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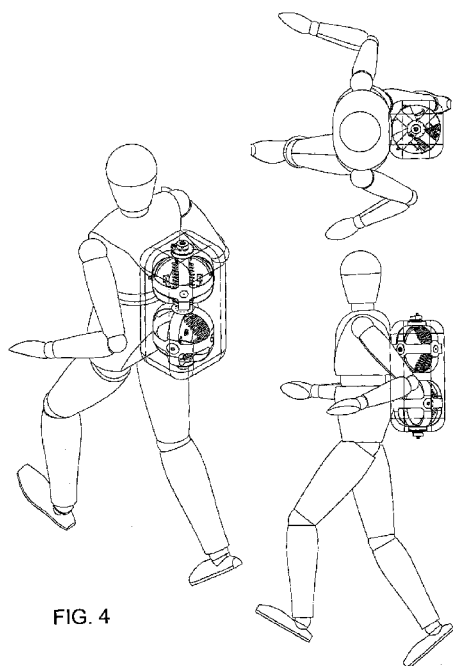


FIG. 4

(57) Abstract: Portable gyroscopic balance assist-
ance device for providing a corrective torque to a
user, including a gyroscope comprising a flywheel
(3) mounted in an inner gimbal (4) having an inner
axle (4'), which inner gimbal (4) is mounted in an in-
termediate gimbal (5) having an intermediate axle
(5'), which intermediate gimbal (5) is mounted in an
outer gimbal (6) having an outer axle (6'), wherein
the intermediate axle (5') is orthogonal with respect
to the inner axle (4') and with respect to the outer
axle (6'), and wherein the outer gimbal is remova-
bly wearable by the user, wherein one of the interme-
diate axle (5') and the outer axle (6') comprises a
torque limited inter-gimbal coupling (1, 2) that gives
way when a predefined torque threshold is exceeded,
thereby preventing a corrective torque being trans-
ferred onto the user.

Portable gyroscopic balance assistance device

The invention relates to a portable gyroscopic balance assistance device for providing a corrective torque to a user, including a gyroscope comprising a flywheel mounted in an inner gimbal having an inner axle, which inner gimbal is mounted in an intermediate gimbal having an intermediate axle, which intermediate gimbal is mounted in an outer gimbal having an outer axle, wherein the intermediate axle is orthogonal with respect to the inner axle and with respect to the outer axle. The preamble relates to a portable gyroscopic balance assistance device, with a general construction of the gyroscope forming part of it. Occasionally the gimbals may be powered with motor drives to effect rotary movement of the gimbals.

US20140260714 A1 and the article "Gyroscopic assistance for human balance", by Dustin Li and Heike Vallery, the 12th IEEE international workshop on advanced motion control, March 25 - 27, 2012, Sarajevo, Bosnia and Herzegovina, disclose the application of a backpack worn by a user to provide the user with balance assist. The backpack contains a set of a number of gyroscopes, such that the gyroscopes are located close to the center of mass of the user. It is suggested to apply variable-speed control moment gyros, wherein the gimbals speeds and rotation speeds of the flywheels are controlled. Additionally it is suggested to provide an open loop system that does not interfere with the natural control system of the user.

The article "Design of a wearable scissored-pair control moment gyroscope for human balance assist", by Jimmy Chiu and Ambarish Goswami, Proceedings of the ASME 2014 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, August 17 - 20, 2014, Buffalo USA relates to gyroscopes used for human balance assist. It reports on research investigating the feasibility of using a wearable scissored pair of gyroscopes, each gyroscope comprising a fast spinning flywheel mounted on a gimbal. The gimbal motion changes the direction of the flywheel rotation axis, which generates a reactionless torque. The paper describes a dual flywheel design, the flywheels having equal inertia and

angular velocities. The gimbals of both flywheels are rotated in opposite direction so that the two output torques add up normal to the sagittal plane of the user but cancel each other out normal to the frontal plane.

5 US2003/0116363 discloses a robotic appliance provided with a gyroscope having a flywheel rotating about an axle and housed in a casing which is connected to an upper part of the robot by a mechanical connection which permits rotational movements about two non-parallel axes, the appliance further comprising sensors for the measurement of an off-balance, and having means to balance the appliance by exerting opposing torques using the support of the gyroscopic flywheel via actuators and an associated command system able to take advantage of the actuators and sensors of the appliance to provide it with equilibrium.

15 The invention has as an object to provide a portable gyroscopic balance assistance device for providing a corrective torque to a user, which is safely usable as a balance assist or in general as an assist for and during movements, particularly although not exclusively for humans.

20 The portable gyroscopic balance assistance device of the invention is embodied with the features of one or more of the appended claims.

25 In a first aspect the portable gyroscopic balance assistance device of the invention has the feature that one of the intermediate axle and the outer axle comprises a torque limited inter-gimbal coupling that gives way when a predefined torque threshold is exceeded, thereby preventing a corrective torque being transferred onto the user. Due to this construction, the gyroscope can be safely used in an appliance for balance assist.

30 Suitably the torque limited inter-gimbal coupling has a first status and a second status, wherein in the first status an exerted torque on said coupling is below a predefined torque value and an orientation of the inner axle, the intermediate axle and the outer axle is maintained orthogonal, and that in the second status wherein an exerted torque on said coupling surpasses said predefined torque value the coupling is released so as to enable that the flywheel can occupy an orientation

which is independent of the outer gimbal's orientation.

Since the second status interrupts the normal gyroscopic functionality of the device, and this second status is inferred in conditions that are identified as potentially dangerous for a user, safe operational conditions for the user are secured. This applies in particular when the correctional torque inferred by the gyroscope surpasses a predefined threshold.

As mentioned the releasable coupling can be positioned either in the intermediate axle or in the outer axle. In a most preferred embodiment of the invention in which the releasable coupling is provided in the intermediate axle, the first status entails that the mutually orthogonal orientation of the inner axle, the intermediate axle, and the outer axle with respect to each other is maintained, and that the second status enables that at least one of the inner axle, the intermediate axle, and the outer axle is capable to depart from their mutually orthogonal orientation.

It is remarked that a certain deviation of the said axles with respect to an exactly orthogonal orientation is allowable since this corresponds with torques that are within the aforementioned range that does not surpass the predefined safety threshold.

