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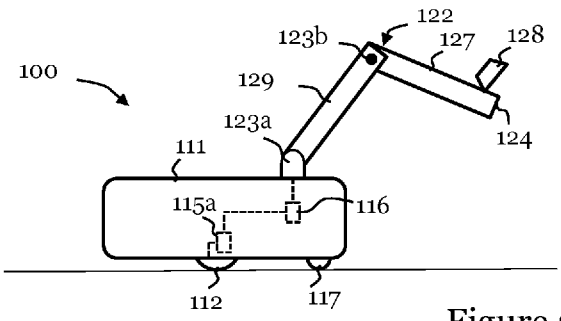

Figure 2

(57) Abstract: The present disclosure relates to a robotic cleaning device (100) comprising a main body (in), a propulsion system (112, 113, 115a, 115b) configured to move the robotic cleaning device (100) over an area to be cleaned, a robotic arm (122) connected to the main body (111), the robotic arm comprising at least two joints (123a, 123b) and an end effector (124), a distal link (127) of the robotic arm (122) being arranged with an object detection sensor (128) configured to acquire data forming a representation of the environment in which the robotic cleaning device (100) moves, and a controller (116) configured to control movement of the robotic cleaning device (100) based on said data acquired by the object detection sensor (128).

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ROBOTIC CLEANING DEVICE WITH CONTROLLABLE ARM

TECHNICAL FIELD

[0001] The present disclosure relates to a robotic cleaning device.

BACKGROUND

[0002] In many fields of technology, it is desirable to use robots with an autonomous behaviour such that they freely can move around a space without colliding with possible obstacles.

[0003] Robotic vacuum cleaners are known in the art, which are equipped with drive means in the form of a motor for moving the cleaner across a surface to be cleaned. The robotic vacuum cleaners are further equipped with intelligence in the form of microprocessor(s) and navigation means for causing an autonomous behaviour such that the robotic vacuum cleaners freely can move around and clean a surface in the form of e.g. a floor. Thus, these prior art robotic vacuum cleaners have the capability of more or less autonomously moving across, and vacuum-cleaning, a room without colliding with obstacles located in the room, such as furniture, pets, walls, doors, etc.

[0004] A problem with robotic vacuum cleaners known in the art is their inability reach into narrow spaces.

SUMMARY

[0005] One objective is to solve, or at least mitigate, this problem and provide a robotic cleaning device with better reach.

[0006] This objective is attained in an aspect by robotic cleaning device comprising a main body, a propulsion system configured to move the robotic cleaning device over an area to be cleaned, a robotic arm connected to the main body, the robotic arm comprising at least two joints and an end effector, a distal link of the robotic arm being arranged with an object detection sensor configured to acquire data forming a representation of the environment in which the robotic cleaning device moves, a controller configured to control movement of the robotic cleaning device based on said data acquired by the object detection sensor.

[0007] Advantageously, with the robotic arm and the object detection sensor being e.g. a 3D camera, the robotic arm may be used to reach into narrow spaces, acquire a view of an environment obscured by an obstacle and even climb over the obstacle. Further, the object detection sensor enables for the controller of the robotic cleaning device to acquire a representation of the environment in which the robotic cleaning device moves.

[0008] In an embodiment, the object detection sensor is arranged on the distal link of the robotic arm to monitor the end effector, and the controller further being configured to control movement of the robotic arm based on the data acquired by the object detection sensor.

[0009] In an embodiment, the controller is further configured to control movement of the robotic arm to have the object detection sensor acquire data forming a representation of the environment located on a side of an obstacle being distal from the robotic cleaning device.

[0010] In an embodiment, the controller is further configured to control movement of the robotic arm to have the end effector facilitate movement of the robotic cleaning device for traversing the obstacle.

[0011] In an embodiment, the robotic arm comprises a proximal link attached to the main body via a first joint of the two joints and a distal link attached to the proximal link via a second joint of the two joints.

[0012] In an embodiment, the distal link is transversally displaced relative to the proximal link at the second joint.

[0013] In an embodiment, the distal link is axially aligned with the proximal link at the second joint.

[0014] In an embodiment, the main body comprises a spacing in which the robotic arm is foldable while maintaining the object detection sensor in a position where data forming a representation of the environment still may be acquired.

[0015] In an embodiment, the robotic arm is completely foldable into the spacing while maintaining the object detection sensor in a position where data forming a representation of the environment still may be acquired.

[0016] In an embodiment, the robotic arm and the object detection sensor is completely foldable into the spacing, a front opening being provided in the main body to allow the object detection sensor to acquire data forming a representation of the environment.

[0017] In an embodiment, the controller is configured to control movement of the robotic arm to push against objects for assisting movement of the robotic cleaning device.

[0018] In an embodiment, the end effector is configured to be arranged with a cleaning tool.

[0019] In an embodiment, the end effector is configured to release a current cleaning tool being attached to the end effector and attach a new cleaning tool.

[0020] In an embodiment, the robotic arm is controlled to drop an object at a starting point of a wall-following cleaning session being performed and detect a cleaning lap having been completed upon encountering the dropped object.

[0021] In an embodiment, the robotic arm comprises a suction channel extending from a dust container in the main body to an inlet at the end effector.

[0022] In an embodiment, the controller is configured to control the robotic cleaning device to perform spot cleaning by first controlling the main body to rotate on the spot while removing dust from the floor via a dust inlet of the main body and then gradually extending the robotic arm forward with the end effector directed towards the floor and slowly moving it outwards while rotating on the spot, so the path of the end effector forms an outward spiral while removing dust from the floor via the inlet of the end effector.

[0023] In an embodiment, the controller is configured to determine a position of the robotic arm and if the position of the robotic arm indicates that the robotic arm currently is not used for cleaning, a valve is controlled to direct an air flow created by a suction fan in the main body via a dust inlet of the main body and if the robotic arm indicates that the robotic arm currently is used for cleaning, the valve is controlled to direct the air flow created by the suction fan via the suction channel of the robotic arm.

[0024] In an embodiment, the controller is configured to control the robotic arm (112) to push away objects from a surface to be cleaned.

[0025] In an embodiment, the controller is configured to control the robotic arm to push against an object to determine a structure of the object based on the pushing force applied by the robotic arm.

[0026] In an embodiment, the first joint is attached to the main body at a centre point of the main body.

[0027] In an embodiment, the first joint is attached to the main body at a wheel axis of the main body.

[0028] In an embodiment, the object detection sensor is arranged with a protective cover being selectively movable over a lens of object detection sensor.

[0029] In an embodiment, the robotic arm comprises an interface adapted to be connected to a mains outlet for charging a battery of the robotic cleaning device.

