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A47L 11/40 (2006.01)

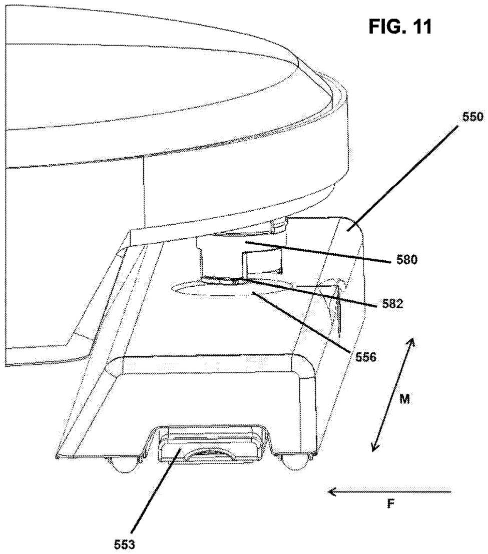
(56) Documents Cited:
CN 105149155 A **JP 2007190305 A**
US 9114440 B1 **US 5959423 A**
US 20160227975 A1 **US 20070051757 A1**

(58) Field of Search:
INT CL **A47L**
Other: **WPI, EPODOC**

(54) Title of the Invention: **Improvements relating to robotic cleaning systems and robots therefor**
Abstract Title: **Robotic cleaning systems**

(57) A cleaning system comprises a cleaning robot and a docking station, each of which comprises a respective at least one reservoir for storing a cleaning fluid, the robot being operable to move over a surface while using said cleaning fluid to clean said surface, the docking station being configured to allow the robot to be docked thereat, wherein the robot and docking station are configured such that the docking of the robot at the docking station automatically causes the transfer of cleaning fluid from the at least one docking station reservoir to the at least one robot reservoir. Also claimed is a window-cleaning robot configured to determine whether the robot is adjacent a frame using a charge sensor. Also claimed is a window cleaning robot having a proximity sensing system that to determine whether the robot is adjacent a window frame and whether the robot is adjacent the window surface. Also claimed is a window-cleaning robot with a linkage that is movably mounted so as to permit movement of a cleaning pad mounting member Also claimed is a window-cleaning robot having a cleaning fluid supply arrangement including a supply conduit with a region of high impedance, which assists in controlling the supply of cleaning fluid to a cleaning pad. Also claimed is a window-cleaning robot with a cleaning fluid supply arrangement that prevents the supply of cleaning fluid when the robot is oriented with a support side facing generally vertically downwards.

FIG. 11



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The print reflects an assignment of the application under the provisions of Section 30 of the Patents Act 1977.

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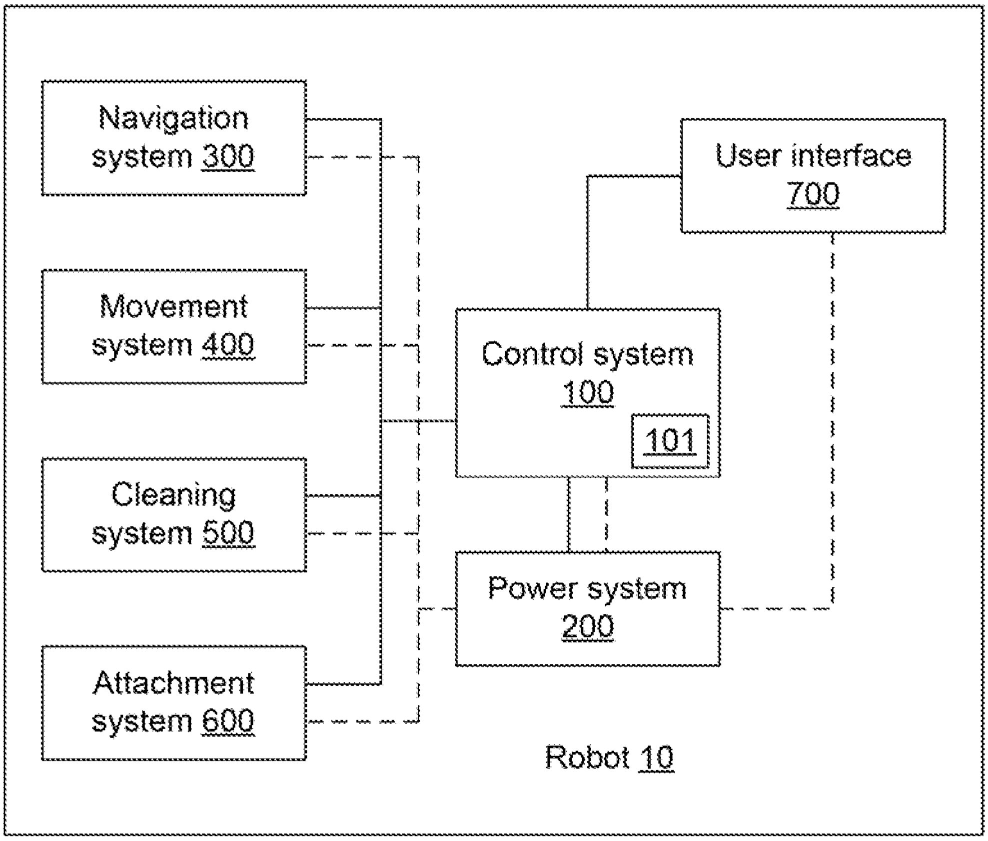
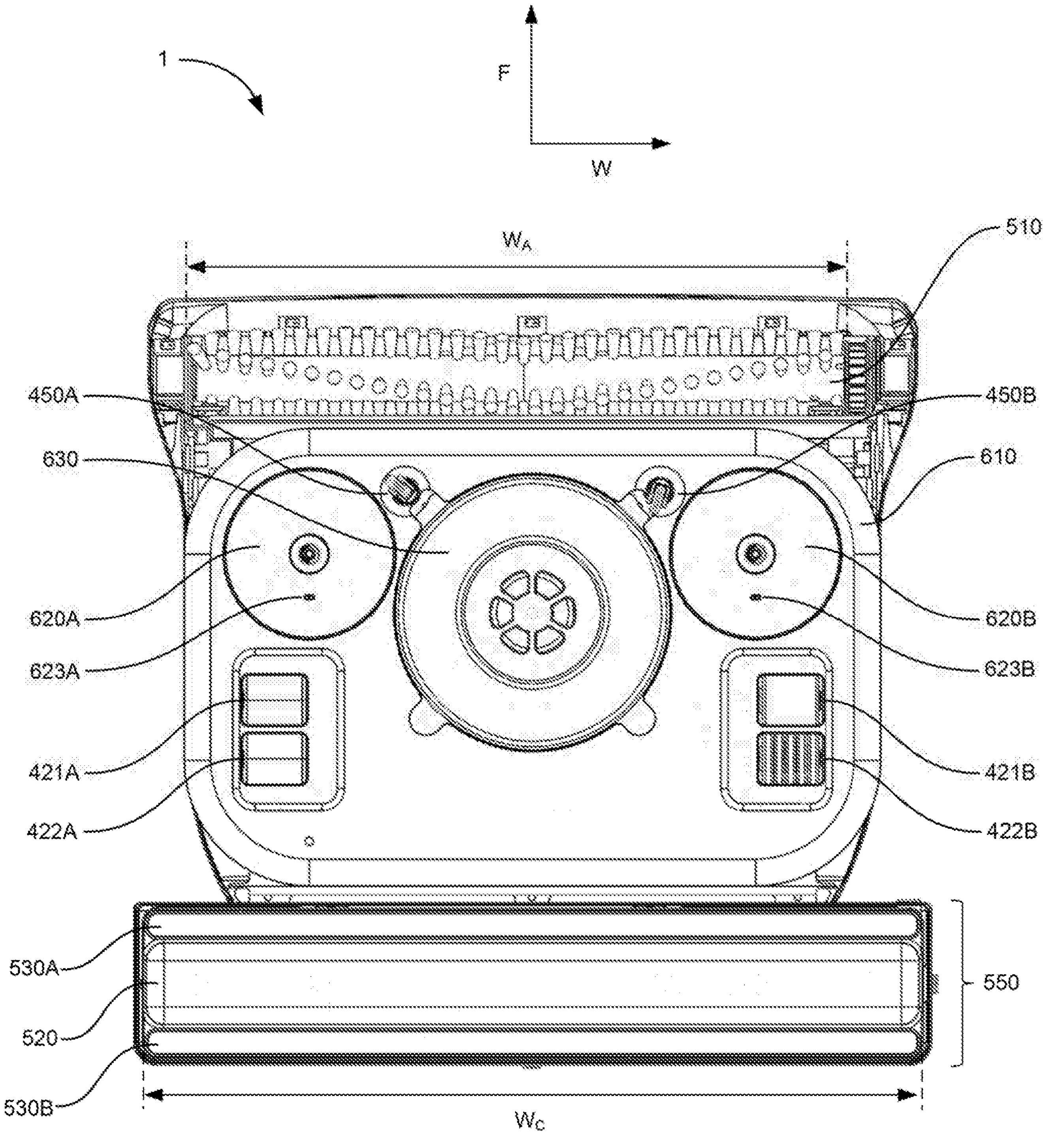

Navigation system 300
Movement system 400
Cleaning system 500
Attachment system 600
User interface 700
Control system 100
101
Power system 200
Robot 10

FIG. 1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F
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450B
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422A
422B
530A
520
530B
550
W_C

FIG. 2

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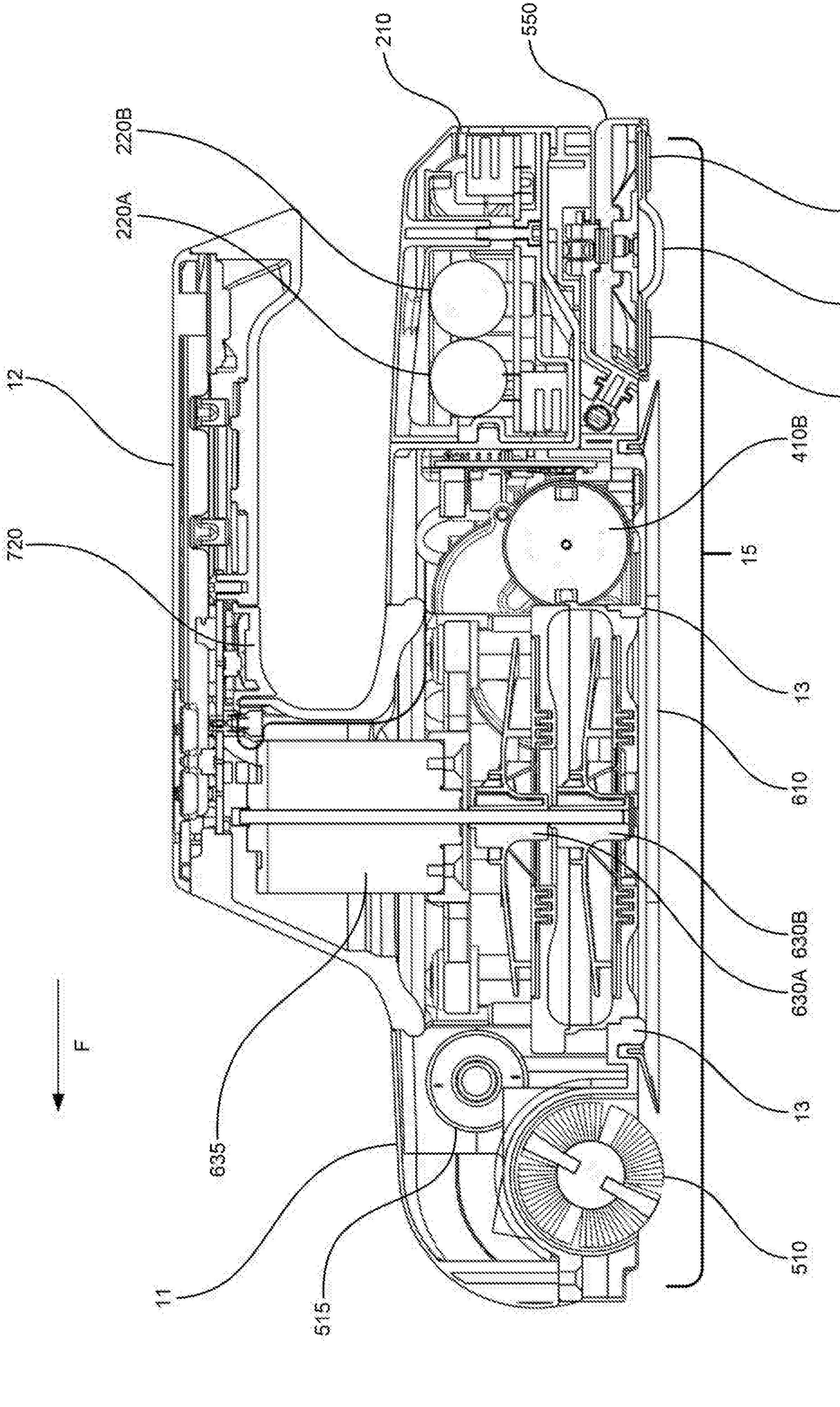
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630B
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13
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F
11
515
510

FIG. 3

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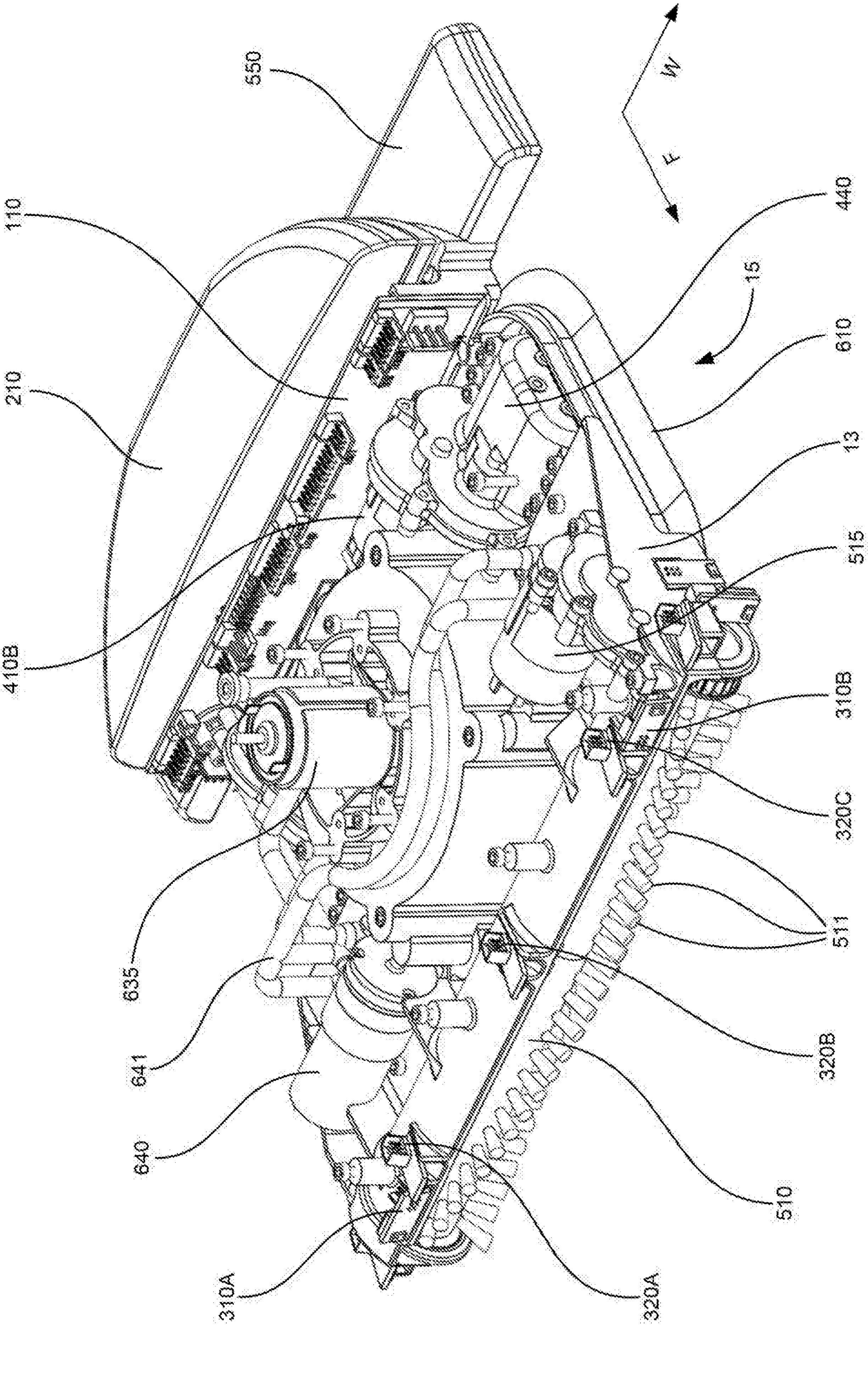

FIG. 4A

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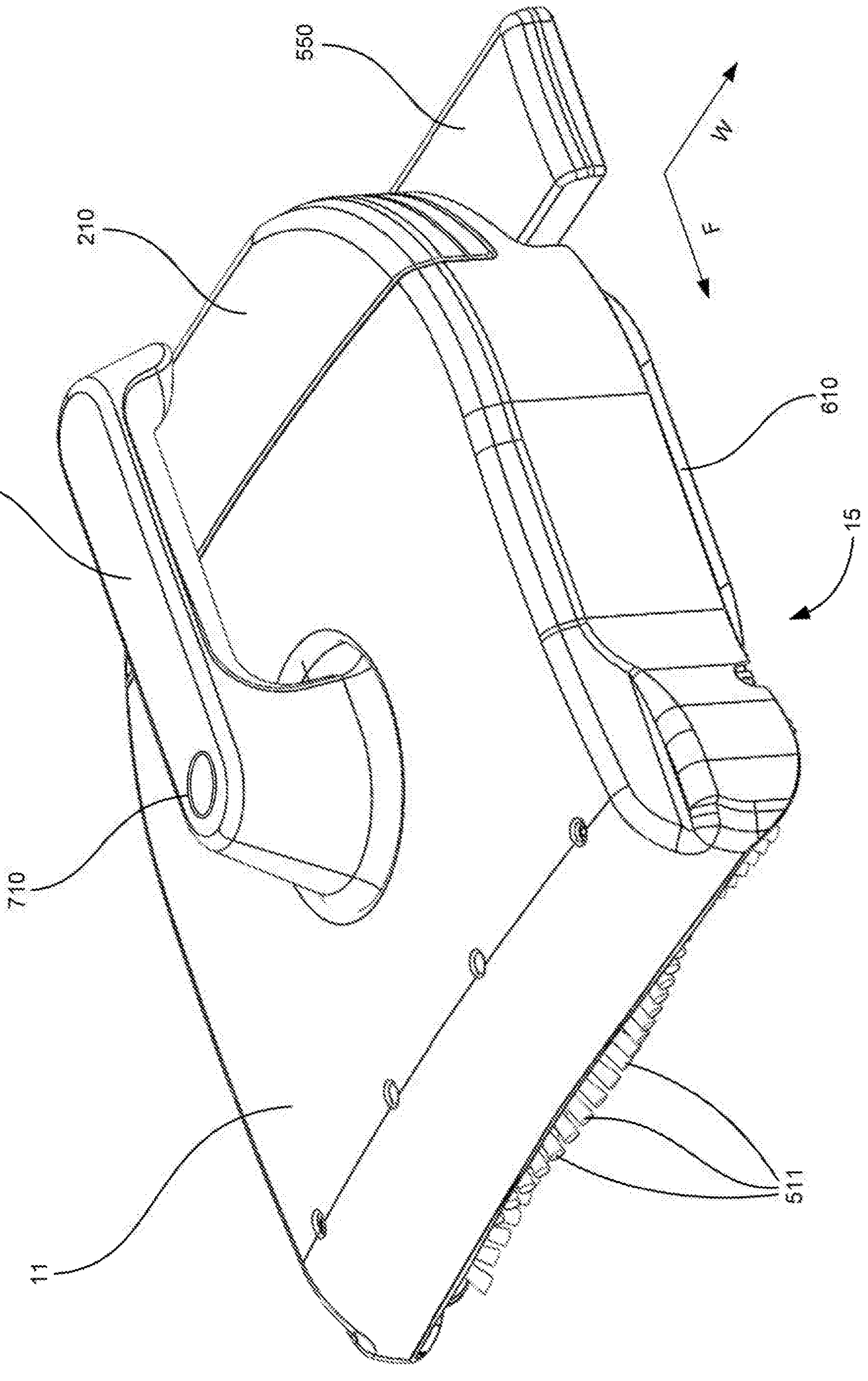