There are numerous ways in which the torque limited inter-gimbal couplings can be embodied, such as:

- an overload-protecting "torque limiter", which disengages when a) a certain maximal torque is exceeded or b) an external trigger event is provided by a control system: examples are provided on

<http://www.mayr.com/en/products/torque-limiters/>

- a rotary spring
- a rotary damper (which is in fact a brake)
- a controlled damper wherein the damping coefficient is depending on external commands
- a combination of spring and damper
- a jaw coupling (which is in fact also a rotary spring):

<http://www.lovejoy-inc.com/products/jaw-type-couplings.aspx>

- an electromagnetic clutch or brake:
<http://www.mayr.com/en/products/electromagnetic-clutches-brakes/>
 - Further examples can be found in:
- 5 - Plooij, M.; Mathijssen, G.; Cherelle, P.; Lefeber, D. & Vanderborght, B. Lock Your Robot: A Review of Locking Devices in Robotics *IEEE Robot Autom Mag*, **2015**, 22, 106-117.

10 Preferably the torque limited inter-gimbal couplings comprise a torque limiter or clutch, and more preferably the couplings additionally or instead of the torque limiter or clutch comprise a spring or springs, and even more preferably a damper or dampers may be provided instead or in addition to the spring or springs.

15 The switching behaviour between the first status and the second status of the torque limited inter-gimbal couplings can effectively be provided by arranging the spring or springs in a configuration where they form a bi-stable mechanism.

20 In another aspect the portable gyroscopic balance assistance device of the invention includes at least one encoder for measuring an angle between the intermediate gimbal and one of the inner gimbal and the outer gimbal. This measured angle, in combination with design parameters of the gyroscope such as the spring or damper characteristics, can be used to calculate
25 the torque that the gyroscope provides to the body it is mounted to. The determined value of the torque can then be used for switching between the first status and the second status of the device.

30 In still another aspect of the invention the portable gyroscopic balance assistance device, that includes a gyroscope which is conventionally provided with a first motor drive for the flywheel, is embodied with no more than two motor drives wherein a second motor drive is provided for relative movement of the intermediate gimbal with respect to either the outer
35 gimbal (in a first embodiment) or (in a second alternative embodiment) with respect to the inner gimbal. The remaining axle is equipped with the torque limited inter-gimbal coupling and has no motor drive, to enable that in a first state indeed the inner axle and a reference axis that in one embodiment may cor-

respond to the outer axle, can be at a slight deviating angle with respect to an exactly orthogonal orientation, and that in a second state the flywheel can indeed occupy an orientation which is independent of the outer gimbal's orientation.

5 It is preferable that the portable gyroscopic balance assistance device is provided with at least two gyroscopes that are mounted in a wearable enclosure. In this appliance it is preferable that the at least two gyroscopes have their flywheel axles non-aligned with respect to each other in their normal
10 configuration.

The invention will hereinafter be further elucidated with reference to the drawing of an exemplary embodiment of an apparatus according to the invention that is not limiting as to the appended claims.

15 In the drawing:

-figures 1A and 1B show a basic and a more complex construction, respectively of a gyroscope forming part of a portable gyroscopic balance assistance device according to the invention according to a first preferred embodiment;

20 -figure 2 shows a basic construction of a gyroscope forming part of a portable gyroscopic balance assistance device according to the invention according to a second alternative embodiment;

25 -figures 3A and 3B show an embodiment of a gyroscope forming part of a portable gyroscopic balance assistance device of the invention provided with springs forming a bi-stable mechanism and in which a variation of the angular orientation of the gimbal axles occurs; and

30 -figure 4 shows a portable gyroscopic balance assistance device according to the invention provided with two gyroscopes in a wearable enclosure, worn by a user.

Whenever in the figures the same reference numerals are applied, these numerals refer to the same parts.

35 Figure 1A and figure 2 schematically show a first and second embodiment of a gyroscope of the invention. Figure 1B shows the gyroscope of figure 1A providing a closer view at its actual realization wherein an electro adhesive clutch forms part of it as will be mentioned hereinafter.

The gyroscope of figures 1A, 1B and 2 forms part of a

portable gyroscopic balance assistance device according to the invention, which embodiments correspond with each other in that each embodiment comprises a flywheel 3 mounted in an inner gimbal 4 having an inner axle 4', which inner gimbal 4 is mounted in an intermediate gimbal 5 having an intermediate axle 5', which intermediate gimbal 5 is mounted in an outer gimbal 6 having an outer axle 6'. The intermediate axle 5' is orthogonal with respect to the inner axle 4' and with respect to the outer axle 6'. The outer gimbal 6 is eventually linked to a support forming part of a portable gyroscopic balance assist device in which the gyroscope can be used, as will be shown hereinafter with reference to figure 4.

In the embodiments of figures 1A and 1B, and the embodiment of figure 2 there is a torque limited inter-gimbal coupling 1, 2 between gimbals of the gyroscope, which coupling is releasable to provide a first status and a second status, wherein in the first status the gyroscope is in the normal operational mode and in the second status the flywheel 3 can occupy an orientation which is independent of the outer gimbal's 6 orientation. In the preferred embodiments of figs. 1A, 1B, (and the embodiment of fig. 3A and 3B), the inner gimbal 4 is coupled to the intermediate gimbal 5 via the coupling 1, 2. In the alternative embodiment of fig 2 the intermediate gimbal 5 is coupled to the outer gimbal 6 via the coupling 1, 2. In figure 1B the inter-gimbal coupling 1, 2 is embodied as an electro adhesive clutch. Evidently this is not the only possible embodiment of the inter-gimbal coupling. It is for instance also possible to apply a magnetorheological clutch to provide a releasable coupling.

The orientation of the outer gimbal 6 of the gyroscope corresponds to the posture of the user. The torque limited inter-gimbal coupling 1, 2 is arranged to give way when a predefined torque threshold is exceeded, thereby preventing a corrective torque being transferred onto the user. Accordingly the torque limited inter-gimbal releasable coupling 1, 2 has a first status and a second status, wherein in the first status an exerted torque on said coupling is below a predefined torque value and an orientation of the inner axle 4', the intermediate axle 5' and the outer axle 6' is maintained orthogonal and the

gyroscope is in the normal operational mode. Conversely in the second status wherein an exerted torque on said coupling surpasses said predefined torque value, the coupling is released so as to enable that the flywheel 3 can occupy an orientation which is independent of the outer gimbal's 6 orientation.