[0030] In an embodiment, the robotic cleaning device further comprises a microphone, a gyroscope or an accelerometer.

[0031] Generally, all terms used in the claims are to be interpreted according to their ordinary meaning in the technical field, unless explicitly defined otherwise herein. All references to "a/an/the element, apparatus, component, means, step, etc." are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. The steps of any method disclosed herein do not have to be performed in the exact order disclosed, unless explicitly stated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] Aspects and embodiments are now described, by way of example, with reference to the accompanying drawings, in which:

[0033] Figure 1 shows a robotic cleaning device according to an embodiment in a bottom view;

[0034] Figure 2 shows a robotic cleaning device according to an embodiment in a side view;

[0035] Figure 3 illustrates an embodiment where the robotic cleaning device approaches an obstacle;

[0036] Figures 4a-c illustrate an embodiment where the robotic cleaning device uses a robotic arm to traverse an obstacle;

[0037] Figure 5 illustrates a robotic cleaning device 100 according to an embodiment having a first robotic arm configuration;

[0038] Figure 6 illustrates a robotic cleaning device according to an embodiment having a second robotic arm configuration;

[0039] Figure 7 illustrates a robotic cleaning device according to the embodiment of Figure 5 where the robotic arm is foldable into a main body spacing;

[0040] Figures 8a and b illustrate a robotic cleaning device according to the embodiment of Figure 6 where the robotic arm is foldable into a main body spacing;

[0041] Figure 9 illustrates a further embodiment of the robotic cleaning device where a robotic arm end effector is arranged to comprise a cleaning tool;

[0042] Figure 10 illustrates an embodiment where a suction canal is arranged inside the robotic arm;

[0043] Figure 11 illustrates an embodiment where the robotic arm utilized for providing tactile feedback;

[0044] Figure 12 illustrates an embodiment where the robotic arm comprises an interface adapted to be connected to a mains outlet for charging a battery of the robotic cleaning device; and

[0045] Figure 13 illustrates an embodiment where the robotic arm is placed along a wheel axis of the robotic cleaning device.

DETAILED DESCRIPTION

[0046] The aspects of the present disclosure will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments of the invention are shown.

[0047] These aspects may, however, be embodied in many different forms and should not be construed as limiting; rather, these embodiments are provided by way of example so that this disclosure will be thorough and complete, and to fully convey the scope of all aspects of invention to those skilled in the art. Like numbers refer to like elements throughout the description.

[0048] The disclosure relates to robotic cleaning devices, or in other words, to automatic, self-propelled machines for cleaning a surface, e.g. a robotic vacuum cleaner, a robotic sweeper or a robotic floor washer. The robotic cleaning device according to embodiments can be mains-operated and have a cord, be battery-operated or use any other kind of suitable energy source, for example solar energy.

[0049] Even though it is envisaged that embodiments may be performed by a variety of appropriate robotic cleaning devices being equipped with sufficient processing intelligence, Figure 1 shows a robotic cleaning device 100 according to an embodiment in a bottom view, i.e. the underside of the robotic cleaning device is shown. The arrow indicates the forward direction of the robotic cleaning device 100.

[0050] The robotic cleaning device 100 comprises a main body 111 housing components such as a propulsion system comprising driving means in the form of two electric wheel motors 115a, 115b for enabling movement of the driving wheels 112, 113 such that the robotic cleaning device 100 can be moved over a surface to be cleaned. Each wheel motor 115a, 115b is capable of controlling the respective driving wheel 112, 113 to rotate independently of each other in order to move the robotic cleaning device 100 across the surface to be cleaned. A number of different driving wheel arrangements, as well as various wheel motor arrangements, can be envisaged. It should be noted that the robotic cleaning device 100 may have any appropriate shape, such as a device having a more traditional circular-shaped main body, or a triangular-shaped main body. As an alternative, a track propulsion system may be used or even a hovercraft propulsion system. The propulsion system may further be arranged to cause the RVC 100 to perform any one or more of a yaw, pitch, translation or roll movement.

[0051] A controller 116 such as a microprocessor controls the wheel motors 115a, 115b to rotate the driving wheels 112, 113 as required in view of information received from an object detecting sensor (not shown in Figure 1) for detecting obstacles in the form of walls, floor lamps, table legs, around which the robotic cleaning device must navigate. The object detecting sensor may be embodied in the form of a 3D sensor system registering its surroundings, implemented by means of e.g. a 3D camera, a camera in combination with lasers, a laser scanner, a radar, a stereo camera pair, a single camera, etc. for detecting obstacles and communicating information about any detected obstacle to the microprocessor 116. The microprocessor 116 communicates

with the wheel motors 115a, 115b to control movement of the wheels 112, 113 in accordance with information provided by the obstacle detecting device such that the robotic cleaning device 100 can move as desired across the surface to be cleaned.

[0052] Moreover, the main body 111 of the robotic cleaning device 100 comprises a suction fan 120 creating an air flow for transporting debris to a dust bag or cyclone arrangement (not shown) housed in the main body via the inlet 118 in the bottom side of the main body 111. The suction fan 120 is driven by a fan motor 121 communicatively connected to the controller 116 from which the fan motor 121 receives instructions for controlling the suction fan 120. The main body 111 may further be arranged with one or more rotating side brushes 114 adjacent to the inlet 118.

[0053] With further reference to Figure 1, the controller/processing unit 116 embodied in the form of one or more microprocessors is arranged to execute a computer program 125 downloaded to a suitable storage medium 126 associated with the microprocessor, such as a Random Access Memory (RAM), a Flash memory or a hard disk drive. The controller 116 is arranged to carry out a method according to embodiments when the appropriate computer program 125 comprising computer-executable instructions is downloaded to the storage medium 126 and executed by the controller 116. The storage medium 126 may also be a computer program product comprising the computer program 125. Alternatively, the computer program 125 may be transferred to the storage medium 126 by means of a suitable computer program product, such as a digital versatile disc (DVD), compact disc (CD) or a memory stick. As a further alternative, the computer program 125 may be downloaded to the storage medium 126 over a wired or wireless network. The controller 116 may alternatively be embodied in the form of a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), a complex programmable logic device (CPLD), etc.

[0054] Figure 2 illustrates the robotic cleaning device 100 in a side view according to an embodiment, where it further can be seen that the robotic cleaning device 100 comprises a robotic arm 122 extending from the main body 111.

[0055] The robotic arm 122 comprises at least two joints 123a, 123b and an end effector 124, where a distal link 127 of the robotic arm 122 is arranged with the previously mentioned object detection sensor 128 configured to acquire data forming

a representation of the environment in which the robotic cleaning device 100 is operating and based on which data the controller 116 is configured to control movement of the robotic cleaning device 100.