FIG. 4B

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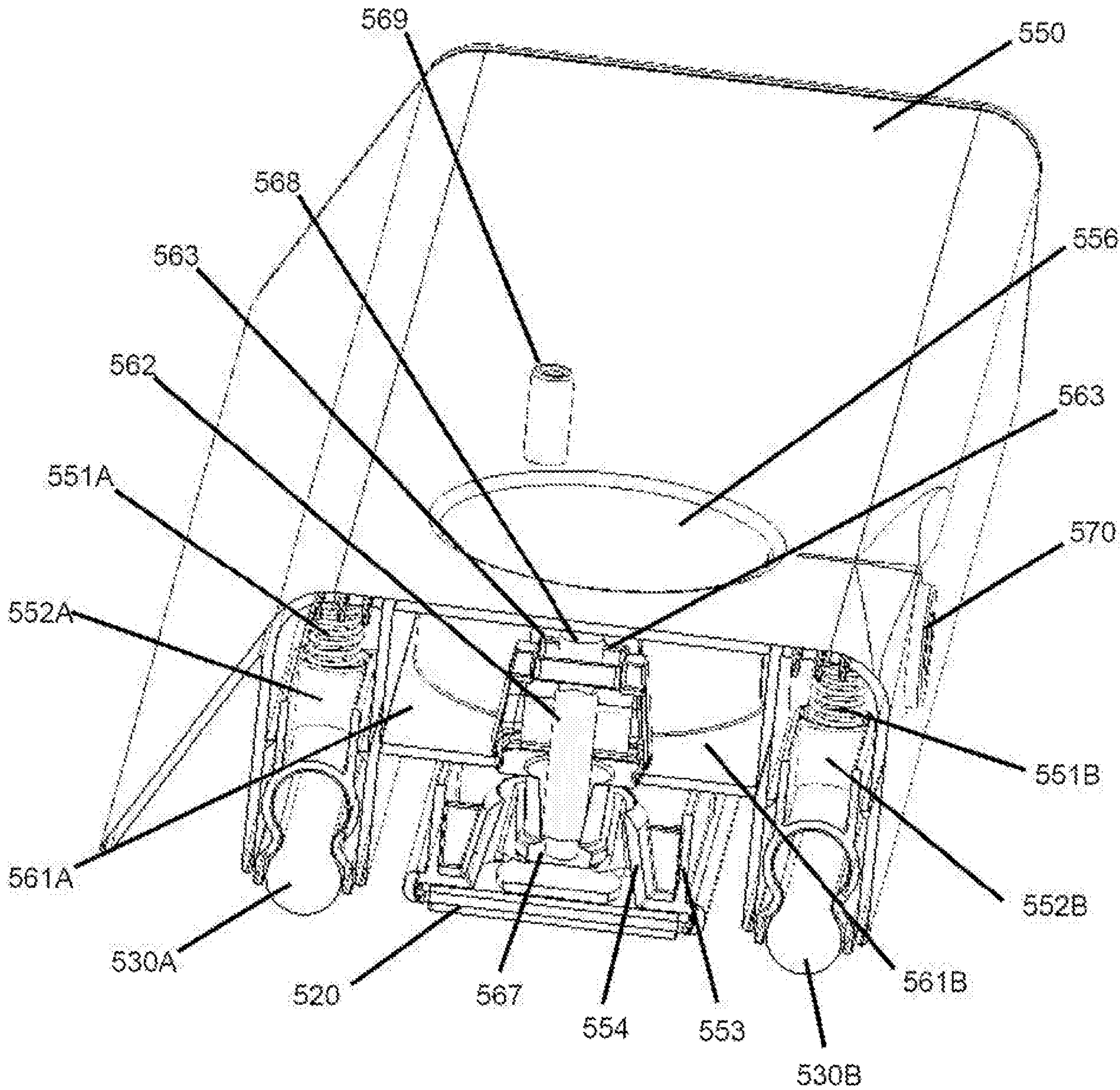
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568
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561B
530B

FIG. 5

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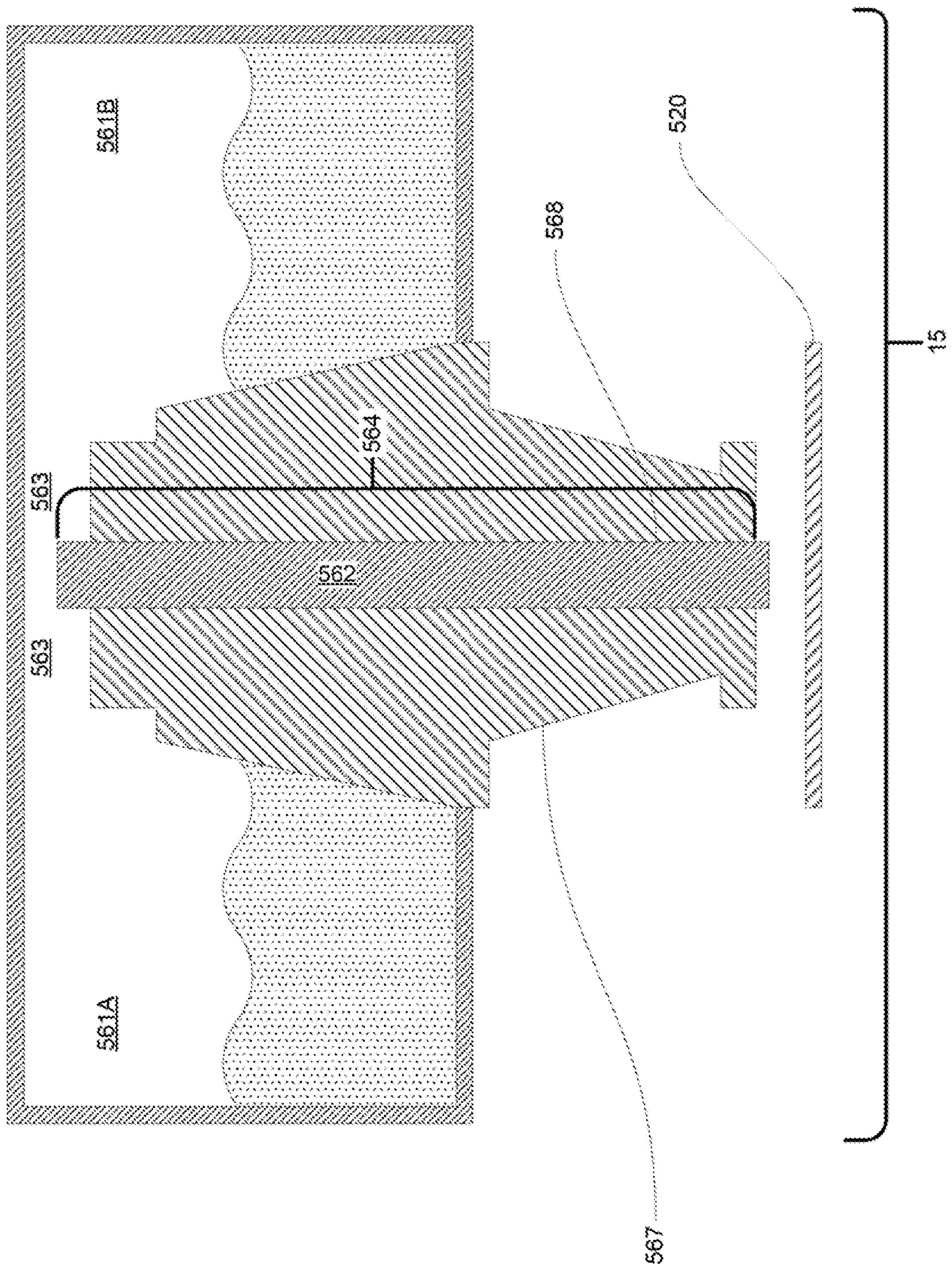

FIG. 6

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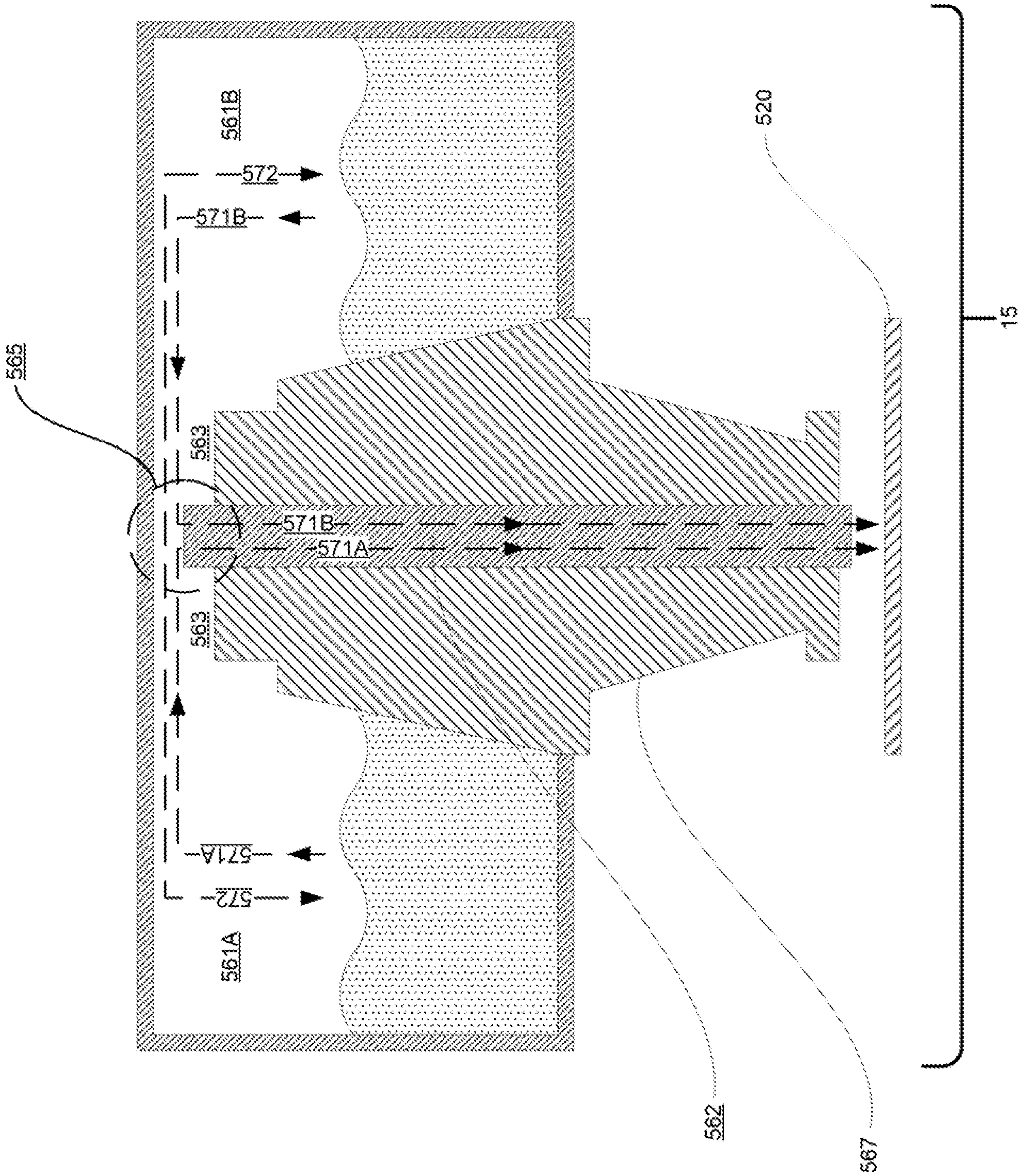
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561A
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15
562
567

FIG. 7

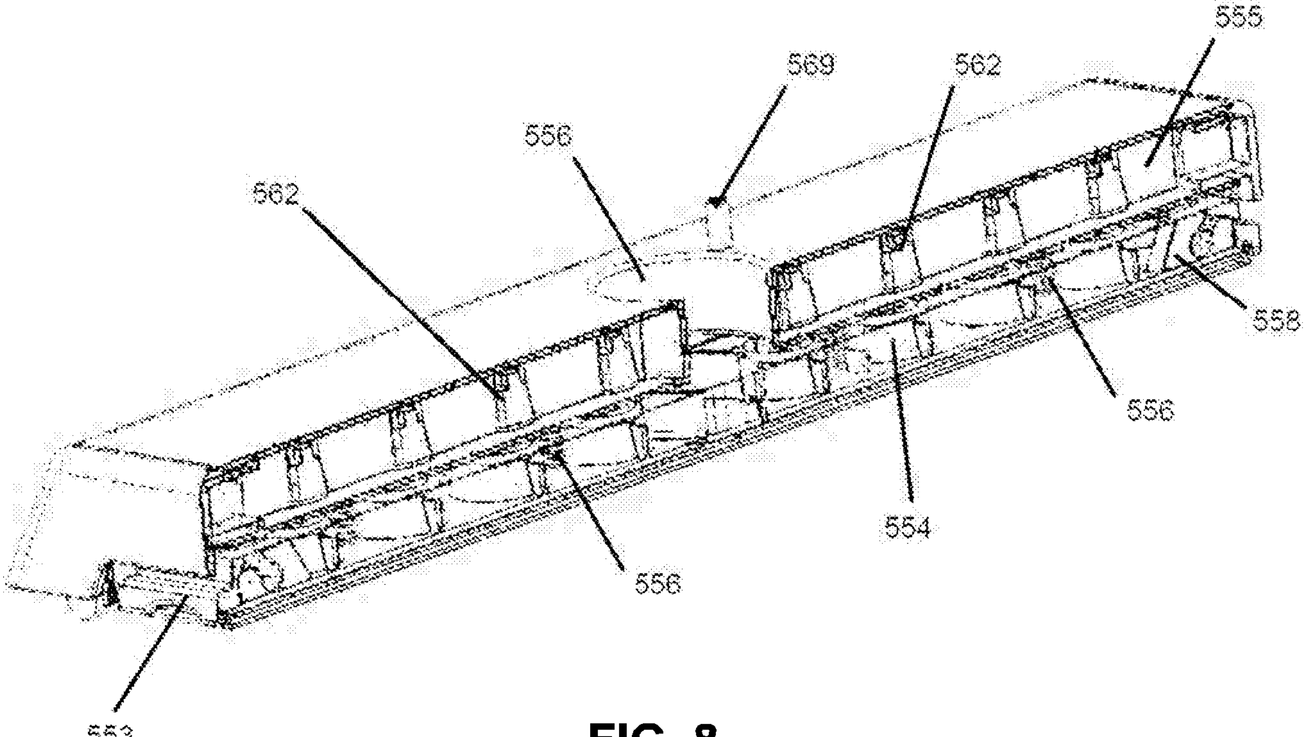

FIG. 8

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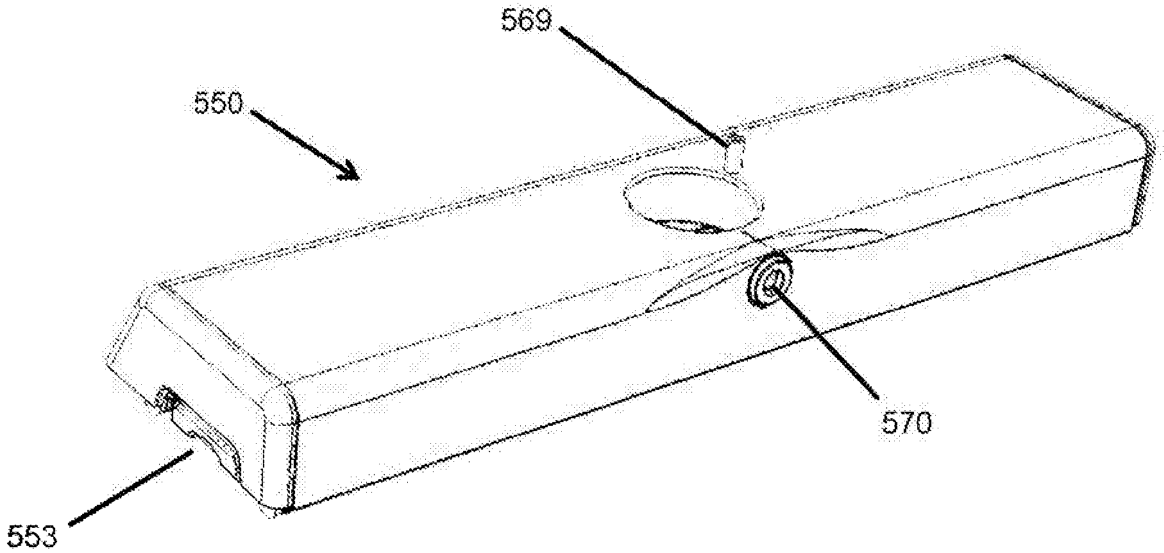

FIG. 9

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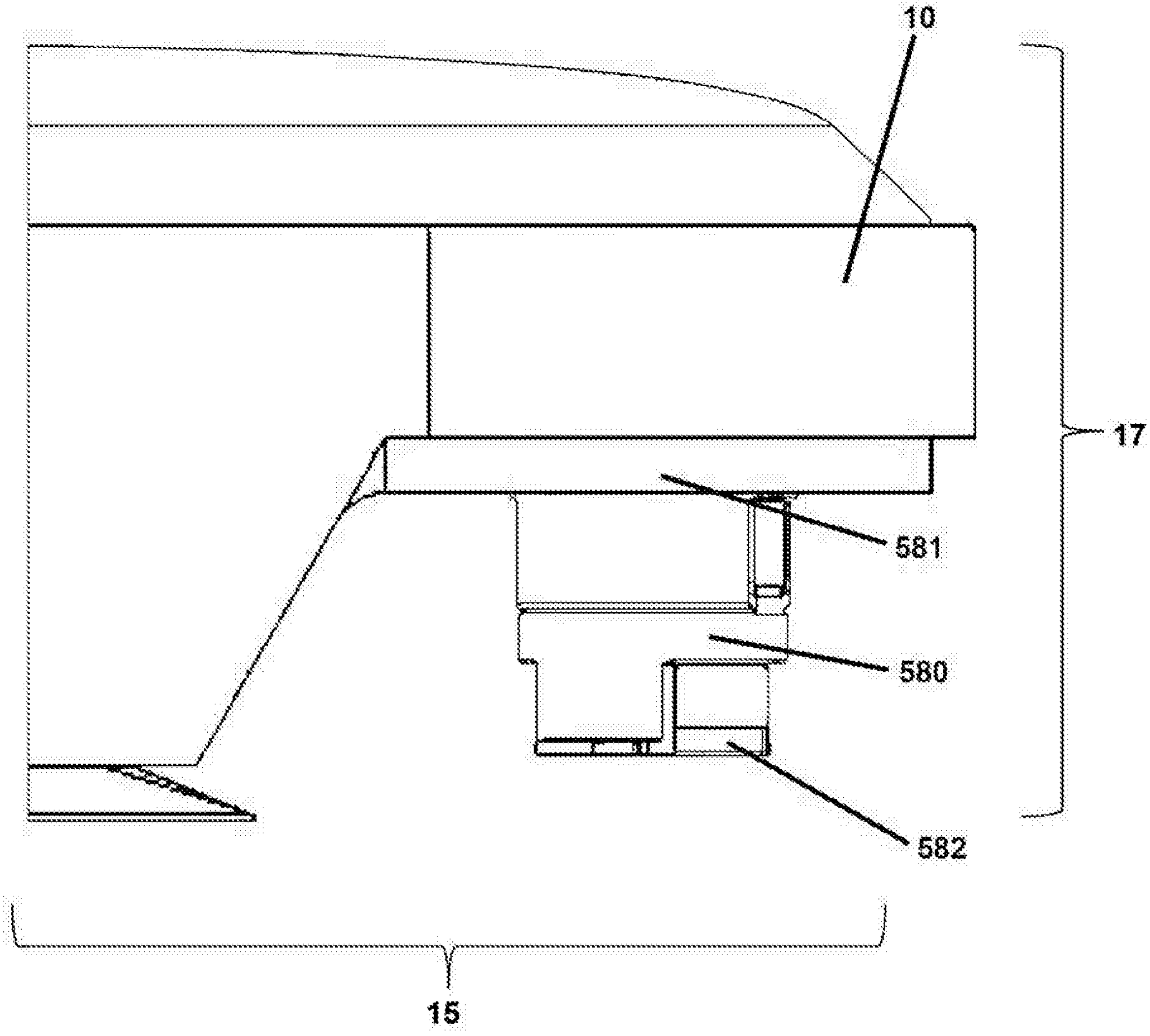

FIG. 10

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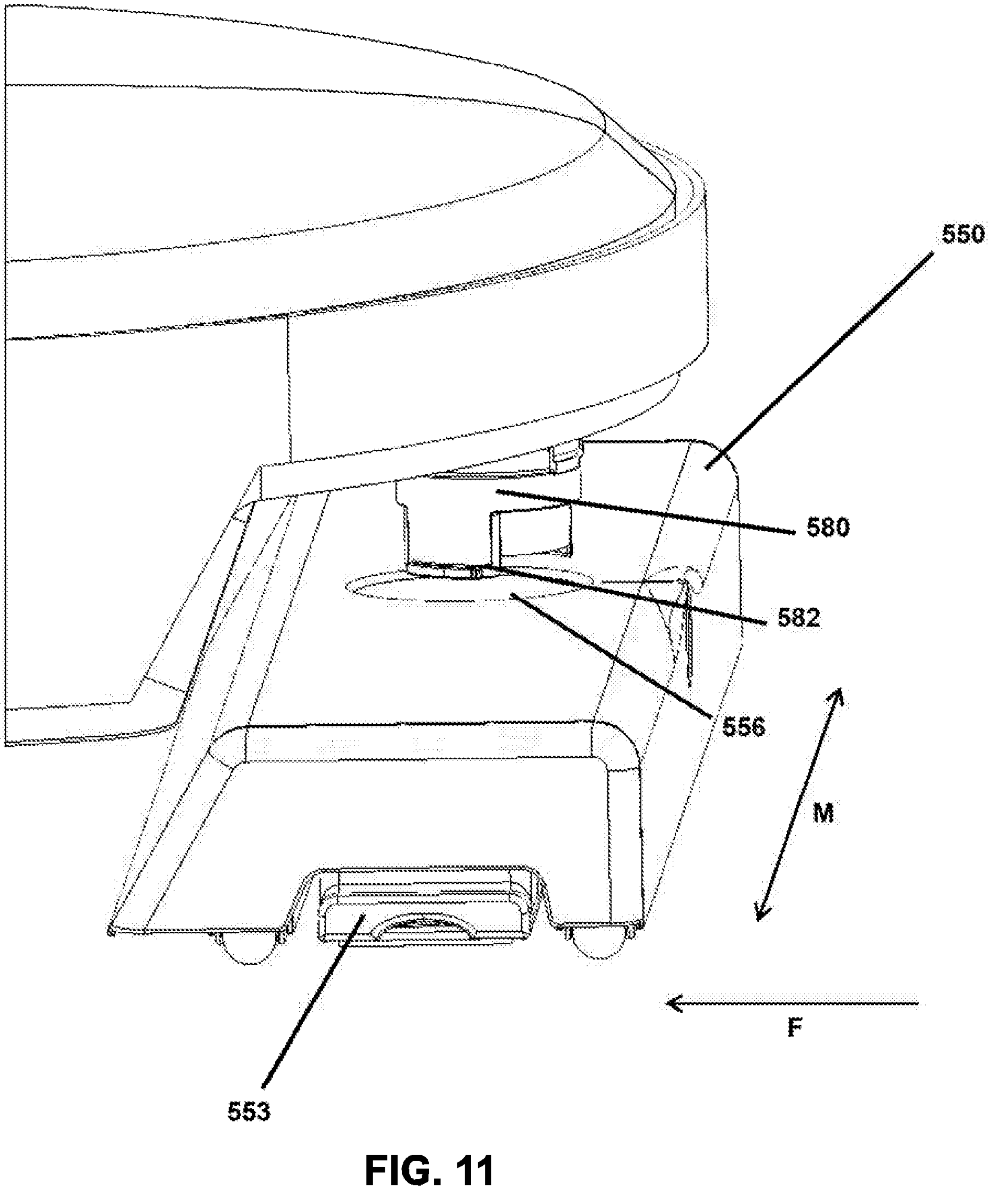