Taking further reference to figures 1A and 1B, with the torque limited inter-gimbal coupling 1, 2 provided in the intermediate axle 5', in this embodiment the first status entails a first orientation of the inner gimbal 4 with the flywheel 3 that corresponds to normal operation that is secured by maintaining the mutually orthogonal orientation of the inner axle 4', the intermediate axle 5', and the outer axle 6' with respect to each other. In the second status however the inner gimbal 4 with the flywheel 3 is enabled to depart from the first orientation by enabling that at least one of the inner axle 4', the intermediate axle 5', and the outer axle 6' is capable to depart from their mutually orthogonal orientation. This is a very suitable way to implement the apparatus of the invention and to realize safe operation of the gyroscope when it is worn by a user, by arranging that in the second status the flywheel 3 can occupy an orientation which is independent of the outer gimbal's 6 orientation.

The inventors note with reference to figure 2 that it is also possible to realize an alternative embodiment in which the torque limited inter-gimbal coupling 1, 2 is comprised in the outer axle 6', wherein the coupling 1, 2 again has a first status and a second status, in which first status the gyroscope operates normally and wherein in the second status the flywheel 3 can occupy an orientation which is independent of the third outer gimbal's 6 orientation.

It is further remarked with reference to the mentioned embodiments that in the first status of the torque limited inter-gimbal coupling 1, 2 a predefined range of angles is possible in which the inner axle 4' may slightly deviate from an exactly orthogonal orientation with respect to a reference axis z that associates with the outer gimbal 6. Within said predefined range of angles the said axle 4' is deemed essentially orthogonal to said reference axis within the terms of this invention. With reference to the first embodiment shown in figure 1, the

reference axis z is co-linear with the outer axle 6', and with reference to the second embodiment shown in figure 2 such reference axis is at right angles with the outer axle 6'.

With reference again to the first embodiment of figures 1A and 1B, the releasable coupling 1, 2 comprises as already mentioned preferably a torque limiter or clutch 1. This element allows free rotation of the inner gimbal 4 with respect to the intermediate gimbal 5 once the coupling is released, that is when the torque has exceeded a maximum threshold value.

In the second embodiment of figure 2, the torque limiter or clutch 1 of the releasable coupling 1, 2 ensures free rotation of the intermediate gimbal 5 with respect to the outer gimbal 6 once the coupling is released, that is when the torque has exceeded the maximum threshold value.

Further the releasable coupling 1, 2 applied in the gyroscope of the device of the invention preferably comprises at least one spring or springs 2. The spring 2 enables in the first embodiment of figures 1A and 1B a deflection of the inner gimbal 4 with respect to the intermediate gimbal 5. In the second embodiment of figure 2 this enabled deflection is between the intermediate gimbal 5 and the outer gimbal 6. It is beneficial that the spring or springs are arranged such that they form a bi-stable mechanism as will be explained hereinafter with reference to figures 3A and 3B. Figure 1B further shows that a damper or dampers 12 may be added to damp the movement of the springs 2. This will also be further shown in figures 3A and 3B to be discussed hereinafter.

Turning back to the first embodiment shown in figure 1A, the gyroscope according to this embodiment includes at least one encoder 8 for measuring the deflection angle between the inner gimbal 4 and the intermediate gimbal 5. This deflection angle can be used to determine the torque that the gyroscope provides, and it can in addition be used to actuate the torque limiter or clutch 1 to move the releasable coupling 1, 2 from the first to the second status.

The gyroscope according to the first embodiment is provided with a first motor drive 9 for the flywheel 3, and has no more than two motor drives wherein a second motor drive 7 is provided for relative movement of the intermediate gimbal 5

with respect to the outer gimbal 6. The remaining axle 5' between the inner gimbal 4 and the intermediate gimbal 5 is equipped with the releasable coupling 1, 2 and has no motor drive, to enable that in a first state the inner axle 4' and the outer axle 6' can be at a slight deviating angle with respect to an exactly orthogonal orientation, or that in a second state the flywheel 3 can occupy an orientation which is independent of the outer gimbal's 6 orientation.

In the second alternative embodiment shown in figure 2 the position of the releasable coupling 1, 2 and the second motor drive 7 is interchanged and then the second motor drive can be used for relative movement of the inner gimbal 4 with respect to the intermediate gimbal 5, and instead of a motor drive the releasable coupling 1, 2 is then provided between the intermediate gimbal 5 and the outer gimbal 6. This enables that in a first state the inner axle 4' and a reference axis z that is at right angles with respect to the outer axle 6' can be at a slight deviating angle with respect to an exactly orthogonal orientation, or that in a second state the flywheel 3 can occupy an orientation which is independent of the outer gimbal's 6 orientation.

Figures 3A and 3B show an embodiment of a gyroscope which is a special case of the basic construction shown in figure 1. In this embodiment, the inner gimbal 4 is realized in the form of a casing that encloses the flywheel 3, and the releasable coupling 1, 2 is realized in the form of two or more linear springs in combination with a lever 10 that can rotate with respect to a support 11 that is rigidly connected to the flywheel casing 4. In the first status of this releasable coupling, the lever 10 engages with the middle gimbal 5. The springs are attached on one side to the flywheel casing 4 and on the other side to the lever 10. This configuration forms a bi-stable mechanism. This mechanism is in equilibrium when the inner axle 4' and the outer axle 6' are exactly orthogonal. When the said axles 4' and 6' deviate slightly from an exactly orthogonal configuration, opposing moments are generated on the inner gimbal 4 and the intermediate gimbal 5 that tend to drive the inner axle 4' and outer axle 6' back to their exactly orthogonal orientation. The bi-stable mechanism will enter a sec-

ond equilibrium once the moment it transmits exceeds a certain threshold value. At that point, the lever arm 10 will flip to either side with respect to its support 11 and disengage from the intermediate gimbal 5. This is reflected in fig. 3A and 3B
5 respectively, which both depict the situation that the flywheel 3 occupies an orientation that is independent of the outer gimbal's 6 orientation. This corresponds to the second status of the releasable coupling 1, 2. Within the first status, the moment that is transmitted by the mechanism can be calculated
10 from the measured angle between the inner axle 4' and outer axle 6' in combination with the known force-displacement characteristics of the springs.