[0056] The distal link 127 is connected to a proximal link 129 of the robotic arm 122 via the second joint 123b (also referred to as elbow joint) while the proximal link 129 is attached to the main body 111 via the first joint 123a (also referred to as shoulder joint).

[0057] While the robotic arm 122 is attached to an upper side of an outer housing of the main body 111 vi the first joint 123a, the robotic arm 122 may alternatively be attached to a bottom plate of the main body, on the side of it or to a mounting interface on top of the main body 111 to make the arm 122 an optional accessory.

[0058] The object detection sensor 128 may be embodied by a 2D or 3D camera to which the controller 116 is operatively coupled for recording images of a vicinity of the robotic cleaning device 100. In the following, the object detection sensor 128 will be exemplified in the form of a 3D camera.

[0059] The 3D camera 128 is controlled by the controller 116 to capture and record a plurality of images per second. Data from the images is extracted by the controller 116 and the data is typically saved in the memory 126 along with the computer program 125. Hence, in an embodiment, the data forming a representation of an environment in which the robotic cleaning device 100 moves are data being extracted from captured images of said environment.

[0060] Further, in an embodiment, the 3D camera 128 is arranged on the distal link 127 of the robotic arm 122 such that it can monitor the end effector 124; the controller 116 will thus be capable of controlling movement of the robotic arm 122 based on the data acquired by the 3D camera 128. Further, the camera 128 may be used to determine the position of the end effector 124, either relative to the surroundings or to the main body 111.

[0061] Figure 3 illustrates an embodiment where the robotic cleaning device 100 approaches an obstacle 130 such as a high threshold. Advantageously, with the robotic arm 122 and the 3D camera 128, the controller 116 of the robotic cleaning device 100 is capable of acquiring a representation of the environment on a distal side

of the threshold 130, for instance to ensure that there is not a stairway on the other side.

[0062] In a related embodiment, the robotic arm 122 may be controlled to reach into a narrow space to be cleaned, such as under a sofa, where the 3D camera 128 may monitor the environment under the sofa such that the controller 116 may create a representation of the monitored environment.

It may further be envisaged that the 3D camera 128 is provided with a transparent protective cover being moveable over its lens, either by the controller 116 sending a control signal to the camera 128 comprising a mechanism for moving the cover or manually by a user. Advantageously, this prevents the lens from becoming dirty. Alternatively, a non-transparent cover is utilized in case the lens of the camera 128 should be covered for integrity reasons. Further, the cover can be used whenever the arm is in the parking position, for privacy provision and dust protection.

[0063] Figures 4a-c illustrate the controller 116 further being configured to control movement of the robotic arm 122 (being placed at the centre of the main body 111) to have the end effector 124 abut an obstacle such as a threshold 130 to lift a front end of the robotic cleaning device 100 for facilitating traversal over the threshold 130, as shown in Figure 4a.

[0064] In Figure 4b, upon the robotic cleaning device 100 being located on the threshold 130, the controller 116 controls movement of the robotic arm 122 to have the end effector 124 abut an opposite side of the threshold 130 to push the robotic cleaning device 100 over the threshold 130.

[0065] In Figure 4c, the robotic arm 122 is utilized to ease movement of the robotic cleaning device 100 from the threshold 130 back down to the floor.

[0066] Other scenarios are envisaged where the robotic cleaning device 100 uses the robotic arm 122 in assisting movement of the main body 111.

[0067] For instance, the robotic arm 122 may be used to push the robotic cleaning device 100 backwards if the robot has driven up on a sloping object, so that one or more wheels 112, 113 have lost traction.

[0068] In another example, the robotic arm 122 is utilized to push an object forward while the robotic cleaning device 100 is reversing, which may be helpful if an

object such as a shoestring, a carpet tassel or a cable has been entangled with the brush roll 117.

[0069] In another example, the robotic arm 122 is used to push on a robot bumper to check its function and ensure that the bumper is not stuck.

[0070] Figure 5 illustrates the robotic cleaning device 100 according to an embodiment in a top view. As can be seen, the distal link 127 is transversally displaced relative to the proximal link 129 at the second joint 123b.

[0071] Figure 6 illustrates the robotic cleaning device 100 according to another embodiment in a top view, where the distal link 127 is axially aligned with the proximal link 129 at the second joint 123b.

[0072] In both Figure 5 and 6, the main body 111 comprises a spacing 131 into which the robotic arm 122 is foldable when not in use. Further, as illustrated, it may be envisaged that the robotic arm 122 is pivotable around a rotational axis of the robotic cleaning device at the first joint 123a. The link configuration of Figure 5 is typically more advantageous when performing wall-following.

[0073] While the robotic arm 122 is attached to the main body 111 via the first joint 123a at a front section of the main body 111, it may be envisaged that the robotic arm 122 is attached to the main body 111 at any appropriate position.

[0074] For instance, the first joint 123a may be placed on or close to a centre point of the main body 111 of the robotic cleaning device 100, in order to have the robotic arm 122 perform a rotation around that point. This simplifies control of the arm 122 and also provides better panorama images captured by the camera 128.

[0075] As seen in Figure 7 and 8a and 8b, the robotic arm 122 of the respective link configuration of Figure 5 and 6 may be folded into the spacing 131 of the main body 111 while still being capable of using the 3D camera 128 for navigation.

[0076] As seen in Figure 8b, in an embodiment, the complete robotic arm 122 including the camera 128 is foldable into the main body 111 while a front opening being provided in the main body 111 allows the camera 128 to still capture images of the environment. This may require the camera 128 to have a slightly smaller height in order to be able to fit the robotic arm 122 and the camera 128 in the spacing 131.

[0077] Further, it may be envisaged that the controller 116 is in communicative connection with a motor (not shown) coupled to the 3D camera 128 for changing viewing angle of the camera for different perspectives.

[0078] Figure 9 illustrates a further embodiment of the robotic cleaning device 100 where the end effector 124 is arranged to comprise a cleaning tool, such as a cleaning brush 132 attached to end effector 124. Other tools may include a suction cup or gripping member for picking items up from the floor, specialized brushes, clothes or sponges for wet cleaning. It may even be envisaged that the cleaning tools are placed on the main body 111 or at e.g. a robot charger, wherein the robotic cleaning device 100 itself changes tool to be attached to the end effector 124.

[0079] Figure 10 illustrates yet an embodiment where a suction canal 133 is arranged to extend from a dust bag 134 or cyclone arrangement along the robotic arm 122 (either inside the arm or extending along the outside of the arm) to an inlet at the end effector 124 for using the resulting suction air flow at the end effector 124 to remove dust and debris from any appropriate surface against which the end effector 124 is directed. As previously discussed with reference to Figure 1, a suction fan 120 (not shown in Figure 10) is utilized creating an air flow for transporting debris to the dust bag 134 housed in the main body 111.