FIG. 11

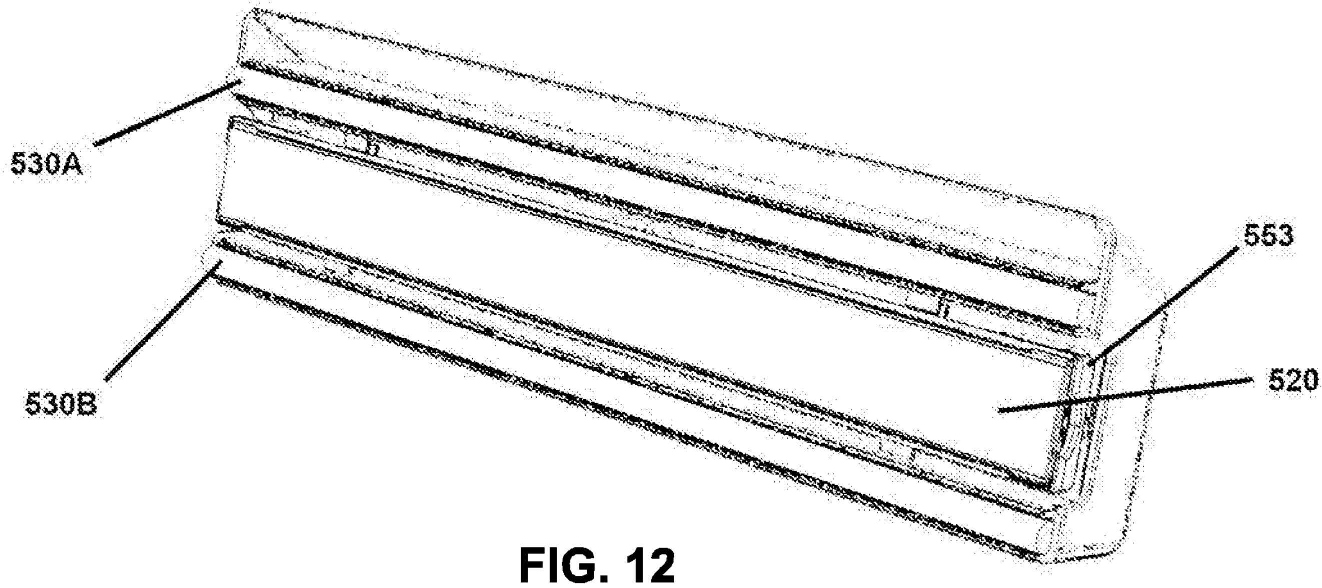

FIG. 12

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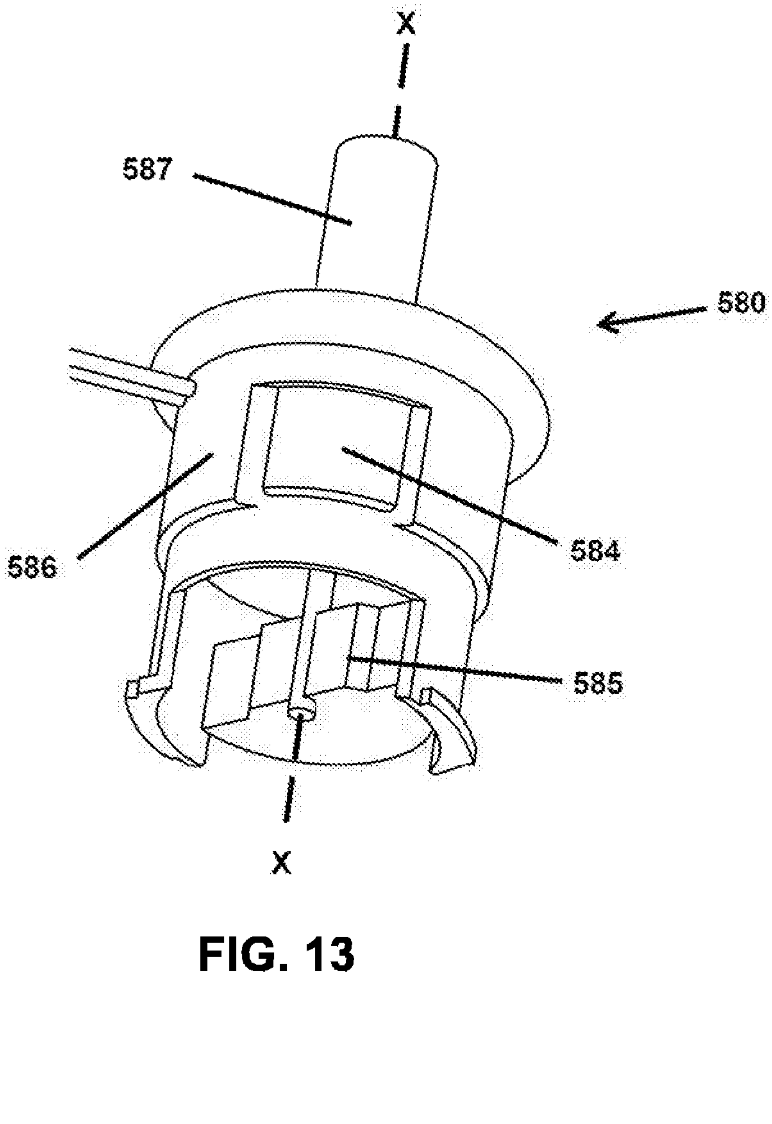

FIG. 13

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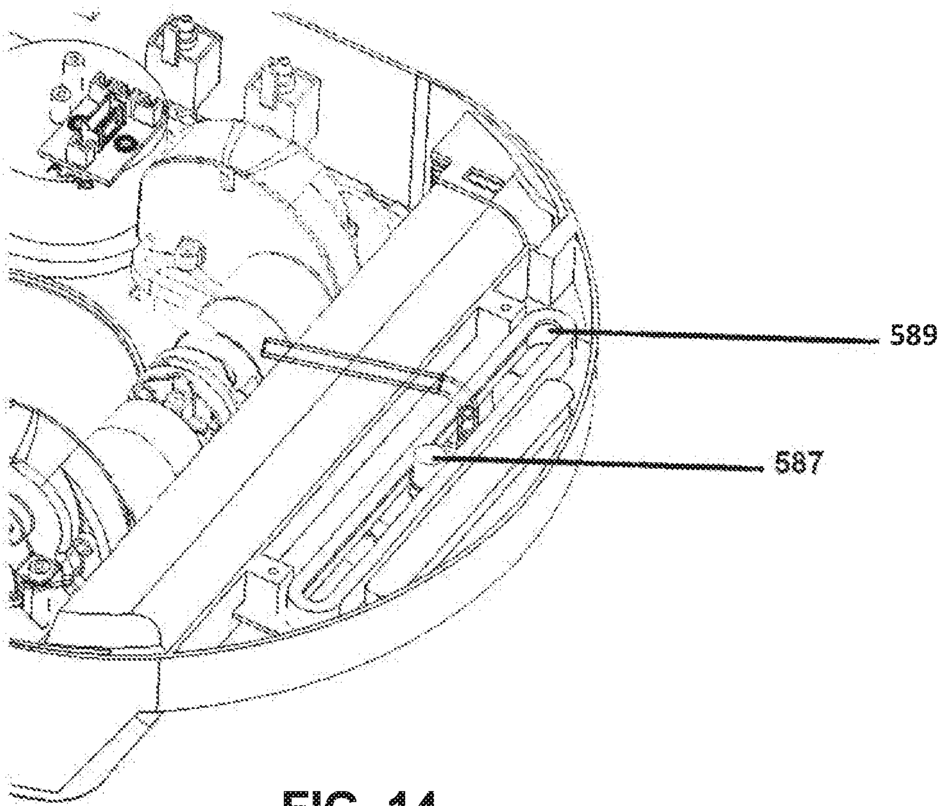

FIG. 14

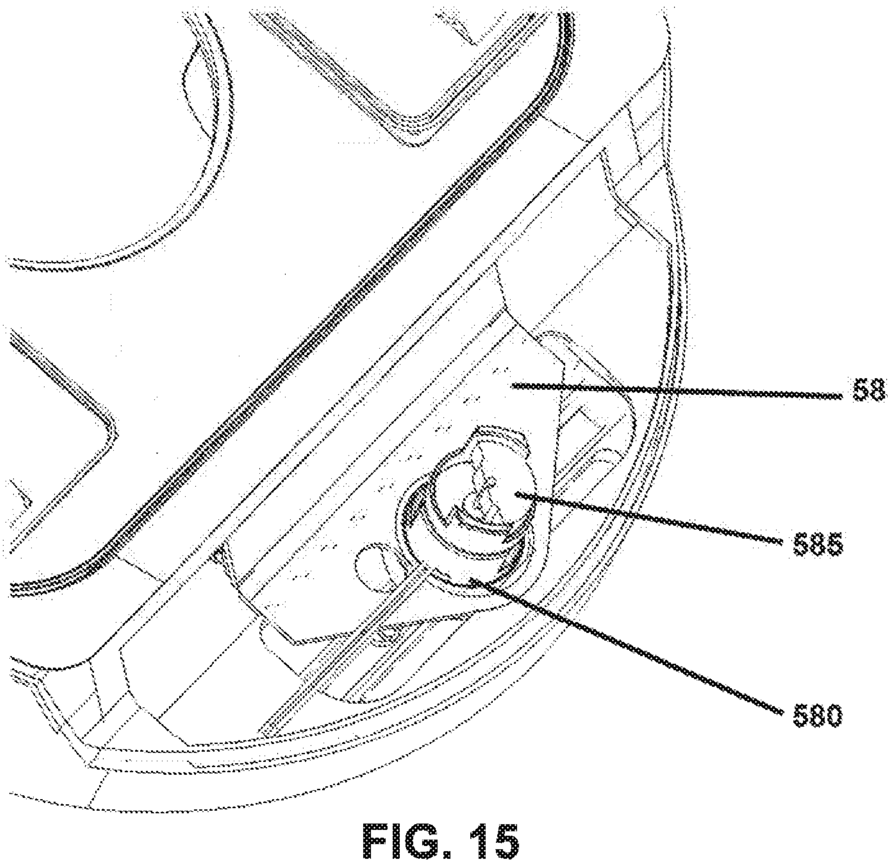

FIG. 15

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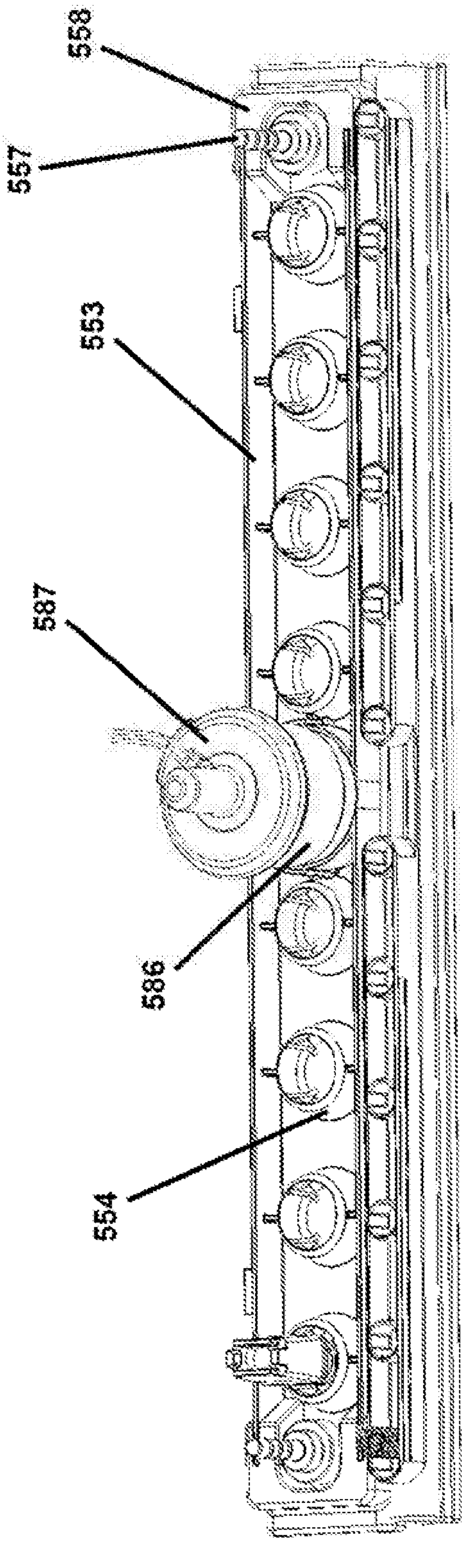

FIG. 16

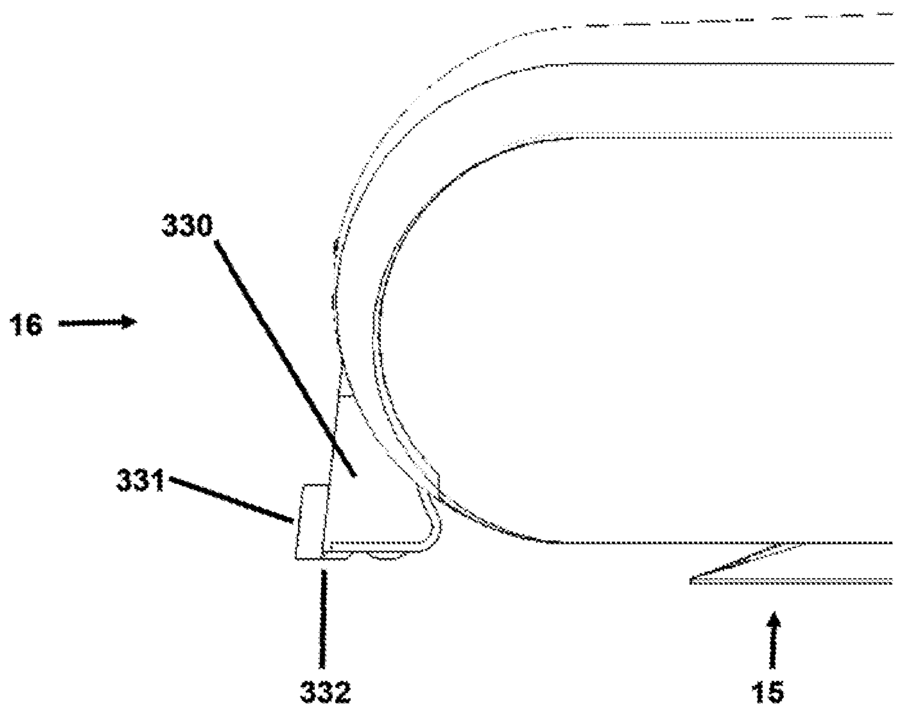

FIG. 17

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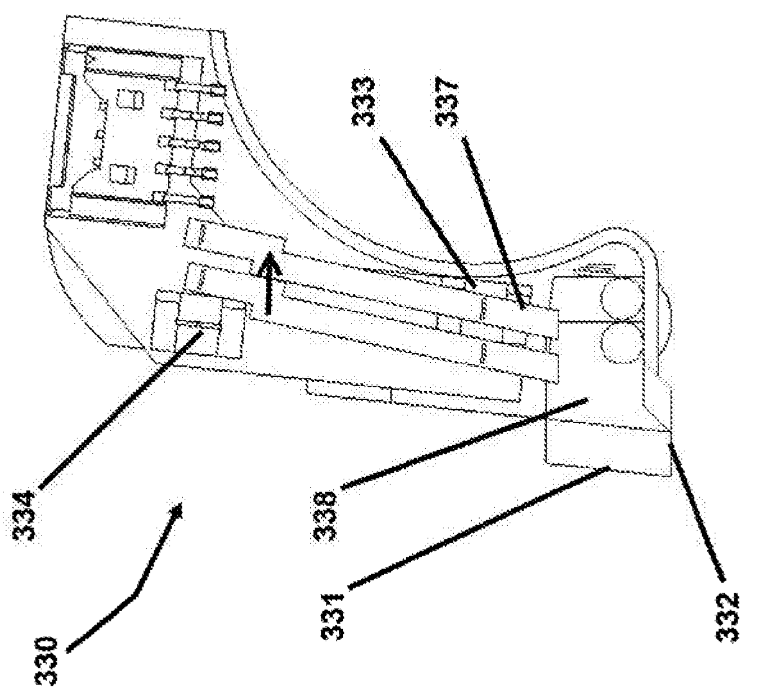

FIG. 18

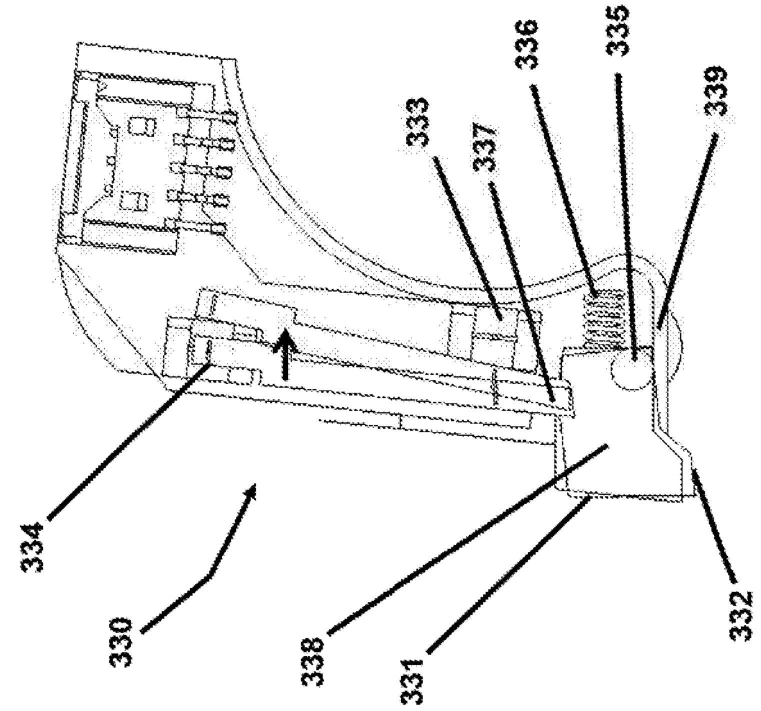

FIG. 19

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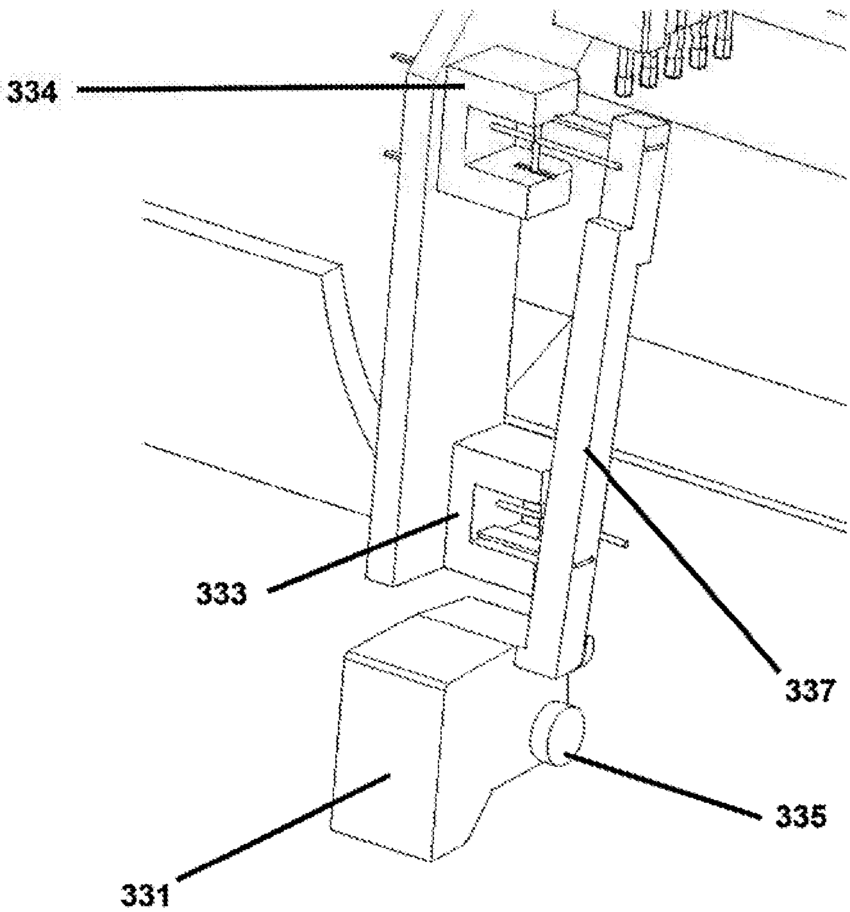