Figures 3A and 3B further shows that the angles that the respective axles can occupy with respect to each other may
15 vary, preferably within a range of approximately 10°. Further both figures 3A and 3B show that the flipping movement causing the compression or relaxation of the springs 2 is subject to the damping action of dampers 12 that, like the springs 2, connect at their opposing ends to the casing 4 of the flywheel 3
20 and to the lever arm 10.

Figure 4 shows the portable gyroscopic balance assistance device for providing a corrective torque to a user according to the invention. The balance assistance device is provided with at least two gyroscopes that are mounted in a
25 wearable enclosure. In this appliance it is preferable that the two gyroscopes have their flywheel axles non-aligned with respect to each other in their normal configuration.

Whenever in the figures the same reference numerals are applied, these numerals refer to the same parts.

30 Although the invention has been discussed in the foregoing with reference to an exemplary embodiment of the gyroscope of the invention, the invention is not restricted to this particular embodiment which can be varied in many ways without departing from the scope of the invention. The discussed exemplary embodiment shall therefore not be used to construe the
35 appended claims strictly in accordance therewith. On the contrary the embodiment is merely intended to explain the wording of the appended claims without intent to limit the claims to this exemplary embodiment. The scope of protection of the in-

vention shall therefore be construed in accordance with the appended claims only, wherein a possible ambiguity in the wording of the claims shall be resolved using this exemplary embodiment.

CLAIMS

1. Portable gyroscopic balance assistance device for providing a corrective torque to a user, including a gyroscope comprising a flywheel (3) mounted in an inner gimbal (4) having an inner axle (4'), which inner gimbal (4) is mounted in an intermediate gimbal (5) having an intermediate axle (5'), which intermediate gimbal (5) is mounted in an outer gimbal (6) having an outer axle (6'), wherein the intermediate axle (5') is orthogonal with respect to the inner axle (4') and with respect to the outer axle (6'), and wherein the outer gimbal is removably wearable by the user, **characterized in that** one of the intermediate axle (5') and the outer axle (6') comprises a torque limited inter-gimbal coupling (1, 2) that gives way when a predefined torque threshold is exceeded, thereby preventing a corrective torque being transferred onto the user.

2. Portable gyroscopic balance assistance device according to claim 1, **characterized in that** the torque limited inter-gimbal coupling (1, 2) has a first status and a second status, wherein in the first status an exerted torque on said coupling is below a predefined torque value and an orientation of the inner axle (4'), the intermediate axle (5') and the outer axle (6') is maintained orthogonal, and that in the second status wherein an exerted torque on said coupling surpasses said predefined torque value the coupling is released so as to enable that the flywheel (3) can occupy an orientation which is independent of the outer gimbal's (6) orientation.

3. Portable gyroscopic balance assistance device according to claim 1 or 2, **characterized in that** the torque limited inter-gimbal coupling (1, 2) is provided in the intermediate axle (5'), and that in the first status the mutually orthogonal orientation of the inner axle (4'), the intermediate axle (5'), and the outer axle (6') with respect to each other is maintained, and wherein in the second status it is enabled that at least one of the inner axle (4'), the intermediate axle (5'), and the outer axle (6') is capable to depart from their mutually orthogonal orientation.

4. Portable gyroscopic balance assistance device according to any one of claims 1 - 3, **characterized in that** the

torque limited inter-gimbal coupling (1, 2) comprises a torque limiter or clutch (1).

5. Portable gyroscopic balance assistance device according to any one of claims 1 - 4, **characterized in that** the torque limited inter-gimbal coupling (1, 2) comprises a spring or springs (2) connecting at its opposite ends directly or indirectly to different gimbals.

6. Portable gyroscopic balance assistance device according to claim 5, **characterized in that** the spring or springs (2) are arranged to constitute or form part of a bi-stable mechanism.

7. Portable gyroscopic balance assistance device according to claim 5 or 6, **characterized in that** the spring or springs (2) are attached on a first side to the inner gimbal (4) for the flywheel (3) and on another side opposite to the first side to a lever (10) that is rotatable with respect to a support (11) that is rigidly connected to the inner gimbal (4) holding the flywheel (3), and wherein the lever (10) connects to the intermediate gimbal (5).

8. Portable gyroscopic balance assistance device according to any one of claims 1 - 7, **characterized in that** it is provided with a damper or dampers (12).

9. Portable gyroscopic balance assistance device according to any one of the previous claims 1 - 8, **characterized in that** it includes at least one encoder (8) for measuring an angle between the intermediate gimbal (5) and one of the inner gimbal (4) and outer gimbal (6).

10. Portable gyroscopic balance assistance device according to any one of the previous claims 1 - 9, provided with a first motor drive (9) for the flywheel (3), **characterized in that** it has no more than two motor drives wherein a second motor drive is provided for relative movement of the intermediate gimbal (5) with respect to the outer gimbal (6) or for relative movement between the inner gimbal (4) and the intermediate gimbal (5).

11. Portable gyroscopic balance assistance device according to any one of claims 1 - 10, **characterized in that** it is provided with at least two gyroscopes mounted in a wearable enclosure.

12. Portable gyroscopic balance assistance device according to claim 11, **characterized in that** the at least two gyroscopes have their flywheel axles non-aligned during normal operation.