[0080] In another embodiment, the robotic cleaning device 100 leaves a cleaning tool such as a wide floor nozzle on the floor where it starts a cleaning session using a smaller nozzle. After the session is complete, the robotic cleaning device 100 returns to the location where it left the wide nozzle and picks the nozzle up.

[0081] If the robotic cleaning device 100 is performing wall following of the perimeter of a room, the location where the wide nozzle was left in the floor serves as an unambiguous marker for the completion of a full lap around the room.

[0082] When arranged the robotic arm 122 with the suction channel 124, so-called spot cleaning may advantageously by first controlling the main body 111 to rotate on the spot while using the suction fan 120 to remove dust from the floor via the dust inlet 118 of the main body 111 and then gradually extending the robotic arm 122 forward with the end effector 124 directed towards the floor and slowly moving it outwards while rotating on the spot, so the path of the end effector 124 forms an

outward spiral. That would be a fast way to cover an area with the end effector 124, which typically has a more concentrated air flow and thus better dust pickup capacity.

[0083] Further, a position of the robotic arm 122 may be determined and used to control a valve that directs the air flow created by the suction fan 120. For instance, in a scenario where the position of the robotic arm 122 indicates that the arm 122 is not used for cleaning (for example in the scenarios of Figures 7 and 8), the air flow created by the suction fan 120 is controlled to be directed via the inlet 118 of the main body 111. To the contrary, if the position of the robotic arm 122 indicates that the arm 122 indeed is used for cleaning (for example in a scenario where an angle formed between the main body 111 and the proximal link 129 exceeds a predetermined threshold value), the air flow created by the suction fan 120 is controlled to be directed via the suction channel 133 of the robotic arm 122.

[0084] Figure 11 illustrates an embodiment where the robotic arm 122 is utilized for providing tactile feedback, for instance by pushing the arm 122 into a thick carpet 135 to determine whether it is solid enough for traversing. This may for instance be determined by measuring current consumption of a motor controlling movement of the robotic arm 122 for determining pushing force of the arm 122.

[0085] In a further embodiment, the robotic cleaning device 100 is equipped with a microphone, a gyroscope of an accelerometer to measure sound or vibration response upon the robotic arm 122 being controlled to move into contact with a surface of object. This may further be used by the robotic cleaning device 100 to determine which type of object is being contacted.

[0086] In another embodiment, the robotic arm 112 could be used to push away an object, such as toys located on the floor, or a curtain under which cleaning is desired.

[0087] Figure 12 illustrates an embodiment where the robotic arm 122 comprises an interface 136 adapted to be connected to a mains outlet for charging a battery 137 of the robotic cleaning device 100. Alternatively, the interface 136 connects to a small custom AC/DC adaptor in the mains outlet. Advantageously, this mitigates risk of high voltage damages and further an interface may be provided that can be adapted to make it easier for the robotic cleaning device 100 to find and connect to the main outlet.

[0088] Figure 13 illustrates a further embodiment where the first joint 123a is placed on or close to a wheel axis of the main body 111 of the robotic cleaning device 100 (in this example slightly to the right of a longitudinal axis of the robotic cleaning device 100), in order to allow the robotic cleaning device 100 to move parallel to a wall while performing wall following using the brush 132 to clean the area by the wall.

[0089] The aspects of the present disclosure have mainly been described above with reference to a few embodiments and examples thereof. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible within the scope of the invention, as defined by the appended patent claims.

[0090] Thus, while various aspects and embodiments have been disclosed herein, other aspects and embodiments will be apparent to those skilled in the art. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

CLAIMS

1. A robotic cleaning device (100) comprising:

a main body (111):

a propulsion system (112, 113, 115a, 115b) configured to move the robotic cleaning device (100) over an area to be cleaned;

a robotic arm (122) connected to the main body (111), the robotic arm comprising at least two joints (123a, 123b) and an end effector (124), a distal link (127) of the robotic arm (122) being arranged with an object detection sensor (128) configured to acquire data forming a representation of the environment in which the robotic cleaning device (100) moves;

a controller (116) configured to control movement of the robotic cleaning device (100) based on said data acquired by the object detection sensor (128).

2. The robotic cleaning device (100) of claim 1, wherein:

the object detection sensor (128) is arranged on the distal link (127) of the robotic arm (122) to monitor the end effector (124); and

the controller (117) further being configured to control movement of the robotic arm (122) based on said data acquired by the object detection sensor (128).

3. The robotic cleaning device (100) of claim 1, wherein:

the controller (117) further is configured to control movement of the robotic arm (122) to have the object detection sensor (128) acquire data forming a representation of the environment located on a side of an obstacle (130) being distal from the robotic cleaning device (100).

4. The robotic cleaning device (100) of claim 3, wherein:

the controller (117) further is configured to control movement of the robotic arm (122) to have the end effector (124) facilitate movement of the robotic cleaning device (100) for traversing the obstacle (130).

5. The robotic cleaning device (100) of any one of the preceding claims, wherein:

the robotic arm (122) comprises a proximal link (129) attached to the main body (111) via a first joint (123a) of the two joints and a distal link (127) attached to the proximal link (129) via a second joint (123b) of the two joints.

6. The robotic cleaning device (100) of claim 5, wherein:

the distal link (127) is transversally displaced relative to the proximal link (129) at the second joint (123b).

7. The robotic cleaning device (100) of claim 5, wherein:

the distal link (127) is axially aligned with the proximal link (129) at the second joint (123b).

8. The robotic cleaning device (100) of any one of the preceding claims, wherein:

the main body (111) comprises a spacing (131) in which the robotic arm (122) is foldable while maintaining the object detection sensor (128) in a position where data forming a representation of the environment still may be acquired.

9. The robotic cleaning device (100) of claim 8, wherein:

the robotic arm (122) is completely foldable into the spacing (131) while maintaining the object detection sensor (128) in a position where data forming a representation of the environment still may be acquired.

10. The robotic cleaning device (100) of claim 8, wherein:

the robotic arm (122) and the object detection sensor (128) is completely foldable into the spacing (131), a front opening being provided in the main body (111) to allow the object detection sensor (128) to acquire data forming a representation of the environment.

11. The robotic cleaning device (100) of any one of the preceding claims, wherein:

the controller (116) is configured to control movement of the robotic arm (122) to push against objects for assisting movement of the robotic cleaning device (100).

12. The robotic cleaning device (100) of any one of the preceding claims, wherein:

the end effector (124) is configured to be arranged with a cleaning tool (132).