FIG. 20

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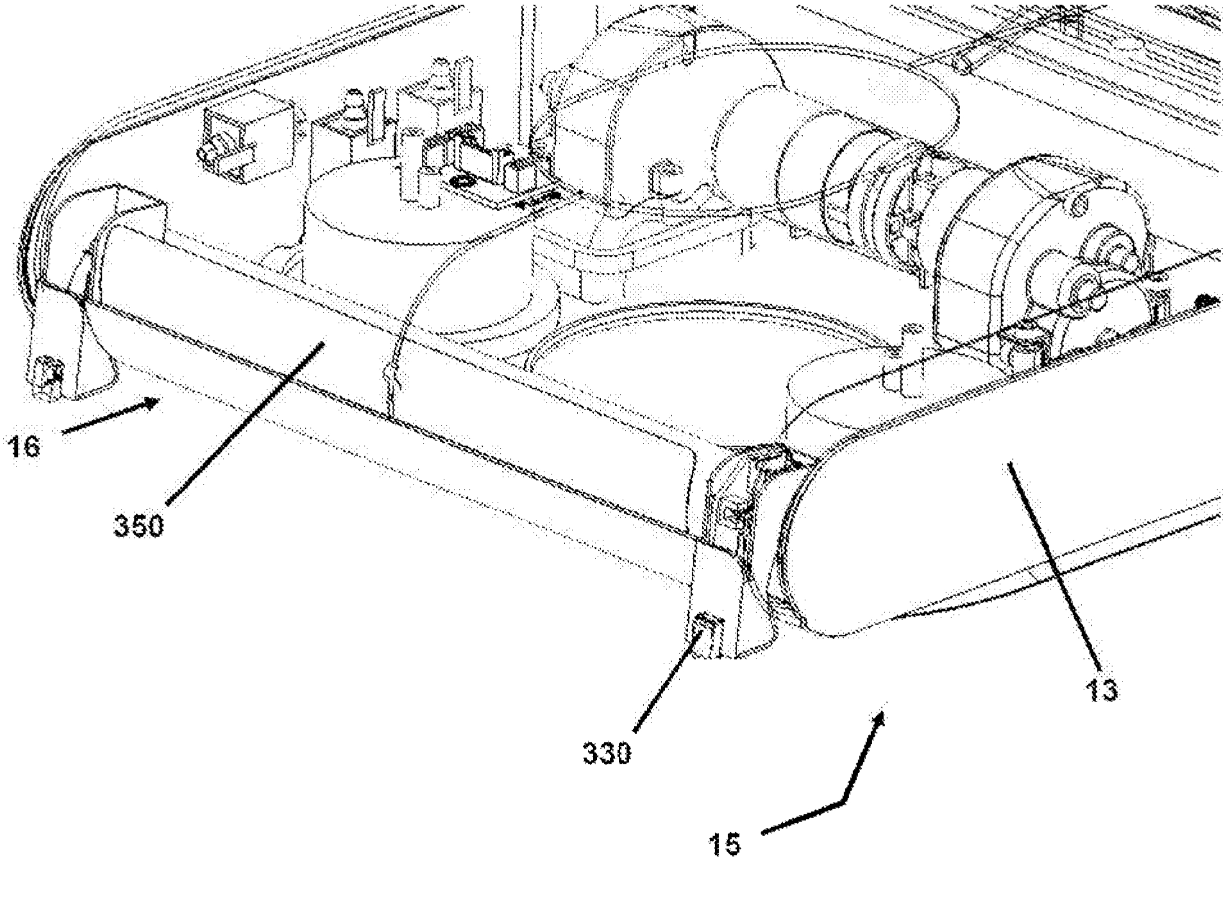

FIG. 21

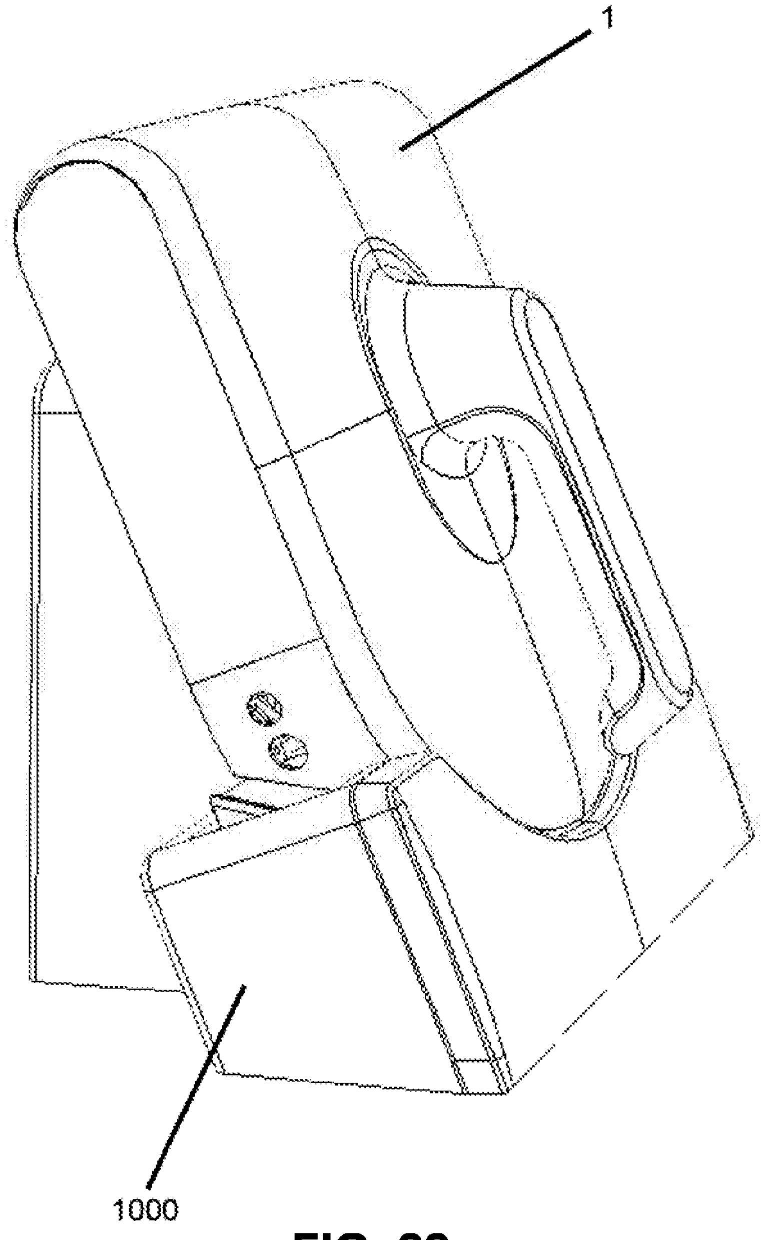

FIG. 22

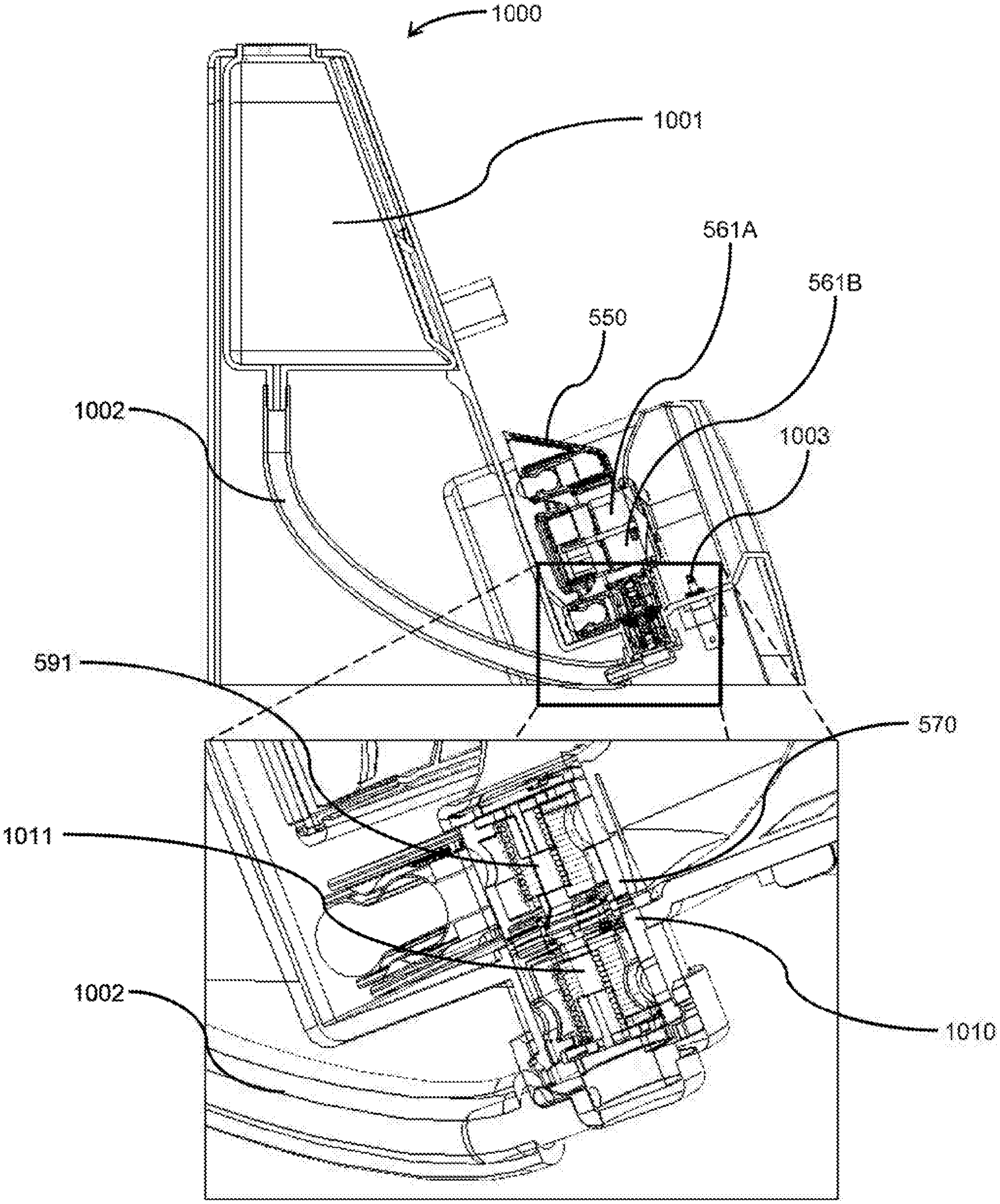

FIG. 23

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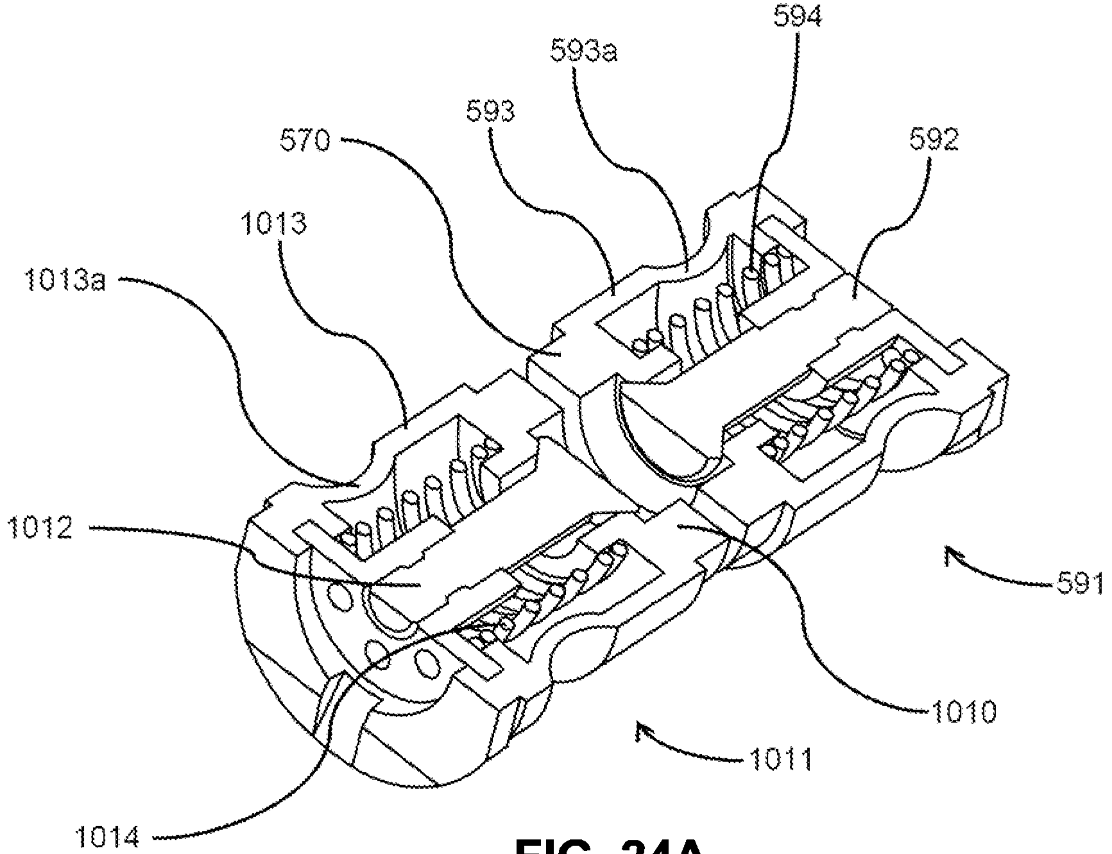

FIG. 24A

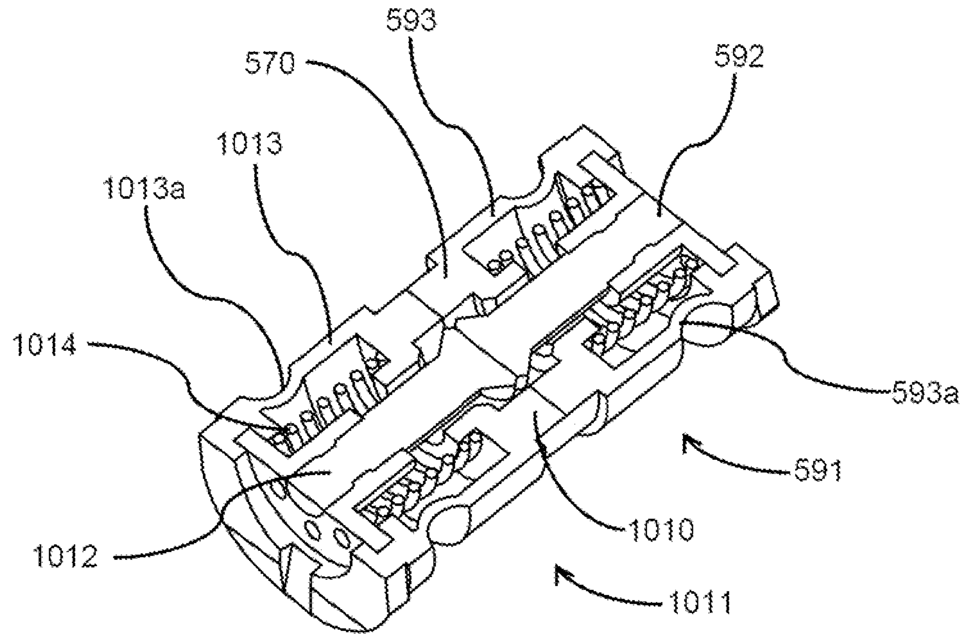

FIG. 24B

IMPROVEMENTS RELATING TO ROBOTIC CLEANING SYSTEMS AND ROBOTS THEREFOR

TECHICAL FIELD

The present invention relates to robotics and, in particular, to robotic cleaning systems (such as robotic window cleaning systems) and cleaning robots that may, for example, form part of such robotic cleaning systems.

BACKGROUND

The use of automated devices is widespread nowadays, and finds countless applications. For instance, robots perform very precise and delicate tasks in the construction of electronic devices, or in medicine and aviation. Robots are also used in applications which require motion, notably, for automatic warehouses, where goods are retrieved and stored by means of computer-actuated robots. Other applications include, e.g., fetching raw materials in the course of industrial manufacturing, and removing and packaging finished pieces.

Attempts have also been made to exploit robots for tasks around the home or garden, such as lawn mowing, snow-blowing, leaf-clearing, floor cleaning, pool cleaning and vacuum cleaning.

By their very nature, autonomous machines such as robots represent a significant labour-saving for consumers. Repetitive and time-consuming tasks may now be carried out without significant supervision or instruction by the user of such autonomous machines.

Cleaning, and particularly the cleaning of surfaces, is an example of such a repetitive and time-consuming task. Many surfaces require regular cleaning, whether for practical purposes, aesthetic purposes, or otherwise. For instance, floor cleaning may be important for reasons of hygiene (particularly in health care centres, such as hospitals, food preparation centres, such as kitchens or food-packing plants, and the like) as well as for maintaining a shiny and attractive floor surface (particularly in hotels, restaurants and the home). With window cleaning, maintaining a clean and shiny surface is likewise desirable.

Robotically cleaning surfaces may be valuable, for example: in reducing manual labour; in enabling surfaces to be cleaned at times convenient for the user (e.g. overnight, when the building is closed); and in enabling surfaces to be cleaned in situations that might be challenging or even dangerous for a human (e.g. cleaning floors in a plant handling dangerous chemicals, or cleaning windows that are usually hard to access, such as the external surfaces of windows and/or windows that are high above the ground).

A few robots for cleaning surfaces are currently available to the consumer (such as, in the case of window cleaning robots, the WinBot™ and Hobot™, or, in the case of floor cleaning robots, the Braava and Rydis™). However, in many respects, robots for cleaning surfaces and the systems of which they form a part have not yet been perfected.

SUMMARY

Aspects of the invention are set out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described with reference to the drawings, in which:

Figure 1 illustrates schematically an example of a robotic window cleaner and the systems thereof;

Figure 2 is a plan view of the side of a window-cleaning robot that attaches to the surface of a window;

Figure 3 is a cross-sectional side view of the robot of Figure 2;

Figure 4A is a perspective view of the robot of Figures 2 and 3 with its top cover removed so as to display various of the robot's internal components;

Figure 4B is a perspective view of the robot of Figures 2 and 3 with the top cover in place;

Figure 5 is a perspective view of a cross-section taken perpendicular to the length of a cleaning pad module for a robot;

Figure 6 and 7 are diagrammatic views of a cross-section through the cleaning pad module of Figure 5, with certain features of the cleaning pad module omitted so as to clearly show the relative arrangement of the conduits, reservoirs, and fluid paths of the cleaning pad module;

Figure 8 is a perspective view of a cross-section taken along the length of the cleaning pad module of Figure 5;

Figure 9 is a perspective view from above of the cleaning pad module of Figure 5;

Figure 10 is a side view of the rearwards end of a robot with a vibrational linkage to a cleaning pad mounting member;

Figure 11 is a perspective view of the rearwards end of the robot of Figure 10 with the cleaning pad module removed;

Figure 12 is a perspective view of the cleaning pad module of Figures 10 and 11 from the window-engaging side;

Figure 13 is a detailed perspective view of the linkage of the robot of Figures 10-12;

Figure 14 is a perspective view from above of the rearwards end of the robot of Figures 10-13;

Figure 15 is a perspective view from below of the rearwards end of the robot of Figures 10-14;

Figure 16 is a perspective view from above of the cleaning pad mounting member of the robot of Figures 10-15;

Figure 17 shown is a detail side view of a robot with a contact-based proximity sensing system;

Figures 18 and 19 are side views of cross-sections taken through the robot of Figure 17, which show the mechanism of the proximity sensing system carrying out respective movements;

Figure 20 is a perspective view of the proximity sensing system of Figures 17-19, with certain portions of the robot omitted for clarity;

Figure 21 is a perspective view of a robot with a capacitive proximity sensing system, with its top cover removed;

Figure 22 is a perspective view of a robot docked at a docking station;

Figure 23 is a view of a cross-section through the robot and docking station of Figure 22, following docking of the robot at the docking station; and

Figures 24A and 24B are cross-sectional views of valves provided on the robot and docking station respectively immediately prior to docking and after docking.

DETAILED DESCRIPTION

Introduction

Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not necessarily limited in its application to the details of construction and the arrangement of the components and/or methods set forth in the following description and/or illustrated in the drawings. The invention is capable of other embodiments or of being practiced or carried out in various ways.

As will be appreciated by one skilled in the art, aspects of the present invention may be embodied as a system, method, with various computer components. The computer components may be in the form of hardware embodiment, software (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a "circuit", "module" or "system.".

Turning now to Figure 1, there is shown schematically an example of a cleaning robot 1, in which various aspects of the present disclosure may be embodied, and details the systems included therein. It should be understood that the details of these systems are merely illustrative and are provided so as to demonstrate ways in which the aspects described in the sections further below may be implemented within a cleaning robot or a robotic system including such a robot.

As is shown in Figure 1, the example robot 1 includes: a movement system 330, for moving the robot over the surface to be cleaned (e.g. a floor or a window surface); a navigation system 300, to enable to robot to navigate around the surface; a cleaning system 350, for removing dirt, debris and the like from a portion of the surface adjacent the robot, as the robot moves over the surface; a power system 200, for powering the various systems, components etc. within the robot; a control system 100, for communicating with and controlling the systems of the robot; and a user interface 700, enabling the user to input commands, information and the like to control the robot's operation and providing an indication to the user of the robot's current state.

The particular example robot 1 shown in Figure 1 also includes an attachment system 600, to enable the robot to attach itself to the surface to be cleaned (and to keep it attached thereto. For instance, such an attachment system 600 may be provided in the case where the robot is configured to clean window surfaces, since these will often be oriented vertically or near-vertically. However, such an attachment system may not be necessary in other cases, such as where the robot is configured to clean floor surfaces.

The control system 100 may, for example, include a main board, and all electronics, as hardware, software and combinations thereof and other components, necessary for the robot 1 to perform all of its operations and functions (known as the main board electronics). The main board includes one or more processors 101 as part of the main board electronics.

As indicated in the drawing with solid lines, the navigation, movement, attachment, cleaning, power and user interface systems are in data communication with the control system, so that the control system can receive data from and/or send instructions to these systems.

The power system 200 may, for example, include: an internal power supply, including one or more batteries (typically rechargeable); battery voltage sensors, typically for each battery, that enable the robot to determine when the power supply is running low; and charging contacts, that enable electrical connection to an external power source so as to allow the internal power supply to be charged. The charging contacts may be connectable to an electrical lead that is connectable, for instance with standard plug, to an external power supply, such as a mains power supply; the lead may include a transformer, where appropriate.

As discussed above, the power system 200 may have a data connection to the control system 100 so that the control system can receive data from the power system, for example relating to the current power level of the internal power supply (e.g. using battery voltage sensors).