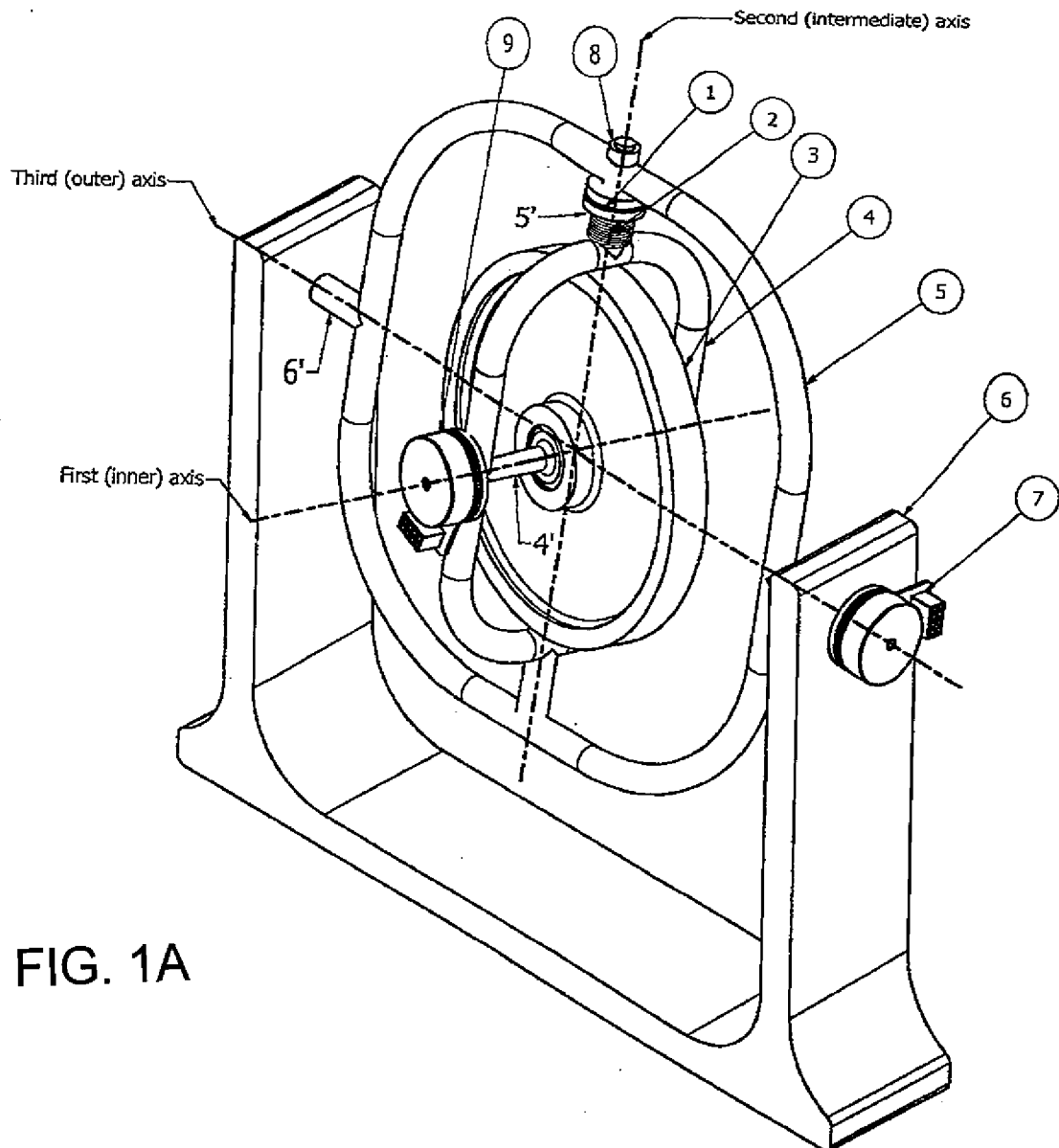


FIG. 1A

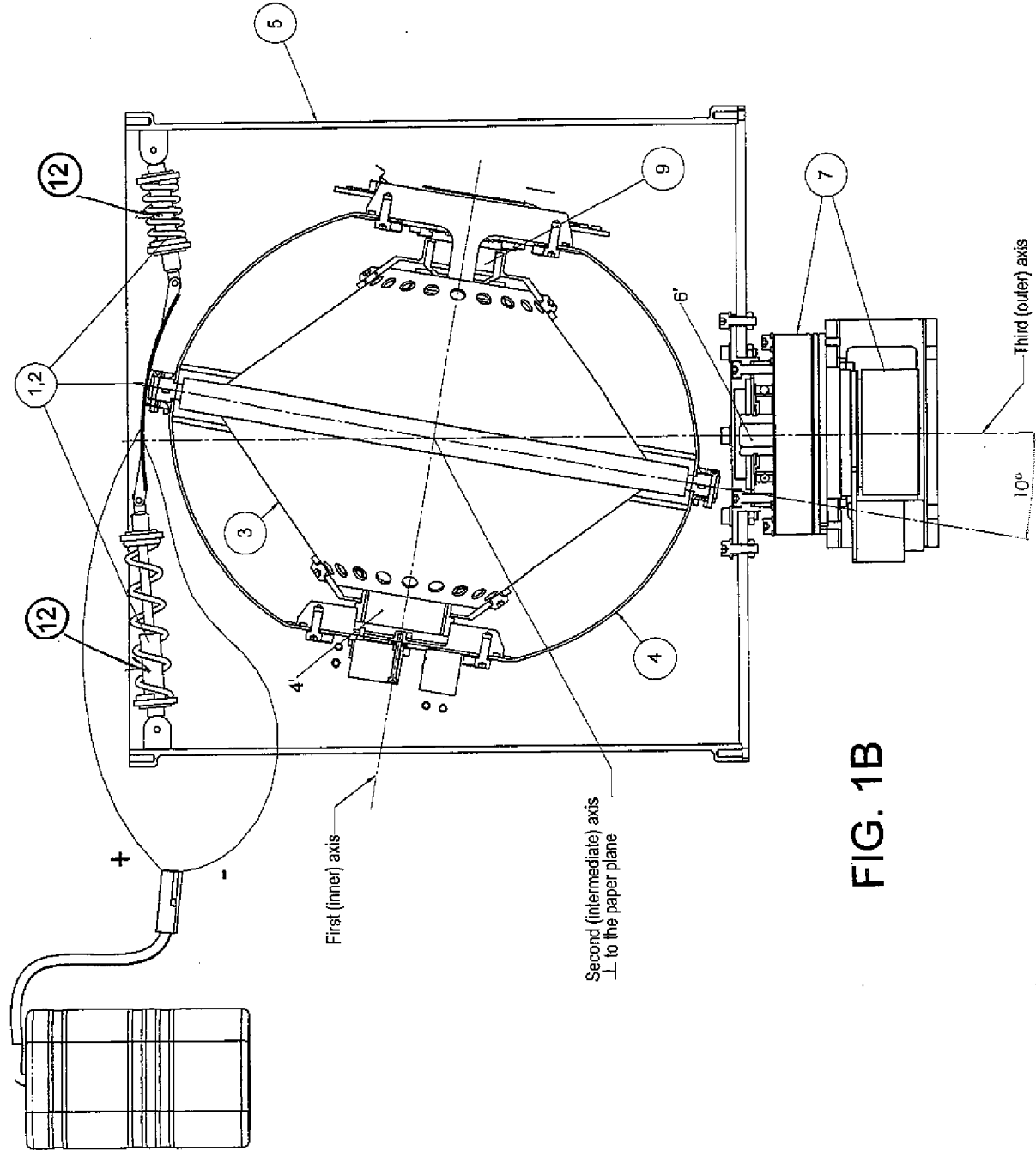