13. The robotic cleaning device (100) of claim 12, wherein:

the end effector (124) is configured to release a current cleaning tool (132) being attached to the end effector (124) and attach a new cleaning tool.

14. The robotic cleaning device (100) of claim 12, wherein:

the robotic arm (122) is controlled to drop an object at a starting point of a wall-following cleaning session being performed and detect a cleaning lap having been completed upon encountering the dropped object.

15. The robotic cleaning device (100) of any one of the preceding claims, wherein:

the robotic arm (122) comprises a suction channel (133) extending from a dust container (134) in the main body (111) to an inlet at the end effector (124).

16. The robotic cleaning device (100) of claim 10, wherein:

the controller (116) is configured to control the robotic cleaning device (100) to perform spot cleaning by first controlling the main body (111) to rotate on the spot while removing dust from the floor via a dust inlet (118) of the main body (111) and then gradually extending the robotic arm (122) forward with the end effector (124) directed towards the floor and slowly moving it outwards while rotating on the spot, so the path of the end effector (124) forms an outward spiral while removing dust from the floor via the inlet of the end effector (124).

17. The robotic cleaning device (100) of claims 15 or 16, wherein:

the controller (116) is configured to determine a position of the robotic arm (122) and if the position of the robotic arm (122) indicates that the robotic arm (122) currently is not used for cleaning, a valve is controlled to direct an air flow created by a suction fan (120) in the main body (111) via a dust inlet (118) of the main body (111) and if the robotic arm (122) indicates that the robotic arm (122) currently is used for cleaning, the valve is controlled to direct the air flow created by the suction fan (120) via the suction channel (133) of the robotic arm (122).

18. The robotic cleaning device (100) of any one of the preceding claims, wherein:

the controller (116) is configured to control the robotic arm (112) to push away objects from a surface to be cleaned.

19. The robotic cleaning device (100) of any one of the preceding claims, wherein:

the controller (116) is configured to control the robotic arm (112) to push against an object to determine a structure of the object based on the pushing force applied by the robotic arm (112).

20. The robotic cleaning device (100) of any one of the preceding claims, wherein:

the first joint (123a) is attached to the main body (111) at a centre point of the main body (111).

21. The robotic cleaning device (100) of any one of claims 1-19, wherein:

the first joint (123a) is attached to the main body (111) at a wheel axis of the main body (111).

22. The robotic cleaning device (100) of any one of the preceding claims, wherein:

the object detection sensor (128) is arranged with a protective cover being selectively movable over a lens of object detection sensor (128).

23. The robotic cleaning device (100) of any one of the preceding claims, wherein

the robotic arm (122) comprises an interface (136) adapted to be connected to a mains outlet for charging a battery (137) of the robotic cleaning device (100).

24. The robotic cleaning device (100) of any one of the preceding claims, the robotic cleaning device (100) further comprising:

a microphone, a gyroscope or an accelerometer.