The robot 1 may be designed such that it can be received by a docking station (not shown) which the robot 1 will return to once its task is complete (e.g. for orderly control and arrangement of the robot), and/or when its internal power supply is running low. While in this docking station, various functions can occur, such as battery recharging (e.g. by means of charging contacts) and the like.

The power system 200 may, instead of having an internal power supply (or in addition to having an internal power supply) rely on power from an external power supply, such as the mains power supply. Where the power system relies solely on power from an external power supply, charging contacts may not be included, but the power system 200 may nonetheless include an electrical lead connectable to an external power source; such an electrical lead may be built-in to the robot 1, so that it cannot be removed by the user and will not detach during normal operation.

As shown by dotted lines in Figure 1, the power system is electrically connected to the control, navigation, movement, cleaning and attachment systems, and the user interface, so as to supply electrical power to these systems and their components.

The navigation system 300 may include a number of sensors that enable the robot to navigate around the surface to be cleaned (e.g. a floor or a window surface), when moving using the movement system 330.

For instance, in the case where the robot is configured as a window-cleaning robot, the navigation system 300 may include one or more sensing systems, each typically comprising a number of suitably configured sensors. Such a sensing system may, depending on the type of sensors employed, be configured to enable the robot: to detect the presence of the window surface adjacent a portion of the robot; to determine its current orientation (e.g. with respect to gravity or a predetermined orientation); and/or to determine its current distance from the window frame (which will typically extend perpendicular to the window surface).

In the case where the robot is configured as a floor-cleaning robot, the navigation system 300 may likewise include a sensing system, typically comprising a number of suitably configured sensors. Such a sensing system may enable the robot to determine its current distance from walls or obstacles extending upwards from the floor surface; and/or to detect the presence of the floor surface adjacent a portion of the robot (and thus that enable to robot to determine when it is contact with the floor).

As shown in Figure 1, the navigation system 300 is in data communication with the control system 100. The control system 100 may therefore receive data from the navigation sensors and control the movement system 330 in dependence upon such data.

As noted above, the attachment system 600 enables the robot to attach itself to surface to be cleaned and keeps it attached thereto. The attachment system 600 may, for example, utilise suction forces to attach the robot to the surface to be cleaned. Accordingly, it may, for instance, include one or more vacuum pumps to provide a suction force and one or more sealing members that contact the surface so as to seal a space between the robot and the surface, with the vacuum pump(s) being configured to reduce the air pressure in this space.

The attachment system 600 might instead (or in addition) utilise magnetic forces to attach the robot to the surface to be cleaned.

For instance, in the case of a window-cleaning robot, the user may be provided with a paired device that is placed on the opposite surface of the window to the side on which the robot operates, with the robot and the paired device being magnetically attracted to each other. Hence, the robot and/or the paired device may, for instance, include one or more magnetic members, such as electromagnets or permanent magnets.

As shown in Figure 1, the attachment system 600 is in data communication with the control system 100 and may therefore receive commands from the control system 100 and send status information to the control system 100. For example, the control system 100 may command the attachment system 600 to increase the attachment force.

The movement system 330, as noted above, enables the robot to move over the surface to be cleaned. Accordingly, it may, for instance, include wheels, tracks and the like that contact the surface and apply a force thereto so as to drive the robot over the surface. As shown in Figure 1, the movement system 330 is in data communication with the control system 100 and may therefore receive commands from the control system 100. For example, the movement system 330 may be commanded by the control system to move the robot along a path calculated by the processor(s) 101 within the control system 100.

In some arrangements, certain components may form a part of both the movement 330 and attachment 600 systems, such as where a number of elements each provide a separate attachment force and are moveable with respect to each other, so as to move the robot over the surface to be cleaned. One example of such a combined attachment and movement system is where two or more separate sealing elements are provided, with these sealing elements being moveable with respect to each other; each of the sealing elements might be provided with a dedicated vacuum pump in such a situation.

The cleaning system 350, as noted above, removes dirt, debris and the like from a portion of the surface to be cleaned (e.g. a floor or a window surface) adjacent the robot, as the robot moves over the surface, using the movement system 330.

The cleaning system may include, for example, a cleaning pad that is wetted with cleaning fluid, a reservoir for such cleaning fluid, a hose for applying cleaning fluid to the surface, and the like. Although in Figure 1 the cleaning system 350 is shown as being in electrical communication with power system 120 and in data communication with control system 100, in some arrangements, the cleaning system might include no powered components, in which case, such connections to the power 200 and control 100 systems would be unnecessary.

In some arrangements, certain components may form a part of both the cleaning system 350 and the attachment system 600, for example, where a suction force is applied through a cleaning pad. In further arrangements, certain components may form a part of the cleaning 350, attachment 600 and movement 330 systems, for example where a number of cleaning pads are provided that may move relative to one another, with a suction force being applied through each cleaning pad.

Turning now to the user interface 700, as noted above, this may enable the user to input commands, information and the like to control the robot's operation and may provide an indication to the user of the robot's current state. Accordingly, it may include a number of controls, such as buttons, dials and the like, and a number of indicators, such as a display screen, LEDs and the like, or a combination of both, such as a touchscreen. It may also include a wireless communication link, so as to connect with a user device, such as a smart-phone, tablet device, laptop, PC etc.

As shown in Figure 1, the user interface 700 is in data communication with the control system 100. The user interface 700 may therefore receive status information from the control system 100 that it then displays or indicates to the user. Conversely, the control system 100 may receive user commands that are inputted using the user interface 700 and may, thereafter, send corresponding commands, for instance, to the movement 330, attachment 600 and cleaning 350 systems. For example, the user may use the user interface 700 to select one of a number of operation modes that the robot (specifically the processor(s) of the control system 100) has been programmed with and the control system 100 may thereafter command, for instance, the movement 330, attachment 600 and cleaning 350 systems in accordance with rules and procedures that are associated with the mode selected by the user.

Attention is now directed to Figures 2 to 4, which illustrate a more specific example of a robot 1 that includes control 100, power 200, navigation 300, movement 330, cleaning 350 and attachment 600 systems and a user interface 700, which generally interact in the manner described above with reference to Figure 1. Though the particular example shown is configured as a window-cleaning robot it should be understood that similar components might be employed in a robot configured to clean other surfaces, such as floor surfaces, with some components perhaps being omitted (such as those of the attachment system 600).

Moreover, it should be noted that the specific details of the systems and components of the robot 1 shown in Figures 2-4 are merely illustrative and are provided so as to demonstrate ways in which the aspects described in the sections further below may be implemented within a surface-cleaning robot or a robotic system including such a robot.

Referring now to Figures 2 to 4, the robot 1 shown is configured such that its movement system 330 has a defined forwards direction, which is indicated by arrow F in Figure 2. In the specific example shown, the forwards direction is perpendicular to the axes of rotation of the wheels 421A-422A, 421B-422B, as well as being parallel to the window surface, though with other movement systems 330 the forwards direction may be defined in different ways (e.g. in a system that uses continuous tracks, it may be parallel to the length direction of each such track).

The forwards direction F defines a “forwards” end for the robot 1; this is the uppermost end in Figure 2, which is a plan view of the side 15 of a window-cleaning robot that attaches to the surface of a window. By contrast, the lowermost end in Figure 2 is the “rearwards” end.

Figure 2 also indicates, using arrow W, a width direction for the robot, which is perpendicular to the forwards direction F and which is parallel to the window surface when the robot is attached thereto.

The forwards direction F may, for example, be distinguished from the opposite, rearwards direction in terms of the rules and policies by which the control system 100 operates the movement system 330. For instance, such rules and policies may be such that the robot 1 will move in the forwards direction D (upwards in Figure 2, though not necessarily upwards with respect to gravity) with significantly greater regularity than in the opposite, rearwards direction (downwards in Figure 2, though, similarly, not necessarily downwards with respect to gravity).

As may also be seen from Figure 2, in terms of its structure the robot 1 has fairly distinct front, middle and rear sections.

In the specific example of a robot shown in Figure 2, the middle section provides many of the components for the attachment system 600 and the movement system 330 of the robot 1.

In more detail, the middle section includes a sealing member 610, which comprises a thin foil surrounding seal, and a vacuum pump, which, in the example shown, is based on a double rotating impeller 630. The inlet for the impeller 630 near-most the window surface is clearly visible in Figure 2.

The sealing member 610 and the impeller-based vacuum pump both form part of a suction-based attachment system 600 for the robot.

The middle section further includes two sets of drive wheel pairs 421A-422A, 421B-422B, where the wheels of each pair are driven with the same transmission and thus move at the same velocity, as well as castor wheels or sliding points 450A, 450B. In the particular example of a robot shown, wheels 421A-422A, 421B-422B are covered by a soft tire (for example, formed of rubber or polyurethane) with a high friction coefficient in respect of glass. The drive wheel pairs 421A-422A, 421B-422B and castor wheels or sliding points 450A, 450B form part of a movement system 330 for the robot shown in Figure 2.

As may be seen from Figure 3, which is a cross-sectional side view of the robot 1 of Figure 2, the robot includes a chassis 13, which supports and/or contains many of the components of the robot. As is also shown in Figure 3, the drive wheels 421A-422A, 421B-422B and castor wheels or sliding points 450A, 450B form a plane which is about 1-2mm from the surface of the chassis 13 that is near-most the window surface. The sealing foil 610 is mounted on the chassis 13 in a manner that closes this gap and thus seals a space, or chamber, between the robot and the window surface. The impeller 630 may then remove air from this space, thus creating a vacuum which attaches the robot 1 to the window surface. The attachment force created by this vacuum squeezes the tires against the window surface, thus increasing the area over which the wheels 421A-422A, 421B-422B contact the window surface, accordingly providing the wheels with a good grip on the window surface.

More particularly, to assist the robot in travelling over the window, the attachment system 600, for example using the impeller-based vacuum pump 630, generates an attachment force that provides sufficient friction between the wheels 421A-422A, 421B-422B of the movement system 330 and the window surface for the robot 1 to be moved over the window surface without slipping. For example, where the robot is oriented vertically, the attachment system 600 may need to provide sufficient attachment force such that the wheels 421A-422A, 421B-422B have sufficient friction to exceed the gravitational force applied on the robot 1.

As the robot 1 moves over the window surface using the movement system 330, the sealing foil 610 slides on the window. The impeller-based vacuum pump 630maintains a vacuum within the space sealed by the sealing foil 610; to do so, they may need to generate continuous flow of air, as some air will typically be lost as a result of the movement of the sealing foil 610 over the window surface. This may be particularly the case where the window is uneven or is especially dirty.

Returning now to Figure 2, the middle section of the robot further includes two suction-cups 620A, 620B, which may provide a low-power “parking” mechanism, for instance for when the robot 1 is operating in a “paused” mode, where it does not move over the window surface 1000. These suction cups 620A, 620B are normally at the chassis surface level (for example so that they do not contact the window surface 1000 and thus generate additional frictional resistance to movement), but may be moved towards the window surface 1000 under the control of the control system 100, with a vacuum then being created within the space sealed by each suction-cup 620A, 620B using a vacuum pump 640.

As may be seen from Figure 4A, which is a perspective view of the robot 1 with its top cover 11 removed so that several of the internal components are visible, the vacuum pump 640 for the suction-cups 620A, 620B is separate from the double-impeller vacuum pump 630 that reduces the air pressure in the space sealed by the sealing foil. Further, the vacuum pump 640 for the suction-cups 620A, 620B may be of a different type to that for the sealing foil 610; for instance it may be a diaphragm vacuum pump. In the robot of Figures 2 to 4, a single vacuum pump 640 is shared between the two suction-cups 620A, 620B (the pipes 641 linking this vacuum pump 640 to the suction-cups 620A, 620B are clearly visible in Figure 4A); however, it will be apparent that a dedicated vacuum pump could be provided for each suction-cup 620A, 620B.

As is shown in Figure 2, each suction cup 620A, 620B has a hole 623 in its surface that communicates with a pressure sensor for sensing the pressure adjacent the suction cup 620A, 620B, in the space between the suction cup and the window surface 1000. These pressure sensors may form a further part of the attachment system 600. When the suction cup 620A, 620B is brought into contact with the window surface 1000 and seals a space between the robot and the window surface 1000, the pressure sensor enables the robot (specifically the control system 100) to determine the level of the vacuum in the thus-sealed space.

The front section of the robot, which is the uppermost section in Figure 2, includes a powered agitator 510. In the specific example shown, the powered agitator is an agitating bristle brush that is driven by a geared motor 515, which is visible in Figure 4A. More particularly, the agitator 510 rotates about an axis that is parallel to the window surface and to width direction W. This agitator 510 forms a part of the cleaning system 350 for the robot 1. As will be discussed in further detail below, the agitator 510 mechanically removes debris from the window surface 1000. In certain arrangements, it may be arranged so as to provide an initial heavy-duty dry cleaning of the window surface 1000 (“dry” in the sense that it may be arranged so as to be spaced apart from any sources of liquid, such as cleaning fluid or water). The agitator 510 may be driven at high speed, for example rotating at around 600RPM. As the agitator 510 is located at the front of the robot 1, it will generally be applied to the window surface 1000 first as the robot 1 moves over the window surface 1000.

The robot of Figures 2-4 includes a navigation system 300, which, as discussed above with reference to the robot of Figure 1, may include one or more sensing systems, each comprising a number of suitably configured sensors.

Accordingly, as indicated in Figure 4A, the front section additionally includes window surface proximity sensors 320A, 320B, 320C, which form part of a proximity sensing system, and distance sensors 310A, 310B, which form part of a distance sensing system. In the specific example shown, these sensors are provided on the housing for the agitator 510.

The proximity sensors 320A, 320B, 320C of the proximity sensing system enable the control system 100 to determine whether the window surface 1000 is present adjacent a portion of the robot 1 (e.g. adjacent a portion of the side 15 that is configured to engage with the window surface 1000). In addition, the control system 100 is able to use the proximity sensing system to determine that a portion of the robot 1 has moved beyond the edge of the window surface, for example in the case of a frameless window.

As will be discussed in more detail below, the control system 100 may control the attachment system 600 based on the output from the proximity sensors 320A, 320B, 320C of the proximity sensing system. For example, the control system 100 may only activate the attachment system when the proximity sensors 320A, 320B, 320C indicate that the robot 1 is adjacent the window surface 1000.

Various types of proximity sensors 320A, 320B, 320C can be used, such as those based on detecting reflected light or infra-red radiation, reflected ultrasound, and the like. For quantitative proximity measurement, time-of-flight based sensors may be used; these may similarly be based on reflected infra-red, light, ultrasound and the like. A particular example of a suitable time-of-flight sensor is the VL6180 optical time-of-flight sensor, supplied by ST Microsystems.

Furthermore, as will be described below with reference to Figures 17-21, a proximity sensing system for a robot may include a mechanism that contacts the window surface or objects that project from the window surface, such as the window frame, with the sensors of such a proximity sensing system sensing the movement of the mechanism.

Still further, as will be described below with reference to Figure 21, a window frame proximity sensing system may include an electrode, to which a voltage is applied, with the charge stored on the electrode in response being sensed.

As to the distance sensing system of the robot 1 shown in Figures 2-4, this inlcudes distance sensors 310A, 310B such as time-of-flight sensors (e.g. VL6180 optical time-of-flight sensors). The distance sensors 310A, 310B may be arranged so as to be forwards looking and may, therefore, be mounted at the forwards end of the robot 1. For instance, they may be located on top of (as shown in the example of Figure 4A) or in front of the agitator 510. The distance sensors 310A, 310B enable the control system 100 to determine the robot's current distance from the frame for the window. Such distance measurements allow the control system 100 to plan the robot's scanning trajectory, with the movement system 330 being directed by the control system 100 to carry out the scanning trajectory.

As may be seen from Figure 2, the rear section of the robot, which is the lowermost section in Figure 2, includes a cleaning pad module 550 that provides a cleaning pad 520 and a pair of polishing pads 530A,530B, one either side of the cleaning pad 520. As the cleaning pad 520 is at the rearwards end of the robot, it will generally be applied to the window surface 1000 after the agitator 510, as the robot moves over the window surface 1000 in the forwards direction F.

As is apparent from Figure 2, the cleaning pad 520 addresses a width W_C in the width direction W that is substantially the same as the width W_A addressed by the agitator 510. Therefore, areas of the window surface 1000 addressed by the cleaning pad 520 will generally already been addressed by the agitator 510. As will be discussed in more detail below, this may provide a more effective clean of the window surface 1000 and/or may extend the lifetime of the cleaning pad 520.

As may also be seen from Figure 2, the cleaning pad 520 is elongate in the width direction W. This may provide a more compact structure for the robot 1.

The cleaning pad module 550 may be moveably mounted on the main body 10. In the particular example shown in Figures 2 to 4, the cleaning pad module 550 of the robot 1 of Figures 2 to 4 is spring-loaded and free to move right/left in the width direction W, with respect to the chassis 13 of the robot 1 and thus with respect to the main body 10 of the robot 1. Such an arrangement may allow the robot 1 to drive next to the window frame, cleaning the window surface 1000 all the way to its edge without the robot body 10 touching the frame 1010 and/or may allow the robot to turn while it is near the window frame. It should be noted that the cleaning pad may be moveably mounted on the main body of a robot in various ways: the construction shown in Figures 2 to 4 is simply one example of a way of achieving this.

Furthermore, the cleaning pad 520 may, for example, be composed of a cloth, such as a microfiber cloth. The microfiber cloth may be kept wet with a cleaning fluid, such as a fluid that dissolves the salts, debris and oil stains on the surface.

As will be discussed in further detail below with reference to Figures 5-9, one or more reservoirs containing cleaning fluid may be provided within the robot adjacent the cleaning pad 520 (for example, within the cleaning pad module 550) and may be configured to supply cleaning fluid to the cleaning pad 520.

Alternatively, the user may apply cleaning fluid to the cleaning pad 520, for example by spraying the fluid onto the cleaning pad using a spray bottle. As a still further alternative, the robot might apply cleaning fluid directly to the window surface 1000, for instance at positions adjacent the cleaning pad 520, so that the cleaning pad will be wetted by the cleaning fluid shortly after application to the window surface 1000.

In the robot shown in Figures 2 to 4, the rear section further includes two elongate polishing pads 530A, 530B, as is perhaps best illustrated in Figure 2.

As is apparent from Figure 2, each of these polishing pads 530A, 530B addresses the same width W_C as the cleaning pad 520 so that the areas of the window surface 1000 addressed by the cleaning pad 520 are generally also addressed by the polishing pads 530A, 530B.

As is also apparent from Figure 2, each of the polishing pads 530A, 530B is elongate in the width direction W; this may assist in providing the robot 1 with a compact structure. In the particular example shown, the polishing pads 530A, 530B are narrower than the cleaning pad and extend parallel to the length of the cleaning pad and to each other, and are disposed on either side of the cleaning pad 520.

The polishing pads 530A, 530B act to thin the layer of cleaning fluid left on the window surface 1000 by the cleaning pad 520, so that it dries evenly, thus providing a good finish. The polishing pads may be configured so as to be pressed against the window surface 1000 with a higher force than the cleaning pad.

As is also shown in Figures 3 and 4A, the rear section further includes batteries 220A-220C, which are provided within a battery housing as part of a battery module 210. The batteries 220A-220C will typically be rechargeable batteries, such as rechargeable Lithium ion batteries. The battery module 210 containing the batteries 220A-220C may be detachable, for instance to allow charging of the batteries 220A-220C contained therein and/or to allow it to be substituted for an extra battery module in the user’s possession (e.g. a battery module that the user has already charged).

Attention is now directed to Figure 4B, which is a perspective view of the robot of Figures 2 and 3 with the top cover in place. As may be seen from Figure 4B, a handle is 12 provided by the robot 1, which allows the user to more easily carry the robot 1 to the window and hold it while it attaches to the window surface 1000. In the robot 1 illustrated in Figures 2 to 4, this handle 12 is part of the top cover 11 for the robot 1.

Various user interface features may suitably be provided on the handle 12. For instance, a "play/pause" button 710 may be provided on the handle. This "play/pause" button switches the robot 1 between a “paused” mode, where it remains stationary on the surface of the window, and a user-selected one of a number of “active” modes, which have been programmed into the processor(s) 101 of the control system 100 and in which the moves, using the movement system 330, over the surface of the window. In addition or instead, the handle may contain a “release” button 720, which assists the user in removing the robot 1 from the window surface 1000. When depressed, the “release” button 720 causes the attachment system 600 to deactivate, such as by turning off the impellers 630 and/or disengaging the suction cups 620A, 620B from the window surface 1000.

Around the "play/pause" button 710 there may also be provided a number of indicators (e.g. LEDs) that provide the user with information about the current status of the robot, such as the current operation mode and battery status. The "play/pause" button, the “release” button 720 and these light indicators may each form a part of the user interface 700 for the robot 1 shown in Figures 2-4.

Figure 4A also shows the main board 110 of the robot, which contains one or more processors (e.g. one or more microprocessors) and drivers for the various motors. These components may form part of the control system 100 for the robot. The main board 110 may additionally include navigation sensors, such as an accelerometer, a gyroscope (for measuring the robot orientation) etc. as well as air pressure sensors. It will of course be appreciated that these sensors could instead be provided remotely from the main board 110, in which case suitable electrical connections to the main board may be provided.

Wetting the cleaning pad using air pressure differential

The following section describes an aspect of the disclosure that relates to a cleaning system for a robotic window cleaner. More particularly, the aspect of the disclosure relates to the way in which cleaning fluid is supplied to the cleaning pad(s) of a robotic window cleaner.

A robot according to an example embodiment of this aspect of the disclosure is illustrated in Figures 5-9. The robot 1 according to this example embodiment may be generally similar to that described above with reference to Figures 2 to 4.

Reference is directed firstly to Figure 5, which is a perspective view of a cross-section taken perpendicular to the length of a cleaning pad module 550 for the robot 1 according to example embodiment. This cleaning pad module 550 may, for example, be configured in generally the same way as that described with reference to Figures 2-4.