FIG. 1B

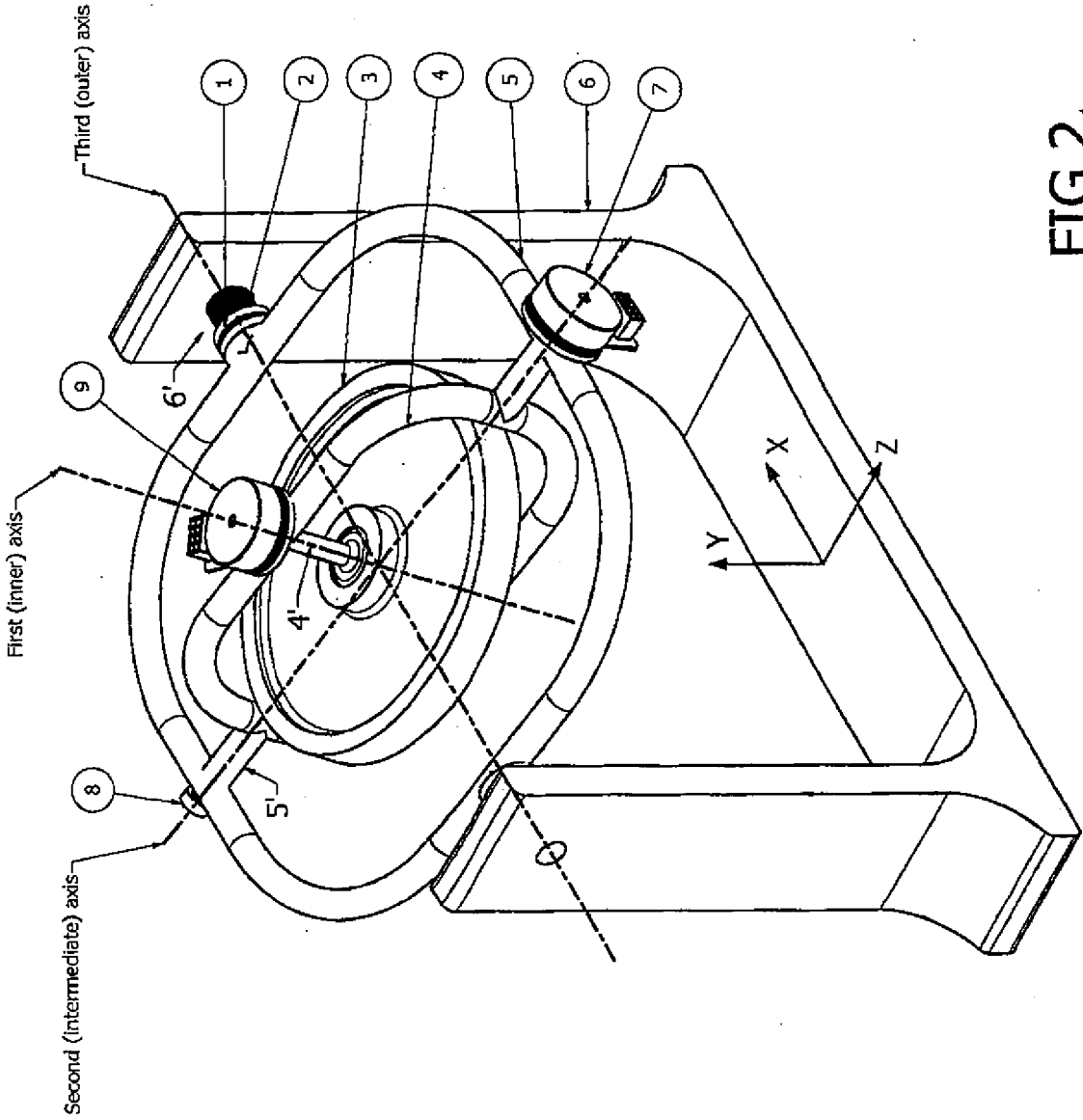