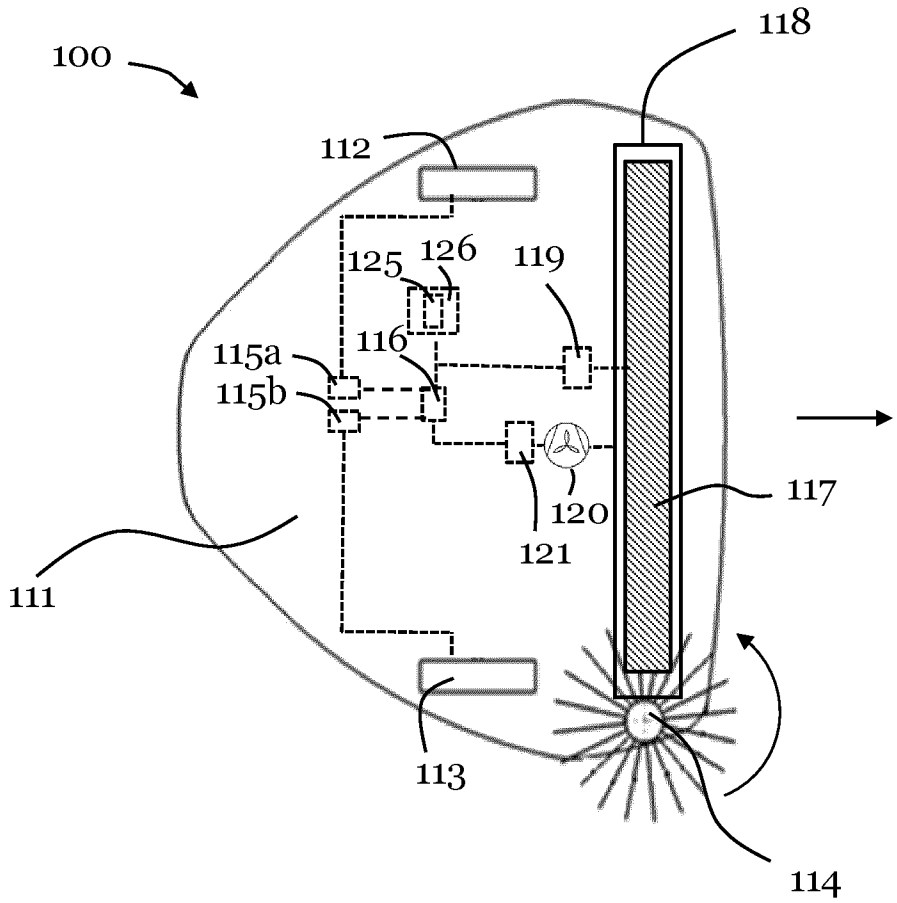

Figure 1

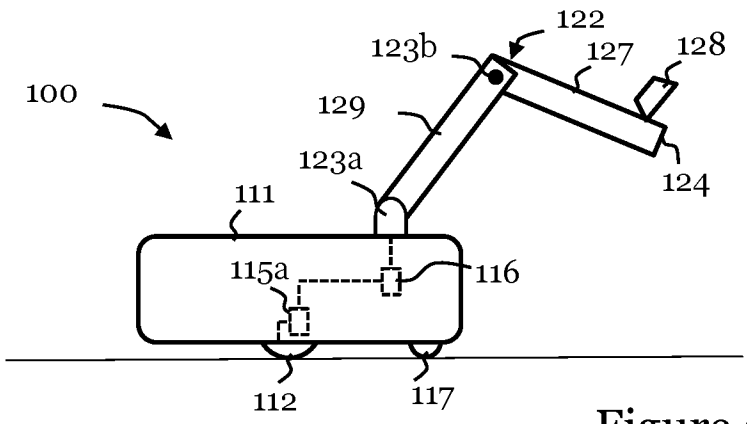

Figure 2

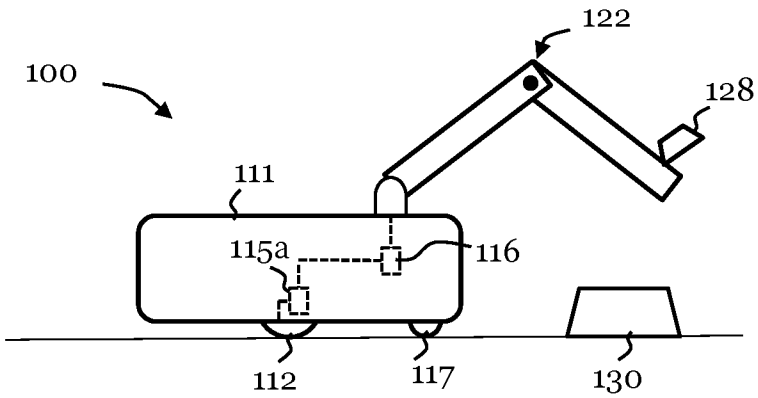

Figure 3

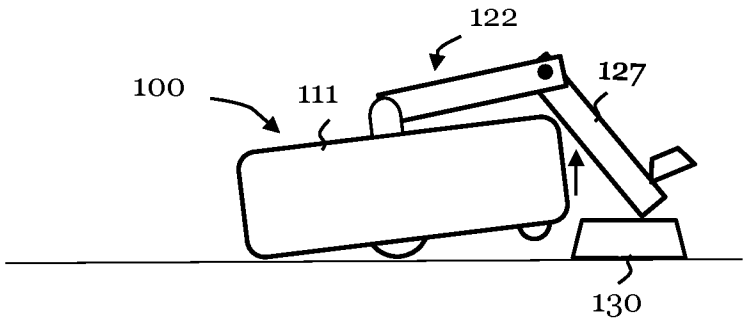

Figure 4a

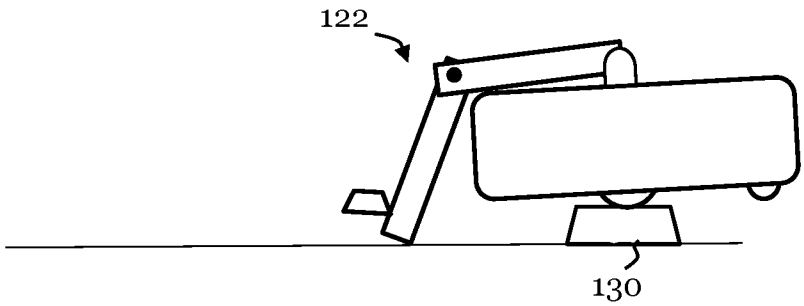

Figure 4b

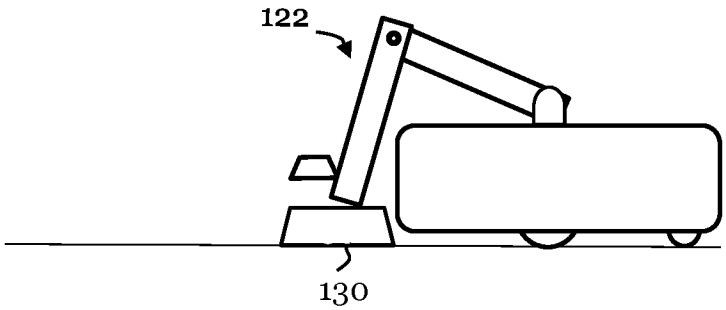

Figure 4c

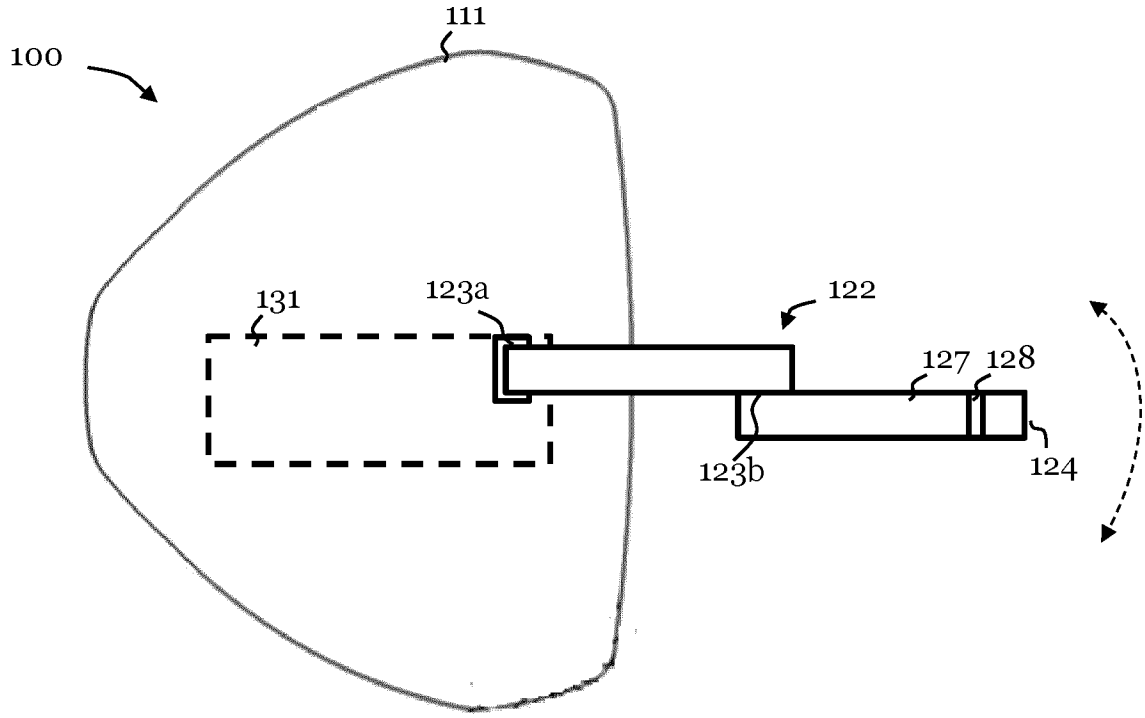

Figure 5

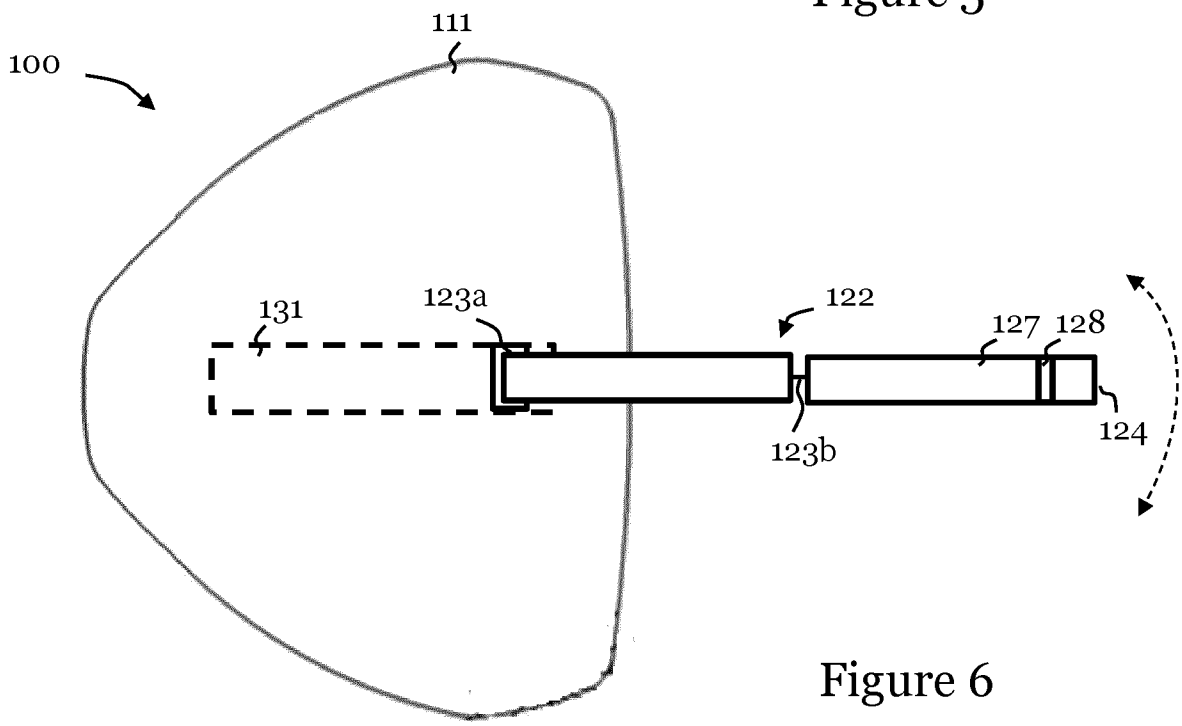

Figure 6

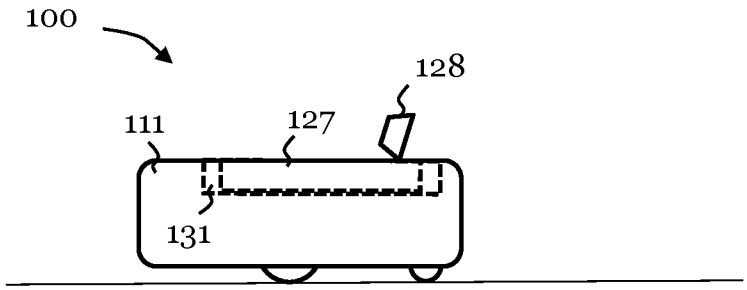

Figure 7

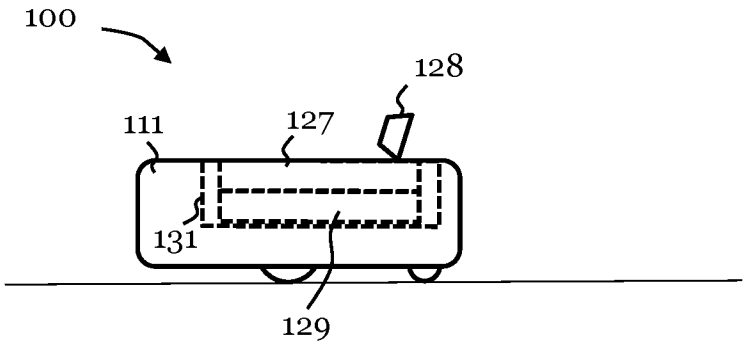

Figure 8a

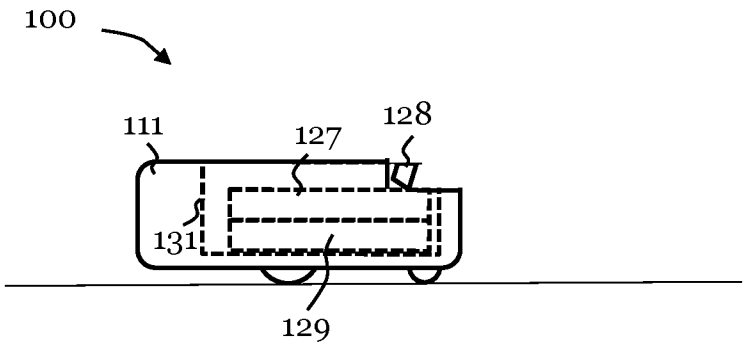

Figure 8b

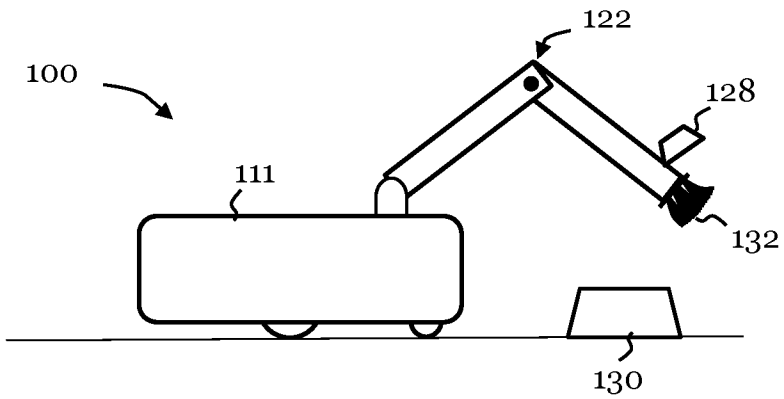

Figure 9

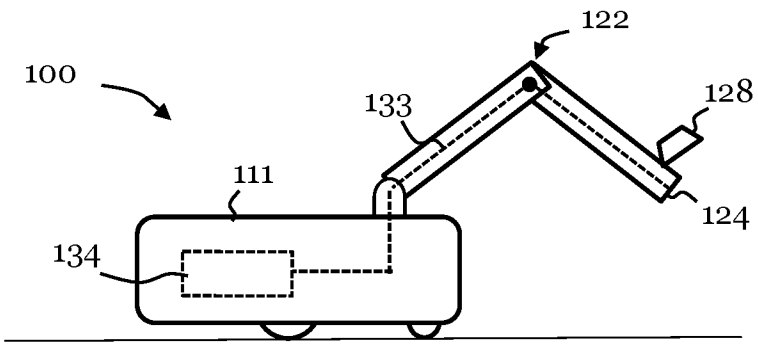

Figure 10

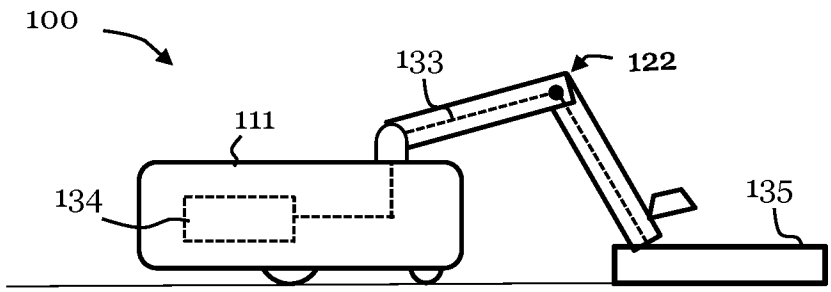

