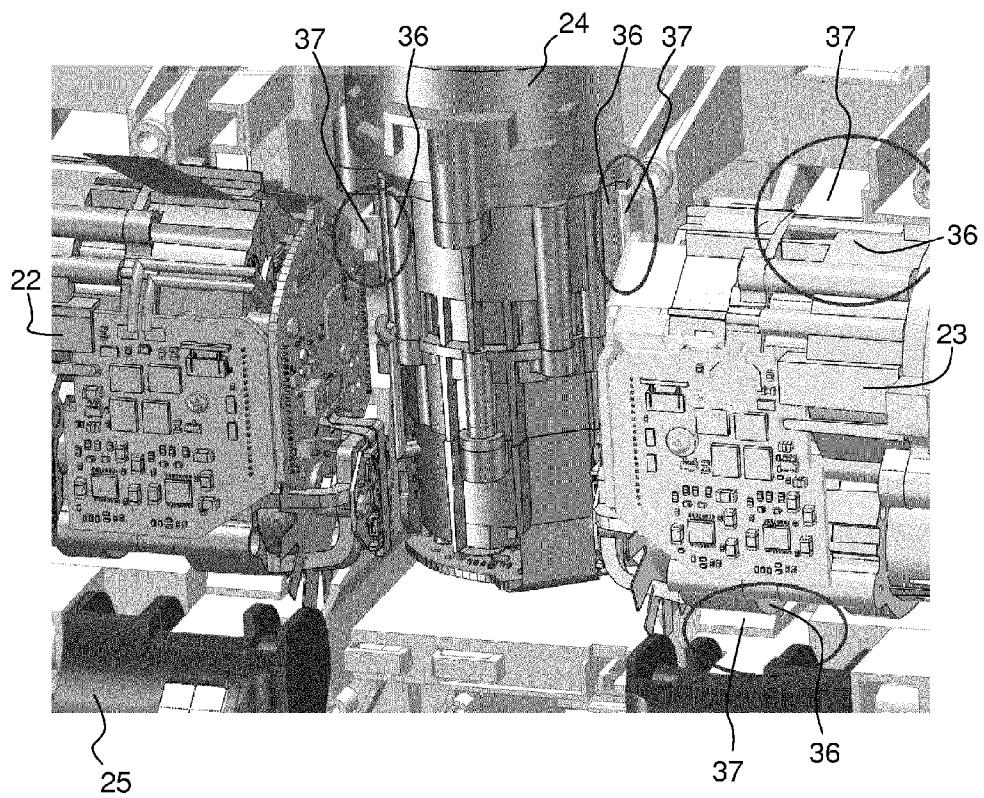


FIG.4b