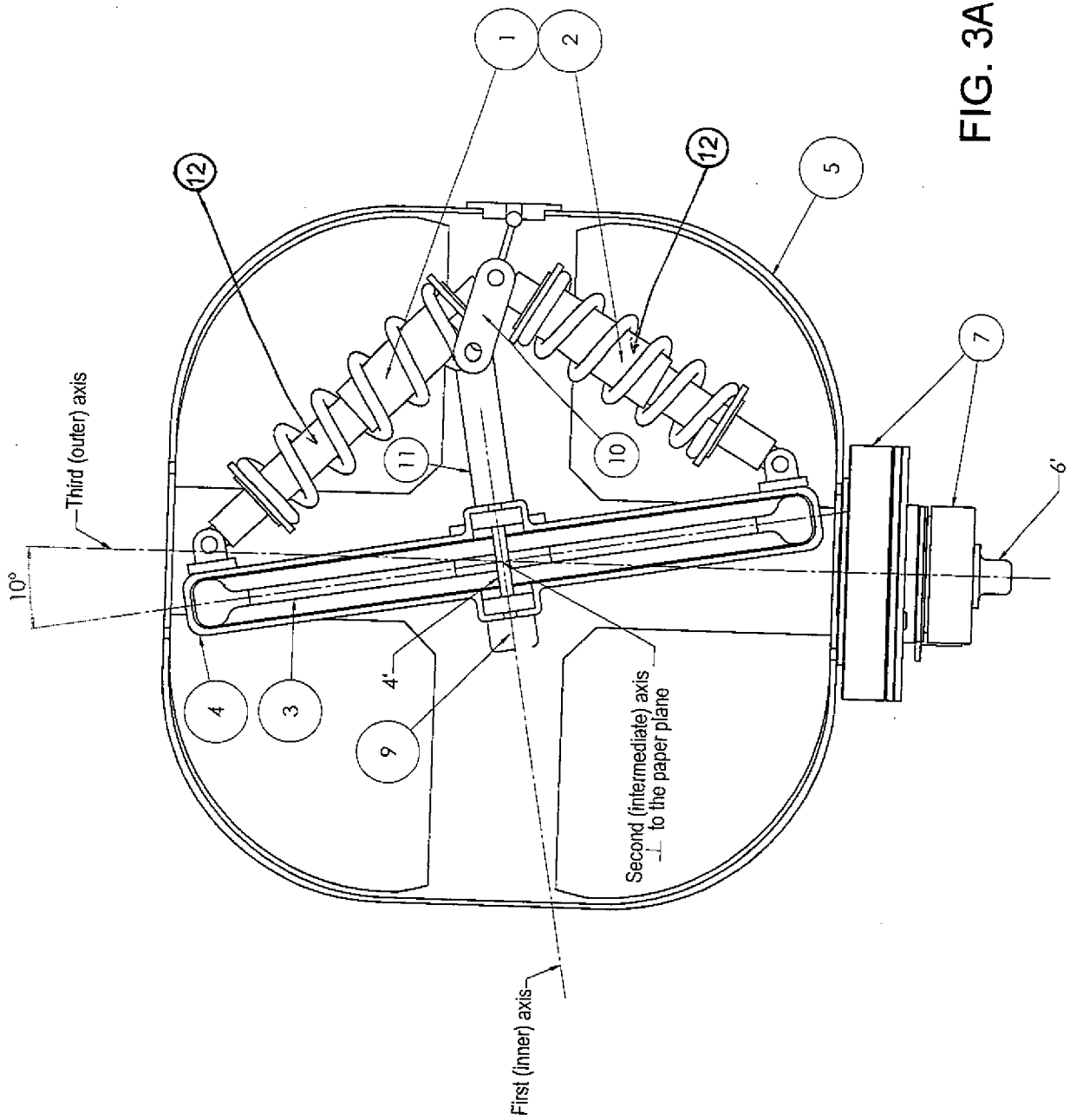
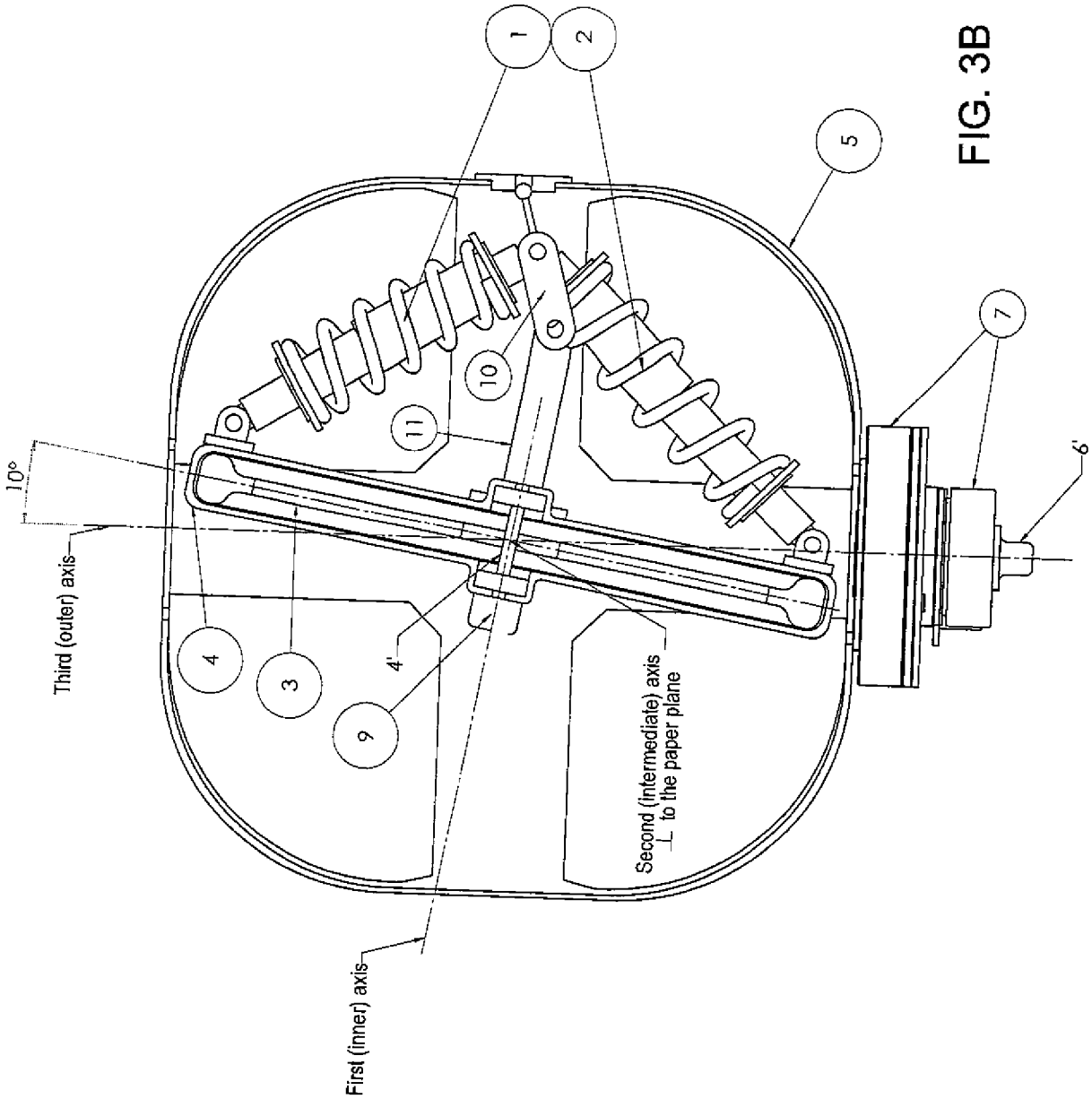


FIG 2.