As may be seen in Figure 5, the robot includes two reservoirs (a first reservoir 561A and a second reservoir 561B) for storing cleaning fluid, as well as a cleaning pad 520, which is configured to be wetted with the cleaning fluid stored in the reservoirs. In the particular example embodiment shown, the two reservoirs 561A, 561B are provided within the cleaning pad module 550; however, in other embodiments the reservoirs could be provided within the main body 10 of the robot 1 or, moreover, in any suitable arrangement within the robot 1. As discussed above, the cleaning pad 520 is configured to be wetted with the cleaning fluid and to contact the window surface so as to remove debris therefrom with the aid of the cleaning fluid.

As may also be seen from Figure 5, the cleaning pad 520 is disposed on the window-engaging side 15 of the robot 1 (the side that is configured to engage with the window surface to enable cleaning thereof by the robot). Figure 5 also illustrates how the robot includes a number of conduits 562, 563 for conveying the cleaning fluid. In the specific example shown, the robot includes two conduits, a first conduit 562 and a second conduit 563. The conduits 562, 563 provide (at least in part) a number of fluid supply paths 571A, 571B, each of which extends from one of the reservoirs 561A, 561B to the cleaning pad 520.

Figure 6 and 7, which are diagrammatic views of a cross-section through the cleaning pad module 550 of Figure 5 (with certain features of the cleaning pad module 550 omitted for clarity), illustrate more clearly the relative arrangement of the conduits 562, 563, the reservoirs 561A, 561B, and the fluid paths 571A, 571B, 572.

As is shown most clearly in Figure 7, in the specific example of Figures 5 to 9 there is a first fluid supply path 571A that extends from the first reservoir 561A to the cleaning pad 520. As may be seen, this first fluid supply path 571A is provided in part by the first conduit 562 and in part by the second conduit 563.

As is also apparent from Figure 7, the robot 1 also includes a second fluid supply path 571B that extends from the second reservoir 561B to the cleaning pad 520. As may be seen, the second fluid supply path 571B is similarly provided in part by the first conduit 562 and in part by the second conduit 563.

Returning now to Figure 6, shown is a high impedance region 564, which is located within the conduits for each of the fluid supply paths 571A, 571B. In the particular example shown, the high impedance region 564 is located substantially within the first conduit 562. The high impedance region 564 is configured to present sufficient impedance to the flow of cleaning fluid along each fluid supply path 571A, 571B that cleaning fluid accumulates within the conduits 562, 563 in the vicinity of said high-impedance region 564.

In the particular example shown in Figures 5 to 9, a filter member 568, which may for example be formed of a porous or fibrous material, is disposed within the high-impedance region 564. Further, the filter member 568 may be wettable by the cleaning fluid so that, for example, once cleaning fluid comes into contact with the filter member 568 the cleaning fluid spreads throughout the filter member 568 owing to capillary forces, while also substantially avoiding dripping onto the cleaning pad 520, again owing to capillary forces.

Furthermore, as may be seen from the drawing, the filter 568 member may be elongate in the same direction as the first conduit 562, in which it is disposed. This may, for instance, result in cleaning fluid being conveyed along the length of the conduit(s) in which the filter member is disposed.

More generally, the characteristics of the filter member 568, such as its length, the material type and its porosity, may be tailored so that the filter member 568 provides a desired level of impedance. For instance, the filter member 568 may be designed so as to contribute the majority of (or substantially all of) the impedance presented by the high-impedance region 564.

While it is noted above that the filter member 568 may be formed of a porous or fibrous material, it could instead (or in addition) be provided by a filter member having a plurality of apertures formed in it (e.g. a substantially planar filter that extends normal to the supply conduit in which it is disposed). Such a filter might, for instance, be coated with a non-wetting coating so as to inhibit the passage of cleaning fluid through the apertures, for instance by causing the cleaning fluid to "ball-up" and accumulate on its surface.

Still further examples of suitable constructions for the high-impedance region 564 will be apparent to those skilled in the art; for instance, the conduits conveying the cleaning fluid might be provided with sections of reduced width and/or surface roughening and/or non-wetting coatings.

Regardless of its particular construction, the high-impedance region 564 presents sufficient impedance to the flow of cleaning fluid along the fluid supply paths 571A, 571B that cleaning fluid accumulates in the vicinity of the high-impedance region 564. To wet the cleaning pad with the thus-accumulated cleaning fluid, the robot is provided with at least one air pump. Each such air pump is configured to apply an air pressure differential across the high-impedance region 564; this air pressure differential is sufficient to force the cleaning fluid accumulated in the vicinity of the high-impedance region 564 through the high-impedance region 564 and to the cleaning pad 520.

As best shown in Figure 5, the first conduit 562 has an outlet at the opposite end to that at which it receives fluid from the reservoirs 561A, 561B, with this outlet being located adjacent the cleaning pad 520, so that the first conduit 562 (which may be referred to as an outlet supply conduit) can provide cleaning fluid thereto through this outlet. As may be seen, each such outlet may be spaced apart from the cleaning pad 520 by a small distance. Hence (or otherwise), the cleaning pad 520 may be spaced apart from each high impedance region 564, so that the fluid accumulated there does not wet the cleaning pad unless an appropriate pressure differential is applied by the air pump(s) across the high impedance region 564. This spacing of each outlet from the cleaning pad 520 may be particularly appropriate in embodiments such as that shown in Figure 5, where a wettable filter is provided within each high impedance region 564, as this may, for instance, prevent fluid being draw by capillary forces directly onto the cleaning pad 520.

As may also be seen from Figure 5, the first conduit 562/outlet supply conduit is provided by a nozzle portion 567, which provides the outlet. The nozzle portion 567 is also shaped so as to direct the cleaning fluid emanating from this outlet towards the cleaning pad 520.

As also shown in Figure 5, the robot 1 further includes a cup-shaped portion 554, which is located adjacent the cleaning pad 520. This cup-shaped portion 554 receives cleaning fluid from the first conduit 562 and holds the cleaning fluid adjacent the cleaning pad 520 so as to wet the cleaning pad 520 with the cleaning fluid.

In the particular example shown in Figures 5 to 9 one of the air pumps that forms a part of the attachment system 600, specifically, vacuum pump 640, is used to apply this air pressure differential. This air pump is accordingly connected to the space within the reservoirs 561A, 561B by way of valve 569 provided on the exterior of the cleaning pad module 550, as may be seen from Figure 9, which is a perspective view from above of the cleaning pad module 550. Of course, in other examples a dedicated air pump might be provided for the cleaning system 350.

As vacuum pump 640 is used to remove air from the space sealed by each suction-cup 620A, 620B, it may conveniently be connected so that the removed air is transferred to the space within the reservoirs 561A, 561B, thus increasing the pressure therein. This increase in pressure is sufficiently abrupt to force cleaning fluid through the high-impedance region and to the corresponding cleaning pad.

It should of course be noted that other types of air pumps may be used to provide such an increase in air pressure on the reservoir side of the high-impedance region 564. Moreover, it should be understood that, in addition or instead, air pumps may be provided that are configured to decrease the air pressure on the cleaning pad side of the high-impedance region 564 (though it should be noted that care may need to be taken, for example by providing a suitable fluid barrier, to avoid cleaning fluid being sucked into the air pump).

Turning now to the control of the air pump, it is contemplated that the air pump may, for example, be configured so that the air pressure differential is generated periodically, for instance as a series of pulses. This might be accomplished by configuring the air pump so that it is under the control of the processor 101 of the control system 100, with the air pump generating air pressure pulses at times determined in accordance with the programming of the processor 101. However, the air pump might also be connected to a simple timing circuit, which causes it to generate air pressure pulses at a defined frequency.

Returning now to Figure 7, it is apparent that the part of each fluid supply path 571A, 571B between the corresponding reservoir 561A, 561B and the high-impedance region 564 is shaped such that, when the robot 1 is oriented with the window-engaging side 15 facing vertically downwards (as depicted in Figure 7), a portion of that part of the fluid supply path is vertically higher than the corresponding reservoir 561A, 561B. In this way, that portion of the fluid supply path 571A, 571B in question provides a barrier to the passage of cleaning fluid from the corresponding reservoir 561A, 561B to the high-impedance region 564.

It will be appreciated that such a barrier to the passage of cleaning fluid may substantially prevent cleaning fluid from reaching the cleaning pad 520 when the robot is oriented with the window-engaging side 15 facing vertically downwards – provided that the air pump(s) do not act to provide the pressure differential across the high-impedance region 564 discussed above.

Moreover, it is contemplated that, in some embodiments, cleaning fluid may be prevented from reaching the cleaning pad 520 regardless of the orientation of the robot with respect to the vertical direction (again, provided that the air pump(s) do not act to provide such a pressure differential across the high-impedance region 564). Specifically, it is contemplated that the high-impedance region 564 may be configured to present sufficient impedance to the passage of cleaning fluid that, in the absence of the pressure differential provided by the air pump(s), cleaning fluid is substantially prevented from passing through the high-impedance region 564 from the reservoirs 561A, 561B to the cleaning pad 520, regardless of the orientation of the robot 1 with respect to the vertical direction. It should indeed be understood that the high impedance region 564 may be so-configured regardless of whether the fluid supply paths 571A, 571B provide the vertical barrier to the flow of fluid discussed above. For instance, the high impedance region 564 may be configured to provide a particularly high impedance to the passage of cleaning fluid so that at all orientations the application of a pressure differential by the air pumps is necessary in order to achieve wetting of the cleaning pad 520.

Returning now to Figure 7, it is apparent that the second conduit 563, as well as providing part of the first fluid supply path 571A and part of the second fluid supply path 571B, also provides a transfer fluid path 572, which extends between the first reservoir 561A and the second reservoir 561B. To this end, the second conduit 563 is fluidically connected at a first end the first reservoir 561A and at a second end to the second reservoir 561B; however, more complex fluidic connection to the reservoirs 561A, 561B may be provided in other embodiments. In general, the second conduit 563, which may be referred to as a transfer conduit, enables the transfer of cleaning fluid between the two reservoirs 561A, 561B.

Further, it should be understood that both the first conduit 562 and the second conduit 563 may be referred to as supply conduits, since each of them provides part of a fluid supply path. Thus, the second conduit 563 may be referred to both as a supply conduit and as a transfer conduit.

As is shown in Figure 7, the two fluid supply paths 571A, 571B are combined within the first conduit 562, as the first conduit 562 provides part of each of the two fluid supply paths 571A, 571B. Thus, the first conduit 562 may be referred to as a combining supply conduit.

As Figure 7 also shows, the second conduit 563 is fluidically connected at a fluid junction 565, located along its length, to the first conduit 562. As is apparent, a portion of the filter member 568 is disposed within this fluid junction 565. This may, for example, result in cleaning fluid contacting the filter member 568 as it is transferred from the first reservoir 561A to the second reservoir 561B moving along the fluid transfer path 572. This may, for instance, allow the filter member 568 to filter the cleaning fluid as it is transferred between the reservoirs 561A, 561B. Further, where the filter member 568 is wettable, having a portion of the filter member 568 disposed within the fluid junction 565 allows it to be wetted by the cleaning fluid when fluid is transferred between the reservoirs 561A, 561B.

Attention is now directed to Figure 8, which is a perspective view of a cross-section taken along the length of the cleaning pad module 550. As may be seen, the robot in fact includes a number of like first conduits 562, with a respective high impedance region 564 being located within each such second conduit 562. The impedance for each high impedance region is provided by a respective filter member 568). While not immediately visible in Figure 8, it may be understood that a respective second conduit 563 is provided for each first conduit, with each second conduit 563 being fluidically connected at a fluid junction 565, located along its length, to a respective first conduit 561.

As is apparent from Figure 8, the first conduits 562 (which are configured as combining conduits) are provided side-by-side in an array. In the specific example shown, the first/combining conduits 562 extend parallel to one another. More particularly, each of the combining conduits extends perpendicular to the window-engaging side 15 of the robot 1.

The second conduits 563 (which are configured as transfer conduits) are similarly provided side-by-side in an array. As may be understood from a consideration of Figures 5 and 8, this array is located between the first reservoir 561A and the second reservoir 561B.

In the specific example shown, the second/transfer conduits extend parallel to one another; however, in other embodiments they could be angled with respect to each other, for example if they were circumferentially arrayed, rather than linearly arrayed. More specifically, each second/transfer conduit extends parallel to the window-engaging side 15 of the robot 1 (as well as to the other transfer conduits).

Although in the specific example robot shown in Figures 5-8, each second conduit 563 is both a supply conduit and as a transfer conduit, it should be understood that it is by no means essential that transfer conduits should in general also be supply conduits. Thus, in certain embodiments some conduits will only be transfer conduits and other conduits will only be supply conduits.

It should be further noted that, while in the specific example robot shown in Figures 5-8 each first conduit 562 is a combining supply conduit, the inclusion of combining supply conduits is, in general, by no means essential.

While the robot shown in Figures 5-9 includes two reservoirs for storing cleaning fluid (specifically, first reservoir 561A and second reservoir 561B), it should be understood that any suitable number of reservoirs might be provided; for example, only one reservoir could be provided, or three, four or more reservoirs might be provided. Likewise, any suitable number of fluid supply paths 571A, 571B might be provided.

While in the example embodiment of Figures 5-9 various features, such as the conduits, reservoirs, and fluid paths, are shown as being located within the cleaning pad module 550 it should be understood that such features need not be provided within the cleaning pad module and, moreover, that a robot according to the present aspect need not include a cleaning pad module 550.

Accordingly, it should be understood that the robot shown in Figures 5-9 is merely an embodiment of a general aspect of this disclosure whereby there is provided a window-cleaning robot comprising: one or more reservoirs for storing a cleaning fluid; one or more cleaning pads, configured to be wetted with the cleaning fluid and to contact a window surface so as to remove debris therefrom with the aid of the cleaning fluid, the robot having a window-engaging side, which is configured to engage with the window surface to enable cleaning thereof by the robot, said one or more cleaning pads being disposed on said window-engaging side; one or more conduits for conveying said cleaning fluid, at least some of said conduits being supply conduits, each of which provides at least part of one or more fluid supply paths, each fluid supply path extending from one of the one or more reservoirs to one of the one or more cleaning pads, a high-impedance region being located within the supply conduit(s) for each of said fluid supply paths; at least one air pump, configured to apply an air pressure differential across each high-impedance region; wherein, for each fluid supply path, the corresponding high impedance region presents sufficient impedance to the flow of cleaning fluid along the fluid supply path in question that, in the absence of said air pressure differential, cleaning fluid accumulates in the vicinity of said high-impedance region within the supply conduit(s) for the fluid supply path; and wherein said air pressure differential is sufficient to force the cleaning fluid accumulated in the vicinity of each high-impedance region through the high-impedance region in question and to the one or more cleaning pads.

Orientation dependent wetting of the cleaning pad

The following section describes an aspect of the disclosure that relates to a cleaning system for a robotic window cleaner. More particularly, this aspect of the disclosure relates to the way in which cleaning fluid is supplied to the cleaning pad(s) of a robotic window cleaner.

This aspect of the disclosure is also embodied in the robot 1 shown in Figures 5-9. As will be apparent from the discussion in the previous section, the reservoirs 561A, 561B and the supply conduits (the first and second conduits 562, 563) are configured such that when the robot 1 is oriented with its window-engaging side 15 facing generally vertically downwards, cleaning fluid is substantially prevented from travelling from the reservoirs 561A, 561B to the cleaning pad via the fluid supply paths 571A, 571B.

According to the present aspect, the window-engaging side 15 should be considered an example of a supporting side for the robot. As referred to herein, a supporting side is a side of the robot 1 which stably supports the robot 1 upon a horizontal surface (e.g. on a table-top or kitchen counter of a user's home) when the robot 1 is placed on the horizontal surface with the supporting side in contact with it. It will be understood that a robot may have a supporting side that is distinct from its window-engaging side; for instance, they could face in directions perpendicular to one another.

A robot whose reservoir(s) and supply conduit(s) are configured such that, when the robot is oriented with its supporting side facing generally vertically downwards, cleaning fluid is substantially prevented from travelling from the reservoir(s) to the cleaning pad(s) via the fluid supply paths, may conveniently not leak cleaning fluid when set down on a horizontal surface, such as a table-top or kitchen counter of a user's home.

In many cases, support sides will include a number of support surfaces that are located on the supporting side of the robot and lie in a common plane (which faces in the same direction as the supporting side). The majority of, or substantially all of, the weight of the robot may be supported by such support surfaces. An example of such support surfaces are the surfaces provided by the sealing member 610 and the cleaning pad 520 in the robot of Figures 2-4. Where the supporting side is distinct from the window-engaging side, the support surfaces might, for example, be provided by a number of rubber feet.

In some embodiments, regardless of the orientation of the robot, the cleaning fluid may have insufficient hydrostatic pressure to reach the cleaning pad(s). For example, in the robot shown in Figures 5-9 this might be accomplished by forming the filter members 568 from a material that provides particularly high impedance to fluid flow. In such embodiments, the robot may be configured to carry out some active step in order for cleaning fluid to reach the cleaning pad(s), such as the opening of a valve, the activation of a pump (e.g. an air pump, as described in the previous section) or similar.

In other embodiments, cleaning fluid may be permitted to travel to the cleaning pad(s) without such an active step being taken. For instance, at certain orientations the cleaning fluid may have sufficient hydrostatic pressure to reach the cleaning pad(s). Hence (or otherwise), the reservoir(s) and supply conduit(s) may be configured such that a necessary condition for cleaning fluid from reservoir(s) to reach the cleaning pad(s) by the action of hydrostatic pressure alone is that the supporting side faces generally vertically downwards or within a relatively narrow angular range (e.g. 0-30 degrees) from the vertically downwards direction.

Regardless of whether wetting of the cleaning pad requires the robot to carry out such active steps or not, barriers to fluid flow may be provided so as to prevent cleaning fluid from travelling from the reservoir(s) to the cleaning pad(s) via the fluid supply paths when the robot is oriented with the supporting side facing generally vertically downwards.

For instance, the arrangement of the reservoir(s) and supply conduit(s) may provide such a barrier, such as by presenting a gravitational potential energy barrier. For example, the reservoir(s) and said supply conduit(s) may be arranged such that, when the robot is oriented with the supporting side facing vertically downwards, at least a portion of each fluid supply path is vertically higher than the corresponding reservoir. As may be appreciated, Figures 6 and 7 show an example of such an arrangement, with the portion of fluid supply paths 571A, 571B within the second conduit 563 being vertically higher than the reservoirs 561A, 561B (and with the window-engaging side 15 being the supporting side).

In addition, or instead, a high impedance region, located within the supply conduit(s) for each fluid supply path, may provide such a barrier. Such high impedance regions may, for example, be configured as described in the previous section (e.g. with reference to high impedance regions 568. For instance, the impedance presented by each such high impedance region may be sufficient to cause cleaning fluid to accumulate within its vicinity; a pump, such as an air pump, may in such cases be used to force the accumulated cleaning fluid accumulated through the high-impedance region and to the cleaning pad (as was described in the previous section).

Filter members (e.g. as described in the previous section) may be provided within such high impedance regions and may, for example, provide at least half of the impedance of each high impedance region. As noted above, such filter members may be wettable, for example so as draw cleaning fluid towards the cleaning pad(s) by capillary forces.

As noted in the previous section, while in the example embodiment of Figures 5-9 various features, such as the conduits, reservoirs, and fluid paths, are shown as being located within the cleaning pad module 550 it should be understood that such features need not be provided within the cleaning pad module and, moreover, that a robot according to the present aspect need not include a cleaning pad module 550.

Accordingly, it should be understood that the robot shown in Figures 5-9 is merely a specific embodiment of a general aspect of this disclosure whereby there is provided a window-cleaning robot comprising: one or more reservoirs for storing a cleaning fluid; one or more cleaning pads, configured to be wetted with the cleaning fluid and to contact a window surface so as to remove debris therefrom with the aid of the cleaning fluid; one or more supply conduits, each providing at least part of one or more fluid supply paths, each fluid supply path extending from one of the one or more reservoirs to one of the one or more cleaning pads; wherein the robot has a supporting side, which stably supports the robot when the robot is placed on a horizontal surface with said supporting side in contact with the horizontal surface; wherein the one or more reservoirs and the one or more supply conduits are configured such that, at least when the robot is oriented with the supporting side facing generally vertically downwards, cleaning fluid is substantially prevented from travelling from said one or more reservoirs to said one or more cleaning pads via said fluid supply paths.

Vibrational mounting of cleaning pad

The following section describes an aspect of the disclosure that relates to a cleaning system for a robotic window cleaner. More particularly, this aspect of the disclosure relates to the way in which cleaning fluid is supplied to the cleaning pad(s) of a robotic window cleaner.

An example embodiment of this aspect of the disclosure is illustrated in Figures 5 and 8-16.

Reference is directed firstly to Figure 10, which is a side view of the rearwards end 17 of a robot 1 that is generally similar to that shown in Figures 2-4. Visible in Figure 10 is a linkage 580, which at its first end 581 is mounted to the main body 10 of the robot 1; a cleaning pad mounting member 553 is mounted on the linkage's second end 582 (e.g. by a snap-fitting connection). This second end 582 is clearly visible in Figure 11, which is a perspective view of the rearwards end 17 of the robot 1 with the cleaning pad module 550 removed.

In the particular example shown in Figure 11, the cleaning pad mounting member 553 is mounted on the linkage's second end 582 by inserting the second end 582 into a correspondingly-shaped aperture 556 provided on the cleaning pad module 550, with the second end 582 snap-fitting into place on the cleaning pad mounting member 553. However, it will be understood that this is by no means essential; the cleaning pad mounting member 553 may be mounted on the linkage's second end 582 in various other ways.

As is best shown in Figure 12, which is a perspective view of the cleaning pad module 550 from the window-engaging side, the cleaning pad mounting member 553 is used to mount a cleaning pad 520. Such mounting may, for example, securely hold the cleaning pad 520 in place so that the cleaning pad 520 is substantially prevented from moving or rotating relative to the cleaning pad mounting member 553. Further, the cleaning pad mounting member 553 might, for example, allow the removable mounting of cleaning pads 520, allowing them to be removed and replaced when worn out by repeated use.