Figure 11

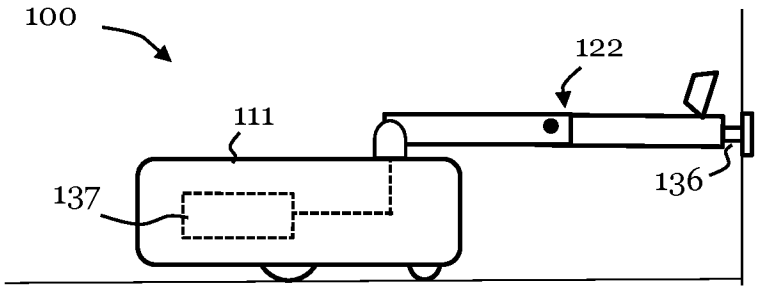

Figure 12

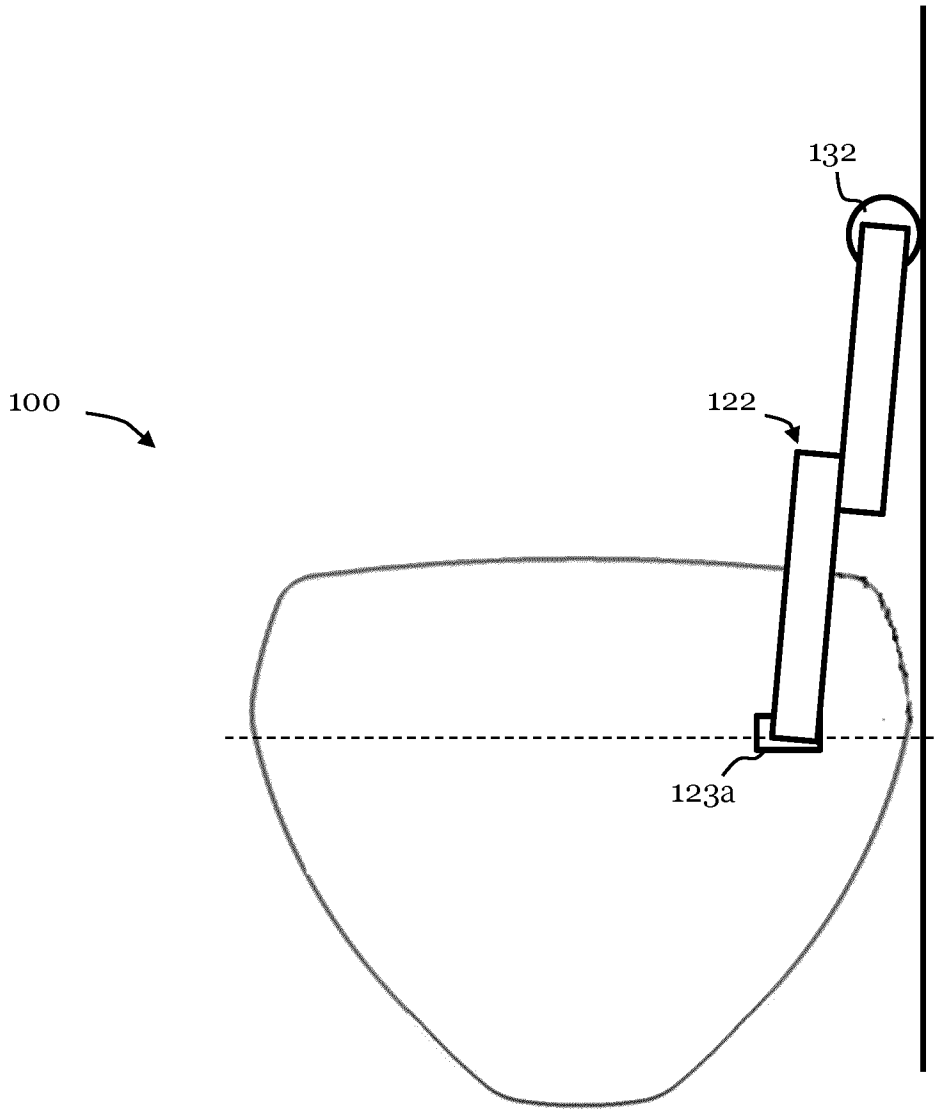

Figure 13

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2021/086165

A. CLASSIFICATION OF SUBJECT MATTER
INV. A47L9/28
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)
A47L

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2019/246858 A1 (KARASIKOV NIR [IL] ET AL) 15 August 2019 (2019-08-15)	1-7,12, 13,16, 23,24
A	the whole document	8-11,14, 17-22
A	WO 2008/142642 A1 (KONINKL PHILIPS ELECTRONICS NV [NL]; DIRKX HUBERTUS C A [NL] ET AL.) 27 November 2008 (2008-11-27) the whole document	1-24
A	EP 3 342 324 A1 (SAMSUNG ELECTRONICS CO LTD [KR]) 4 July 2018 (2018-07-04) the whole document	1-24
A	JP 2021 168960 A (SUZUKI MASAHIRO) 28 October 2021 (2021-10-28) abstract; figures 1, 2	1-24

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 July 2022	14/07/2022

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Jezierski, Krzysztof

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2021/086165

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2019246858 A1	15-08-2019	US 2019246858 A1	15-08-2019
		WO 2019159162 A1	22-08-2019
WO 2008142642 A1	27-11-2008	NONE	
EP 3342324 A1	04-07-2018	AU 2016346447 A1	26-04-2018
		CN 108366707 A	03-08-2018
		EP 3342324 A1	04-07-2018
		KR 20170048815 A	10-05-2017
		US 2018317725 A1	08-11-2018
		WO 2017073955 A1	04-05-2017
JP 2021168960 A	28-10-2021	NONE	