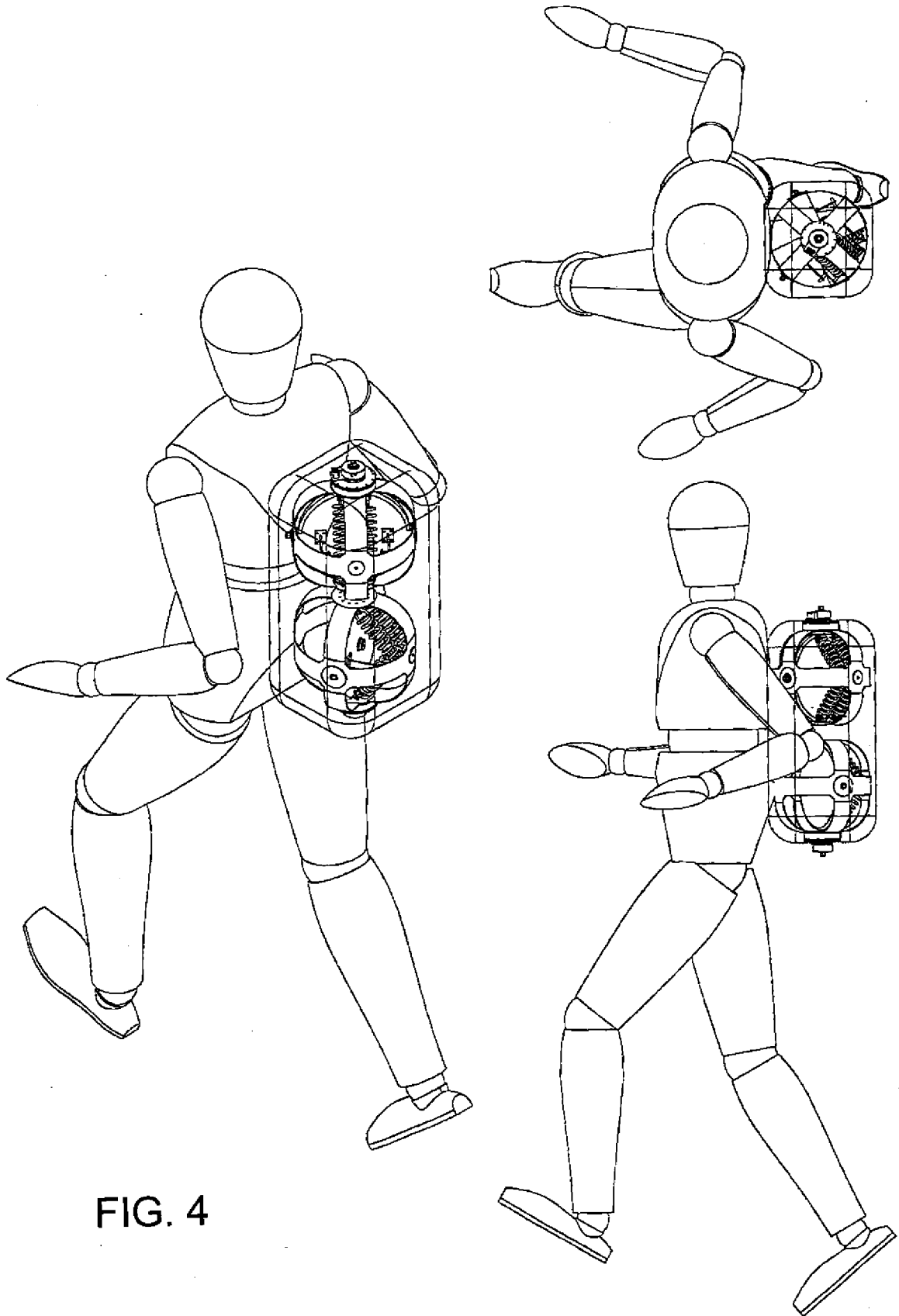


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No

PCT/NL2016/050394

A. CLASSIFICATION OF SUBJECT MATTER
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ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01C G05D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2011/016996 A1 (SUDA YOSHIHIRO [JP] ET AL) 27 January 2011 (2011-01-27) paragraphs [0044] - [0056], [0063], [0093] - [0096]; figures 1,2,14 -----	1-12
A	PL00IJ MICHEL ET AL: "Lock Your Robot: A Review of Locking Devices in Robotics", IEEE ROBOTICS & AUTOMATION MAGAZINE, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 22, no. 1, 1 March 2015 (2015-03-01), pages 106-117, XP011575407, ISSN: 1070-9932, DOI: 10.1109/MRA.2014.2381368 [retrieved on 2015-03-12] cited in the application p.109 - Friction based locking devices p.111 Bistable brakes ----- -/--	1-12



Further documents are listed in the continuation of Box C.



See patent family annex.

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INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2016/050394

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2014/260714 A1 (VALLERY HEIKE [AE] ET AL) 18 September 2014 (2014-09-18) cited in the application paragraphs [0110] - [0111]; figure 10 -----	1-12
A	US 2012/245735 A1 (LEE SUNG-HEE [KR] ET AL) 27 September 2012 (2012-09-27) abstract -----	1-12
A,P	EP 2 896 933 A1 (HONDA MOTOR CO LTD [JP]) 22 July 2015 (2015-07-22) abstract -----	1-12

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/NL2016/050394

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2011016996 A1	27-01-2011	AT 506215 T CN 101573245 A EP 2103471 A1 JP 5064779 B2 JP 2008143390 A US 2011016996 A1 WO 2008072542 A1	15-05-2011 04-11-2009 23-09-2009 31-10-2012 26-06-2008 27-01-2011 19-06-2008
US 2014260714 A1	18-09-2014	NONE	
US 2012245735 A1	27-09-2012	JP 5897105 B2 JP 2014508660 A US 2012245735 A1 WO 2012129259 A1	30-03-2016 10-04-2014 27-09-2012 27-09-2012
EP 2896933 A1	22-07-2015	EP 2896933 A1 JP 2015135328 A US 2015202113 A1	22-07-2015 27-07-2015 23-07-2015