Referring now to Figure 13, shown is a detailed perspective view of the linkage 580. As may be seen, the robot 1 further includes a motor 584, which is configured to cause vibrational movements of the linkage 580. These vibrational movements in turn cause vibrational movements of the cleaning pad mounting member 553 and thus of the cleaning pad 520. Such vibration of the cleaning pad may provide an effective clean of the window surface. Vibrational movements may, for example, be transferred sequentially from the motor 584, to the linkage 580, to the cleaning pad mounting member 553 and to the cleaning pad 520, in that order.

It may be noted that, in the particular embodiment shown, the motor 584 is disposed within the linkage; however, this is by no means essential and in other embodiments the motor 584 might, for example, be located on the main body 10.

The linkage 580 is moveably mounted on the main body 10. Such mounting of the linkage in turn permits movement of the cleaning pad mounting member 553 relative to the main body parallel to the window surface.

In the particular embodiment shown, the mounting of the linkage 580 on the main body 10 is such that movement of the cleaning pad mounting member 553 relative to the main body 10 is restricted to a straight-line path parallel to the window surface, as indicated by double-headed arrow M. However, in other embodiments, movement of the cleaning pad mounting member 553 might be restricted to a curved path, or movement might be restricted to a two-dimensional region lying parallel to the window surface.

As shown in Figure 11, the straight line path M for the cleaning pad mounting member 553 may extend perpendicular to the forwards direction of the robot, indicated in the drawing by arrow F. This may, for example, enable the robot 1 to turn more easily when adjacent to the window frame, since the cleaning pad mounting member 553 may move out of the way of the window frame as the robot turns.

It may further be noted that, in the particular embodiment shown in Figures 5 and 8-16, the linkage 580 is moveably mounted so that its own movement is restricted to a path lying in a plane parallel to the window surface. As may be appreciated, the movement paths for the linkage 580 and for the cleaning pad mounting member 553 are substantially the same shape (specifically, both are straight-line paths perpendicular to the forwards direction F). The movement paths for the linkage 580 and for the cleaning pad mounting member 553 may, for example, differ only in terms of their distance from the window surface.

Referring once more to Figure 13, indicated in the drawing is the longitudinal axis (X-X) of the linkage 580, which extends from the first end 581 to the second end 582 of the linkage 580. As may be appreciated, this longitudinal axis (X-X) is oriented perpendicular to the window-engaging side 15 of the robot 1.

Also apparent from Figure 13 is that, in the particular embodiment shown, a weight 585 is disposed within the linkage 580. The motor 584 drives the movement of this weight 585, which in turn causes the vibrational movements of the linkage 580.

In the particular embodiment shown, the motor 584 drives the rotation of a shaft. The weight 585 is eccentrically disposed on the shaft, so that such rotation of the shaft by the motor 584 causes vibrational movements of the weight 585, and so, the linkage 580.

Of course, it will be understood that this is merely one example of a way in which a motor may drive the movement of a weight so as to cause vibrational movements of the linkage; in other embodiments, the weight might be mounted on a shaft, with the motor causing oscillation of the shaft along its axis, and thereby vibrational movement of the weight.

More generally, it will be understood that Figure 13 shows merely one example of an arrangement in which the motor 584 may cause vibrational movements of the linkage 580.

It may be understood that the vibrational movements of the linkage 580 are in various directions lying in a plane parallel to the window; for example, the direction of vibrational movement may precess about an axis perpendicular to the window surface.

Though in the particular embodiment shown this is achieved using a weight 585 that is eccentrically disposed on a shaft, it should be appreciated that other arrangements may provide vibrational movements of the linkage 580 in various directions lying in a plane parallel to the window. Such vibrational movements of the linkage 580 may in turn cause vibrational movements of the cleaning pad mounting member 553, and thus the cleaning pad 520, in various directions lying in a plane parallel to the window, which may provide an effective clean of the window surface.

Further apparent from Figure 13 is that, in the particular embodiment shown, the linkage 580 includes a relatively rigid body portion 586 (e.g. formed of a hard plastic), located at the first end 581 of the linkage 580, and a relatively flexible cap portion 587 (e.g. formed of silicone rubber). As may be seen, the motor 584 and weight 585 may be disposed within the body portion 586.

Attention is now directed to Figures 14 and 15, which illustrate further details of the arrangement by which the linkage is mounted on the main body. As may be, the linkage 580 is moveably mounted on the main body 10 by way of a sliding member 583. In the particular example shown, the flexible cap portion 587 sits within a correspondingly shaped aperture within the sliding member 583. Further, as visible in Figure 14, the top of the cap portion 587 moves within a linear opening 589 within the rearwards end of the main body 10 of the robot 1.

It should be noted that, while in the particular embodiment shown the linkage 580 is moveably mounted on the main body 10 in such a way that first end 581 of the linkage moves with respect to the main body 10 (and, moreover, the whole of the linkage 580 moves with respect to the main body 10) this is not essential. Accordingly, in some embodiments the linkage 580 may be moveably mounted on the main body 10 such that only a part of the linkage 580 moves with respect to the main body 10. For instance, the first end of the linkage 581 might be prevented from carrying out translational movement with respect to the main body 10 (e.g. it might be restricted to rotational movement), whereas other parts of the linkage, such as the second end 582, may carry out translational movement with respect to the main body 10. Such translational movements of the second end 582 may, for example, enable the cleaning pad mounting member 553 to move relative to the main body parallel to the window surface.

Referring now to Figure 8 and also to Figure 16, it may be noted that, in the particular embodiment shown, the cleaning pad mounting member 553 is moveably mounted on a housing 555 for the cleaning pad module 550. For instance, the cleaning pad mounting member 553 may be suspended from the housing 555 using springs 556. Hence (or otherwise) the cleaning pad module 550 is mounted on the linkage 580 via the cleaning pad mounting member 553 (rather than being directly mounted on the linkage 580).

In some embodiments, mass of the cleaning pad module 550 may be substantially greater than the mass of the cleaning pad mounting member 553 (e.g. during use, or otherwise). A possible consequence of this is that, though the cleaning pad module 550 is mounted on the cleaning pad mounting member 553, which is vibrated by the linkage 580, the cleaning pad module 550 does not vibrate substantially (or at least the amplitude of its vibrations are substantially smaller). In testing carried out by the Applicant, keeping polishing pads 510A, 510B relatively stationary, while a cleaning pad 520 is vibrated has been found to give a good clean of the window surface.

It may be noted in this regard that, as is apparent from Figure 5, the polishing pads 530A, 530B are mounted on the housing 555 for the cleaning pad module 550. For example, the polishing pads 530A, 530B may, as shown in Figure 5, be suspended from the housing 555 using springs 551A, 551B. As may be seen, in the particular embodiment shown, each polishing pad 530A, 530B is held by a respective clamp 552A, 552B (which may, for example, enable each polishing pad 530A, 530B to be removed and replaced when worn out through use), which is in turn mounted on the housing 555 for the cleaning pad module 550 by means of a respective series of springs 551A, 551B (it being noted that only one such spring is visible in the cross-sectional view that is shown in Figure 5). It should however be understood that the polishing pads 530A, 530B may be mounted on the housing 555 for the cleaning pad module 550 in any suitable manner.

With regard to the mass of the cleaning pad module 550, it should be noted that, in the particular example shown in the drawings, a substantial contribution to the mass of the cleaning pad module 550 is made by the reservoirs 561A, 561B and, more particularly, the fluid contained therein during use. Alternatively (or in addition), the cleaning pad module 550 could include weights to provide additional mass to the cleaning pad module 550.

In some embodiments, movement of the cleaning pad mounting member 553 relative to the housing 555 may be restricted to a path that is parallel to the length direction of the cleaning pad 520 and/or perpendicular to the forwards direction. As may be seen from Figure 16, which is a perspective view of the cleaning pad mounting member 553 from above, this may be accomplished using bearings 557, which are retained within a portion of a bearing housing 558 (e.g. made of rubber), provided on the cleaning pad mounting member 553. More particularly, the bearings 557 may, for example, include a cylindrical surface (e.g. provided by a rotatable wheel) that is retained within the bearing housing 558. Of course, other structures may also be used to restrict the movement of the cleaning pad mounting member 553 relative to the housing 555 a path that is parallel to the length direction of the cleaning pad 520 and/or perpendicular to the forwards direction.

It should be appreciated from the foregoing discussion that a wide variety of structures may utilised for the linkage 580. For instance, the linkage might have a frame-like structure, for instance with articulated joints.

Accordingly, it should be understood that the robot shown in Figures 5 and 8-16 is merely an embodiment of a general aspect of this disclosure whereby there is provided a window cleaning robot comprising: a main body; a cleaning pad mounting member, upon which a cleaning pad may be mounted; a linkage having a first end, at which the linkage is mounted on said main body, and a second end, on which said cleaning pad mounting member is mounted; a motor, configured to cause vibrational movements of said linkage, which in turn causes vibrational movements of the cleaning pad mounting member and thus of said cleaning pad; wherein the robot has a window-engaging side, which is configured to engage with a window surface to enable cleaning thereof by the robot, said cleaning pad being disposed on the window-engaging side of the robot; and wherein the linkage is moveably mounted on the main body so as to permit movement of the cleaning pad mounting member relative to the main body parallel to the window surface, when the robot is engaged therewith.

Contact-based proximity sensing system

The following section describes an aspect of the disclosure that relates to a proximity sensing system for a robotic window cleaner. More particularly, the aspect of the disclosure relates to a sensing system that enables the robot to determine whether it (or a portion of it) is adjacent the window surface and that also enables the robot to determine whether it (or a portion of it) is adjacent an object that projects from the window surface (such as a frame for the window).

A robot 1 according to an example embodiment of this aspect of the disclosure is illustrated in Figures 17-21; the robot 1 according to this embodiment may be generally similar to that described above with reference to Figures 2-4.

Turning first to Figure 17, shown is a detail side view of the robot 1. In this view, part of a mechanism 330 for a proximity sensing system is visible. In particular, a first portion 331 and a second portion 332 are visible.

Further details of this mechanism are shown in Figures 18 and 19, which are side views of cross-sections taken through the robot and, as will described in detail below, each show the mechanism 330 carrying out a respective movement.

As is apparent from Figures 18 and 19, the proximity sensing system includes, in addition to mechanism 330 (which includes the first and second portions 331, 332), a first sensor 333 and a second sensor 334 (though any appropriate number of sensors could be utilised). So that the orientation of the mechanism 330 may be understood, Figures 17-19 also indicate the window-engaging side 15 of the robot 1 (the side which is configured to engage with a window surface to enable cleaning thereof by the robot).

Referring now to Figure 18, shown is the mechanism 330 in two configurations as it carries out a first movement, which is indicated in the drawing by an arrow.

In more detail, the mechanism 330 is configured so that when the robot moves over the window surface, with the window-engaging side 15 engaged with the window surface, and the first portion 331 contacts an object that projects from the window surface (such as the window frame) and that obstructs the robot’s movement, the object applies force to the first portion 331. As is apparent from Figure 18, this application of force to the first portion 331 causes the mechanism 330 to carry out the first movement (which, for the particular embodiment shown, appears in Figure 18 as a movement generally from left to right).

To illustrate this first movement, Figure 18 shows the mechanism 330 in a configuration prior contact being made between the first portion 331 and such an object projecting from the windows surface (the left-most configuration in Figure 18), as well as in a configuration after contact between the first portion 331 and such an object (the right-most configuration in Figure 18). The arrow indicates the mechanism moving between these two configurations; that is to say, carrying out the first movement.

Referring now to Figure 19, shown is the mechanism 330 in two configurations as it carries out a second movement, which is indicated in the drawing by an arrow.

More particularly, the mechanism 330 is configured so that when the window-engaging side 15 approaches and engages with the window surface (e.g. when the user brings the robot to the window surface, so as to attach thereto using its attachment system 600), the window surface contacts the second portion 332 and applies force to it. As is apparent from Figure 19, this application of force to the second portion 332 causes the mechanism to carry out a second movement (which, for the particular embodiment shown, appears in Figure 19 as a clockwise movement).

To illustrate this second movement, Figure 19 shows the mechanism 330 in a configuration prior to the second portion 332 contacting the window surface, as well as in a configuration after the second portion 332 contacts the window surface. As with Figure 18, the arrow in Figure 19 indicates the mechanism moving between these two configurations; that is to say, carrying out the second movement.

Turning now to the subject of the sensors 333 and 334 of the proximity sensing system, these are operable to detect if the mechanism 330 is carrying out the first movement and thereby whether an object projecting from the window surface, such as the window frame, is in proximity to the robot.

As the proximity sensing system makes use of a single mechanism for sensing whether the robot (or a portion of it) is adjacent the window surface and also for sensing whether the robot (or a portion of it) is adjacent an object that projects from the window surface (such as a frame for the window), it may be relatively compact, while also providing reliable detection.

In the particular embodiment shown in Figures 17-21, first sensor 333 is able to detect the first movement, whereas the second sensor 334 is able to detect the second movement. Conversely, the first sensor 333 cannot detect the second movement, and the second sensor cannot detect the first movement. However, it will be understood that the provision of a dedicated sensor for each of the first and second movements is by no means essential. Therefore, in other embodiments certain sensors could, for example, detect both of these movements.

It may further be noted that in the particular embodiment shown in Figures 17-21, the sensors 333, 334 are photo-interrupter sensors. Hence movement of the mechanism 330 may be detected by a sensor when a portion of the mechanism obstructs the beam of that sensor as a result of such movement. The beams are directed perpendicular to the plane of the page in Figures 18 and 19.

It will of course be appreciated that in other embodiments alternative sensor types could be utilized, such as pressure sensors or magnetic field sensors (e.g. with a magnetic element being provided on a portion of the mechanism 330) or electrical sensors (e.g. with a conductive element(s) being provided on the mechanism that complete a circuit).

Regardless of their type, the output of the sensors 333, 334 may be provided, either directly or indirectly to the control system, with such sensor output, for example, being processed by the processor(s) 101 within the control system 100. The processor(s) may, based on this sensor output, alter the operation of the various systems within the robot, such as the movement system 330, cleaning system 350, attachment system 600 etc.

In one example, the processor(s) might alter the movements that the robot is carrying out using its movement system 330, based on this sensor output. For instance, if the sensor output from the proximity sensing system indicates that the robot is adjacent the window frame, the control system 100 may cause the movement system 330 to stop movement of the robot along its current path and cause it to commence movement along a different path away from the window frame.

In another example, the processor(s) might alter the power level of the attachment system 600. For instance, if the sensor output from the proximity sensing system indicates that the robot has just been brought into contact with the window surface, the control system may cause the attachment system 600 to enter a high-power mode so as to securely attach the robot to the window surface. By contrast, if the sensor output from the proximity sensing system indicates that the robot is not in contact with the window surface, the control system may cause the attachment system 600 to enter a low-power mode so as to save energy.

Considering now the relative location of the mechanism, as is apparent from Figures 17-19, the first and second portions 331, 332 are provided at an edge of the window-engaging side 15 of the robot 1. This may, for example, ensure that objects projecting from the window surface (such as the window frame) contact the first portion 331 prior to other portions of the robot 1.

Furthermore, as may be seen from Figure 21, which is a perspective view of the robot 1 with its top cover 11 removed, the first and second portions 331, 332 may be provided at the forwards end 16 of the robot 1, which in many cases will be the part of the robot that is most likely to encounter obstructions. However, in other embodiments they could be provided at a rearwards end, or at one of the lateral sides of the robot (e.g. at the left-hand side and/or the right-hand side). Indeed, respective proximity sensing systems could be provided at each of these locations.

Turning now to the shape and configuration of the mechanism 330, as best shown in Figures 18 and 19, the first portion 331 may include a first surface, which faces in a direction generally perpendicular to the direction in which the window-engaging side 15 faces. This first surface contacts objects, such as the window frame, that project from the window surface.

As is also apparent from Figures 18 and 19, the second portion 332 may include a second surface, which faces in a direction generally parallel to the direction in which the window-engaging side 15 faces. This second surface contacts the window surface when the robot is brought into engagement with it.

It should however be understood that in other embodiments the first and second portions 331, 332 may be configured differently, depending for example on the particular mechanism 330 used. For example, each of the first and second portions could be provided by a respective rolling element.

As is apparent from Figures 18 and 19, the mechanism 330 is biased against the first movement and the second movement. In the particular embodiment shown, this biasing is provided by spring 336.

Considering now the nature of the first and second movements, it will be appreciated from a comparison of Figures 18 and 19 that, in the particular embodiment shown, the first movement is substantially translational (specifically, from left to right in the depiction of Figure 18), whereas the second movement is substantially rotational (specifically, clockwise in the depiction of Figure 19). It is considered that, in embodiments where one of the first and second movements is substantially rotational and the other is substantially translational, the mechanism may be relatively compact, while also affording robust detection of the two movements. It should thought be understood that this is by no means essential and that in other embodiments both the first and second movements could be substantially translational or both the first and second movements could be substantially rotational.

Considering in further detail the mechanism 330 of the particular embodiment shown in Figures 17-21, it may be noted that the mechanism 330 includes a moveable member 338, which provides the first 331 and second 332 portions. The shape of this moveable member 338 is shown most clearly in Figure 20, which is a perspective view of the proximity sensing system and which omits the portions of the robot within which the moveable member is mounted, so that the moveable member may be seen clearly. As shown in the drawing, the moveable member 338 may be a rigid object, for example being integrally formed.

As is apparent from Figures 18 and 19, the first movement and the second movement correspond to respective movements of this moveable member 338. Specifically, the first movement corresponds to translational movement of the moveable member 338, whereas the second movement corresponds to rotational movement of the moveable member 338. To this end, the mechanism 330 is configured to allow the moveable member 338 to rotate and to translate. It is considered that arrangements where the mechanism 330 is configured to allow the moveable member 338 to rotate and to translate may be relatively compact, while also allowing relatively robust detection of the two movements.

In the particular embodiment shown, the moveable member 338 accordingly includes a cylindrical element 335, which is free to travel along a generally flat surface 339. As is apparent from Figures 18 and 19, the cylindrical element 335 slides along the surface 339 to afford translational movement of the moveable member 338 (when the mechanism 330 carries out the first movement) and rolls on the surface 339 to afford rotational movement of the moveable member 338 (when the mechanism carries out the second movement).

Considering in more detail the shape of the moveable member 338 shown in Figures 17-21, the moveable member 338 is shown as including a main body 338 and an elongate portion 337 extending from the main body 338. As may be appreciated from Figures 18 and 19, this main body provides the first 331 and second 336 portions; thus, it contacts the window surface and/or objects projecting therefrom so as to detect their presence adjacent the robot. The elongate portion 337, by contrast, enables the movements of the moveable member to be detected by the sensors 333, 334.

It will of course be understood that the particular moveable member 338 shown in Figures 17-21 and the way in which it is mounted is by no means essential; other suitable designs for a moveable member will be apparent to those skilled in the art in light of the teaching above.

More generally, it should be understood that the particular mechanism 330 and the particular arrangement and type of sensors 333, 334 shown in Figures 17-21 is by no means essential; other suitable mechanisms, sensor arrangements and sensor types will be apparent to those skilled in the art in light of the teaching above.

Accordingly, it should be understood that the robot shown in Figures 17-21 is merely an embodiment of a general aspect of this disclosure whereby there is provided a window cleaning robot comprising: a window-engaging side, which is configured to engage with a window surface to enable cleaning thereof by the robot; and a proximity sensing system, which comprises one or more sensors and a mechanism comprising a first portion and a second portion; wherein the mechanism is configured such that: when the robot moves over the window surface, with said window-engaging side engaged with the window surface, and the first portion contacts an object that projects from the window surface and that obstructs the robot's movement, the object applies force to the first portion, causing the mechanism to carry out a first movement; and when the window-engaging side approaches and engages with the window surface, the window surface contacts the second portion and applies force to it, causing the mechanism to carry out a second movement; wherein the one or more sensors of the proximity sensing system are operable to detect if the mechanism is carrying out said first movement and thereby whether an object projecting from the window surface is in proximity to the robot; and to detect, using the one or more sensors of the proximity sensing system are operable to detect, if the mechanism is carrying out said second movement and thereby whether the window surface is in proximity to that portion of the robot where the mechanism is located.

Capacitive proximity sensing system

The following section describes an aspect of the disclosure that relates to a proximity sensing system for a robotic window cleaner. More particularly, the aspect of the disclosure relates to a sensing system that enables the robot to determine whether it (or a portion of it) is adjacent is adjacent an object that projects from the window surface (such as a frame for the window).

A robot 1 according to an example embodiment of this aspect of the disclosure is illustrated in Figure 21, which is a perspective view of the robot 1 with its top cover 11 removed. The robot 1 according to this embodiment may be generally similar to those described above with reference to Figures 1-4.

Though Figure 21 also illustrates mechanism 330 that forms part of a proximity sensing system as described in the previous section, it should be well-noted that this proximity sensing system entirely separate to the window frame proximity sensing system that shall be described in this section of the document. Accordingly, the inclusion of a proximity sensing system as described in the previous section is entirely optional in embodiments according to the aspect described in the present section of the disclosure.

Returning now to Figure 21, as may be seen, the robot 1 includes an electrode 350, disposed adjacent an exterior surface of the robot 1 (e.g. located on its chassis 13, as shown in Figure 21). This electrode forms part of a window frame proximity sensing system for the robot, which enables the robot to determine whether it is adjacent the frame of the window on which the robot is operating, for example by suitable programming of the processor(s) 101 of its control system 100.

The window frame proximity sensing system further includes a voltage source (not shown in Figure 21), which is configured to apply a voltage to the electrode 350, for instance by suitable electrical connection of the voltage source to the electrode 350 (e.g. using wiring provided on the chassis 13).

As a result of such application of voltage to the electrode 350, where an object is present adjacent the robot, the electrical field emitted through the air by the electrode 350 may cause a build-up of charge on the object, for example by electrostatic attraction or repulsion (depending on the polarity of the voltage applied to the electrode 350) of free electrons within or on the surface of the object. As will be understood, there will also be a corresponding build-up of charge on the electrode 350.

The electrode 350 may thus be considered to operate effectively as one terminal of a capacitor, with the object adjacent the robot 1 being the other terminal of the capacitor. The capacitance of this capacitor changes as a function of the distance to the frame owing to the different electrostatic nature of the metal or wood in the window frame, as compared with the air.

The window frame proximity sensing system further includes a charge sensor (not shown in Figure 21), which is operable to determine the charge stored at the electrode 350. This charge sensor is connected to the processor(s) 101 of the robot's control system 100 so as to provide an output signal thereto. The processor(s) 101 can then use this output signal to determine whether the robot 1 is adjacent the frame for the window on which the robot is operating. For instance, the processor(s) 101 may determine that the frame is adjacent the robot where the output signal from the charge sensor indicates that the charge stored by the electrode 350 has exceeded a predetermined threshold value. Of course, more complicated determination procedures could be used, for example taking into account the rate-of-change (e.g. the rate of increase) in the charge stored on the electrode 350.

Regardless, of the particular determination process utilized by the processor(s), such a window frame proximity sensing system may conveniently be able to sense the presence of the window frame prior to the robot making contact with it. This may, for example, enable the robot to move more efficiently over the window surface, since its path may be altered away from the window frame at an earlier point.

Considering now the charge sensors of the sensing system, it should be appreciated that a variety of different charge sensors may be suitable for determining the charge stored at the electrode 350.

In one series of embodiments, the charge sensor may include a reference capacitor (e.g. a capacitor having known capacitance) and a voltage sensor that determines the voltage across this reference capacitor, this voltage being generally indicative of the charge stored on the reference capacitor.

In such embodiments, the window frame proximity sensing system may first connect the voltage source to the electrode 350, causing the storage of charge thereupon, as described above. The reference capacitor may optionally be discharged at this stage.

Then, the system electrically connects the electrode 350 to the reference capacitor, thus transferring charge stored at the electrode 350 to the reference capacitor. As a result of this transfer of charge, the voltage of the reference capacitor will increase, with the increase typically depending on the transferred charge in a predictable manner. Thus, by reading off the voltage across the reference capacitor it is possible for the processor(s) 101 to determine the amount of charge transferred, and in turn the charge stored on the electrode 350.

In some such embodiments, substantially all of the charge on the electrode 350 will be transferred to the reference capacitor. However, in other such embodiments only part of the charge from the electrode 350 could be transferred. For example, the electrode 350 could be connected to the reference capacitor for a predetermined time period that is (in general) too short to allow full transfer of the electrode charge; in such an example, the charge on the electrode 350 might be estimated using this time period, as well using the voltage on the reference capacitor (which, as noted above, is indicative of the charge transferred).

It may be the case that the charge stored on the electrode 350 is, in practice, quite small. Essentially, this means that the effective capacitance of the electrode 350/window frame combination is small.

Hence, or otherwise, the window frame proximity sensing system may be configured to carry out a series of transfer cycles, in each of which the electrode 350 charge is transferred to the reference capacitor. More specifically, each transfer cycle may include: applying, a known voltage (e.g. a stable, reference voltage) to the electrode 350, thus causing the storage of charge at said electrode; electrically connecting the electrode 350 to the reference capacitor, thus transferring substantially all of the charge stored at the electrode 350 to the reference capacitor; disconnecting the electrode 350 from the reference capacitor; and discharging the electrode 350. It should be noted that, prior to carrying out such a series of transfer cycles, the reference capacitor may be discharged.

By carrying out a large number of such transfer cycles, charge is gradually accumulated on the reference capacitor (which may therefore be considered an integrating capacitor). As successive transfer cycles are carried out, the amount of charge that is transferred to the reference capacitor will decrease (typically exponentially) in a known manner that depends on the ratio between the capacitance of the electrode 350/window frame combination and the capacitance of the reference capacitor.

Accordingly, the charge sensor may count the number of transfer cycles required for the reference capacitor to achieve a predetermined voltage, with this number being used as a measure of the charge stored at the electrode 350. Alternatively, a predetermined number of transfer cycles may be carried out, with the charge sensor determining the voltage of the reference capacitor thereafter, with the thus-determined voltage value being used as a measure of the charge stored at the electrode 350.

In order to provide good responsiveness to the sensing system, such transfer cycles may be carried out at high frequency, for example between 100kHz and 250kHz.

Considering now the configuration of the electrode 350, it may be noted that the electrode 350 is located on the forwards side 16 of the robot 1. In many in many cases, this will be the part of the robot that is most likely to encounter the window frame. However, in other embodiments, the electrode 350 could be provided on a different lateral side of the robot, such as the left-hand side, the right-hand side or the rearwards side. Indeed, respective electrodes could be provided at each of these locations.

It is further apparent from Figure 21 that the electrode 350 is generally planar, extending in a plane generally normal to the forwards side 16 of the robot. This may afford a good sensing cross-section when the window frame is present, thus resulting in a sensing system with good reliability.

Further, where the size of the electrode is similar to that of the window frame, the sensing system may have good reliability. Accordingly, the area of the electrode 350 may suitably be half or more that of the side on which it is disposed. Similarly, the width of the electrode 350 may suitably be half or more that of the side on which it is disposed.

As will be appreciated from the discussion above, various modifications may be made to the specific embodiment of a robot shown in Figure 21. Accordingly, it will be understood that the robot of Figure 21 is merely an example embodiment of a more general aspect of this disclosure.

According to this aspect there is provided a window cleaning robot comprising: at least one processor; and a window frame proximity sensing system, which comprises: an electrode, disposed adjacent an exterior surface of said robot; a voltage source, configured to apply a voltage to said electrode, which, where an object is present adjacent the robot, causes the storage of charge on the electrode and a corresponding build-up of charge with the opposite polarity on said object; a charge sensor, operable to determine the charge stored at said electrode and connected to said at least one processor so as to provide a charge sensor output thereto; wherein the at least one processor is programmed to determine, based on said charge sensor output, whether the robot is adjacent a frame for a window on which the robot is operating.

Docking Station with Automatic refill

The following section describes an aspect of the disclosure that relates to a robotic cleaning system, for example a cleaning system including a robot configured for cleaning surfaces (e.g. a robot configured to clean window surfaces, or a robot configured to clean floor surfaces). More particularly, the aspect of the disclosure relates to the way in which the robot's on-board supply of cleaning fluid is replenished.

A robotic cleaning system including a robot 1 and a docking station 1000 according to an example embodiment of this aspect of the disclosure is illustrated in Figures 22-24. The robot 1 that forms a part of the system according to this example embodiment may be generally similar to those described above with reference to Figures 1 to 21.

Turning first to Figure 22, shown in the drawing is a perspective view of the robot 1 docked at a docking station 1000. As will be described in further detail below, such docking enables the robot's on-board supply of fluid to be replenished. In the particular embodiment shown in the drawing, the docking station 1000 is configured such that it can rest on a flat surface, such as the floor, or a table or counter surface; however, in other embodiments, the docking station 1000 might attach to the window surface.

Referring now to Figure 23, shown is a cross-section through the robot 1 and docking station 1000 of Figure 22, following docking of the robot 1 at the docking station 1000. So as to illustrate clearly the interaction of the robot 1 with the docking station 1000, the main body 10 of the robot is not shown.

As may be seen from Figure 23, each of the robot 1 and the docking station 1000 includes at least one reservoir for storing cleaning fluid. In the specific example shown, the docking station 1000 includes one reservoir 1001 and the robot 1 includes two reservoirs 561A, 561B, thought each might have any suitable number of reservoirs.

As with the robots described above, the robot 1 shown in Figures 22 and 23 is operable to move over a surface (e.g. a floor surface or a window surface), using the cleaning fluid stored in its reservoir(s) 561A, 561B to clean the surface. In the particular embodiment shown, the robot 1 accordingly includes a cleaning pad 520, which may be wetted in a manner described above.

It may further be noted that, in the particular embodiment shown, the robot reservoir(s) 561A, 561B and cleaning pad 520 are provided by a cleaning pad module 550 of the robot 1 (for example as described above with reference to Figures 1-16). It will however be understood that this is not essential and the robot reservoir(s) 561A, 561B may be disposed at any suitable location within the robot 1.

According to this aspect of the disclosure, the robot 1 and docking station 1000 are configured such that the docking of the robot 1 at the docking station 10000 automatically causes the transfer of cleaning fluid from the docking station reservoir(s) 1001 to the robot reservoir(s) 561A, 561B.

It should be appreciated that the capacity of the docking station reservoir(s) 1001 may be substantially greater than the capacity of the robot reservoir(s) 561A, 561B. This is because, generally speaking, the capacity of the robot reservoir(s) 561A, 561B will be limited by electrical power considerations: larger robot reservoir(s) 561A, 561B will tend to significantly increase the weight of the robot 1, thus requiring more power to move the robot 1 over the window surface. Such considerations typically do not however apply to the docking station 1000 and thus the user can fill the docking station 1000 with a relatively large amount of cleaning fluid (for example, enough for a year’s worth of typical operation). The docking station 1000 can then handle the regular refilling of the robot’s reservoir(s) 561A, 561B in a controlled and convenient manner.

As will be explained in further detail below, in the particular example shown, the mechanical action of the docking of the robot 1 at the docking station 1000 causes the automatic transfer of cleaning fluid from the docking station reservoir(s) 1001 to the robot reservoir(s) 561A, 561B. However, in other examples, the system might include (as part of the robot 1 and/or as part of the docking station 1000) electrically powered components that are configured so as to, in response to the docking of the robot 1 at the docking station 1000, cause the transfer of cleaning fluid from the docking station reservoir(s) 1001 to the robot reservoir(s) 561A, 561B. Such components might include electrically powered pumps, electrically powered valves, and the like.

As is also shown in Figure 23, the docking station 1000 and the robot 1 each have a port 1003, 570 on their respective exterior. While in the particular example shown only one port is provided for each of the docking station 1000 and the robot 1, it will be understood that any suitable number of ports may be provided.

As is apparent from Figure 23, during the transfer of cleaning fluid from the docking station reservoir(s) 1001 to the robot reservoir(s) 561A, 561B, cleaning fluid proceeds through the docking station port 1010 and then the robot port 570. Hence (or otherwise), during the docking of the robot 1 at the docking station 1000, the docking station port 1010 and the robot port 570 may be configured to form a fluid-tight seal with each other.

It is further apparent from Figure 23 that the docking station 1000 and the robot each include a respective valve 1011, 591. The structure and configuration of the valves 591, 1011 is shown in further detail in Figures 24A and 24B, which are cross-sectional views of these valves; Figure 24A shows the valves immediately prior to docking and Figure 24B shows the valves after docking.

The docking station valve 591, when in a closed position, as shown in Figure 24A, acts to retain cleaning fluid within the docking station reservoir(s) 1001. The robot valve 591, when in a closed position, as shown in Figure 24A, acts to obstruct the flow of cleaning fluid to the robot reservoir(s) 561A, 561B (and may also act to retain fluid within the robot reservoir(s) 561A, 561B).

When the docking station valve 1011 and the robot valve 591 are opened (as a result of the act of docking), as shown in Figure 23 and 24B, the transfer of cleaning fluid from the docking station reservoir(s) 1001 to the robot reservoir(s) 561A, 561B occurs automatically. In the particular example shown, this automatic transfer occurs as a result of gravity acting on the fluid within the reservoirs 561A, 561B, 1001, causing fluid to flow from the vertically higher docking station reservoir 1001, along a conduit 1002 within the docking station 1000, through the opened valves 591, 1011 and to the robot reservoirs 561A, 561B.

Further details of the valves 591, 1011 are apparent from Figures 24A and 24B. Specifically, each valve 591, 1011 includes a valve body 593, 1013 and a valve member 592, 1012, which are moveable with respect to one another between a closed configuration (shown in Figure 24A), where they form a fluid-tight seal with one another, and an open configuration (shown in Figure 24B), where cleaning fluid is able to flow through the valve body 593, 1013 and around the valve member 592, 1012.

As is also apparent from Figures 24A and 24B, both the robot valve 591 and the docking station valve 1011 are biased to their respective closed configurations; in the particular embodiment shown, this is accomplished with respective biasing springs 572, 1004.

It is further apparent from Figures 24A and 24B that, as the robot 1 docks with the docking station 1000, the valves 591, 1011 contact and apply force to each other, causing them to open. More particularly, the valve bodies 593, 1013 contact and apply force to each other.

In the specific embodiment shown, each valve body 593, 1013 includes a flexible portion 593a, 1013a, which accommodates such movement; the deformation of these flexible portions 593a, 1013a is visible in Figure 24B. As the docking station 1000 in the specific embodiment shown in Figures 22 and 23 supports the robot's weight when docked therein, the robot's weight causes such deformation of the flexible portions 593a, 1013a.

It should be noted that in other examples the valve members themselves might not contact each other. Rather, moveable member(s) provided on the docking station 1000 might contact corresponding moveable member(s) provided on the robot 1, with the robot moveable member(s) causing the robot valve 591 to open and the docking station moveable member(s) causing the docking station valve 1011 to open. To this end, such moveable members might, for example, be mechanically connected to the corresponding valve members 591, 1011.

In still further examples, each moveable member might form part of a valve body, or indeed a valve member. The embodiment shown in Figures 22 and 23 may therefore be seen as a special case of this class of examples, where each moveable member is a valve body.

Considering now the relationship between the ports 570, 1010 and the valves 591, 1011, it is apparent from Figures 23 and 24 that part of the robot valve 591 is disposed within the robot port 570 and, similarly, part of the docking station valve 1011 is disposed within the docking station port 1010. However, it should be understood that this is not essential and in other embodiments the valves might be located distant from the ports, for example where the valves are not opened by mutual contact (e.g. where a more complex mechanical arrangement is used, or where the opening of the valves is electrically powered).

Turning now to the configuration of the docking station and robot reservoirs 1001, 561A, 561B, it should be understood that in the embodiment shown in Figures 22 and 23 substantially all of the energy for the actual transfer of cleaning fluid from the docking station reservoir 1001 to the robot reservoir(s) 561A, 561B (excluding the energy involved in opening the valves 591, 1011), is provided by the gravitational potential energy of the cleaning fluid within the docking station reservoir 1001.

This may, for example, be accomplished by configuring the robot 1 and docking station 1000 so that their reservoirs 1001 561A, 561B are in a suitable relative arrangement when the robot 1 is docked. In particular, the centroids of the respective internal spaces defined within the reservoirs may be suitably arranged, since the centroid of such an internal space corresponds essentially to the centre of mass of the fluid when the space is full.

As may be apparent from Figures 22 and 23, in the docked position the centroid for the docking station reservoir 1001 (which is roughly half-way up the reservoir 1001) is at a greater vertical height than the centroid for the robot reservoirs 561A, 561B (which is generally in-line with docking station valve 1011). Moreover, the centroid for the docking station reservoir 1001 is at a substantially greater vertical height than the vertically highest point of robot reservoirs 561A, 561B.

Though the discussion above focusses on the role of the docking station 1000 in replenishing the fluid in the robot's reservoirs 561A, 561B, it should be appreciated that the docking station 1000 may have other functions. For example, it may recharge an internal power source (e.g. a rechargeable battery pack) within the robot 1, or communicate with the robot, e.g. to download data from the robot 1, apply software upgrades to the robot 1 etc. The docking station 1000 shown in Figure 23 accordingly includes an electrical connector 1003 that may carry out one (or potentially both) of these functions.

It may be noted from Figure 23 that, in the particular embodiment shown, the robot port 570 is located on a rearwards side of robot 1, specifically on the rearwards side cleaning pad module 550. Providing the port 570 on the rearwards side of robot 1 may, for example, enable the robot's weight to assist with the docking of the robot 1 at the docking station 1000. However, this is of course not essential and the robot port 570 could be disposed at any suitable location on the robot 1.

Furthermore, it will of course be appreciated that, while in Figures 22-24 the robot reservoirs 561A, 561B, valve 591 and port 570 are all shown as being provided on a cleaning pad module 550, this is by no means essential and these features could be provided within the main body 10 of the robot, or at any suitable location. Moreover, cleaning pad module 550 itself could be omitted.

Still further, while in the example embodiment shown in Figures 22-24 the opening of each valve is powered substantially entirely by the mechanical action of the docking of the robot 1 at the docking station 1000, in other examples the robot valve 591 and/or the docking station valve 1011 might be electrically powered; in such cases, the respective one of the robot 1 and the docking station 1000 might include one or more sensors to detect the docking, with the electrically powered valves being drive in response.

Accordingly, it should be understood that the robot shown in Figures 22-24 is merely an embodiment of a general aspect of this disclosure whereby there is provided a robotic cleaning system comprising a cleaning robot and a docking station, each of which comprises a respective at least one reservoir for storing a cleaning fluid, the robot being operable to move over a surface while using said cleaning fluid to clean said surface, the docking station being configured to allow the robot to be docked thereat; wherein the robot and docking station are configured such that the docking of the robot at the docking station automatically causes the transfer of cleaning fluid from the at least one docking station reservoir to the at least one robot reservoir.

Combinations

It is envisaged that the concepts discussed above may be combined in a variety of ways within a cleaning robot or a robotic cleaning system.

For example, features disclosed in the “wetting the cleaning pad using air pressure differential” section may be implemented in a robot as described in the “Orientation dependent wetting of the cleaning pad” section and vice versa. Further, features disclosed in the “Introduction” section may be implemented in a robot or robotic system as described in any other section.

further, it should be noted that the descriptions of the various embodiments of the present invention have been presented for purposes of illustration, but are not intended to be exhaustive or limited to the embodiments disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the described embodiments.

The terminology used herein was chosen to best explain the principles of the embodiments, the practical application or technical improvement over technologies found in the marketplace, or to enable others of ordinary skill in the art to understand the embodiments disclosed herein.

The word “exemplary” is used herein to mean “serving as an example, instance or illustration”. Any embodiment described as “exemplary” is not necessarily to be construed as preferred or advantageous over other embodiments and/or to exclude the incorporation of features from other embodiments.

The word “optionally” is used herein to mean “is provided in some embodiments and not provided in other embodiments”. Any particular embodiment of an aspect of this disclosure may include a plurality of “optional” features unless such features conflict.

It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention, which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable subcombination or as suitable in any other described embodiment of the invention. Certain features described in the context of various embodiments are not to be considered essential features of those embodiments, unless the embodiment is inoperative without those elements.

Although the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims.

CLAIMS

1. A robotic cleaning system comprising a cleaning robot and a docking station, each of which comprises a respective at least one reservoir for storing a cleaning fluid, the robot being operable to move over a surface while using said cleaning fluid to clean said surface, the docking station being configured to allow the robot to be docked thereat;

wherein the robot and docking station are configured such that the docking of the robot at the docking station automatically causes the transfer of cleaning fluid from the at least one docking station reservoir to the at least one robot reservoir.

2. A robotic cleaning system according to Claim 1, wherein the mechanical action of the docking of the robot at the docking station causes the transfer of cleaning fluid from the at least one docking station reservoir to the at least one robot reservoir.

3. A robotic cleaning system according to Claim 1, further comprising one or more electrically powered components that are configured so as to, in response to the docking of the robot at the docking station, cause the transfer of cleaning fluid from the at least one docking station reservoir to the at least one robot reservoir.

4. The robotic cleaning system of Claim 1, wherein the docking station comprises:

at least one docking station valve that, when closed, retains cleaning fluid within the at least one docking station reservoir.

5. The robotic cleaning system of Claim 1 or Claim 4, wherein the robot comprises:

at least one robot valve that, when closed, obstructs the flow of cleaning fluid to the at least one robot reservoir.

6. The robotic cleaning system of Claim 4 and Claim 5, wherein each of the docking station and the robot comprises at least one moveable member; and

wherein, as the robot docks at the docking station, the at least one moveable member of the robot and the at least one moveable member of the docking station contact and apply force to one another, with the at least one robot moveable member causing the robot valve to open and the at least one docking station moveable member causing the docking station valve to open, thus enabling said transfer of cleaning fluid from the at least one docking station reservoir to the at least one robot reservoir.

7. The robotic cleaning system of Claim 6, wherein each docking station valve comprises a valve member and a valve body, the valve member and valve body being moveable with respect to one another between: a closed configuration, where the valve member forms a fluid-tight seal with the valve body so as to retain cleaning fluid within the at least one docking station reservoir; and an open position, where cleaning fluid is able to flow through the valve body past the valve member out of the at least one docking station reservoir.

8. The robotic cleaning system of Claim 7, wherein the at least one docking station moveable member is mechanically connected to a docking station valve member or a docking station valve body.

9. The robotic cleaning system of Claim 7 or Claim 8, wherein each docking station moveable member forms part of a docking station valve body;

preferably wherein each docking station valve body is a docking station moveable member.

10. The robotic cleaning system of Claim 7 or Claim 8, wherein each docking station moveable member forms part of a docking station valve member; and

preferably wherein each docking station valve member is a docking station moveable member.

11. The robotic cleaning system of any one of claims 6 to 10, wherein each robot valve comprises a valve member and a valve body, the valve member and valve body being moveable with respect to one another between: a closed configuration, where the valve member forms a fluid-tight seal with the valve body that obstructs cleaning fluid flowing to the at least one robot reservoir; and an open position, where cleaning fluid is able to flow through the valve body past the valve member to the at least one robot reservoir.

12. The robotic cleaning system of Claim 11, wherein the at least one robot moveable member is mechanically connected to a robot valve member or a robot valve body.

13. The robotic cleaning system of Claim 11 or Claim 12, wherein each robot moveable member forms part of a robot valve body;

preferably wherein each robot valve body is a robot moveable member.

14. The robotic cleaning system of Claim 11 or Claim 12, wherein each robot moveable member forms part of a robot valve member; and

preferably wherein each robot valve member is a robot moveable member.

15. The robotic cleaning system of any one of claims 5-14 and Claim 4, wherein the opening of the at least one docking station valve is powered substantially entirely by the mechanical action of the docking of the robot at the docking station.

16. The robotic cleaning system of any one of claims 4-15 and Claim 5, wherein the opening of the at least one docking station valve is powered substantially entirely by the mechanical action of the docking of the robot at the docking station.

17. The robotic cleaning system of Claim 4, wherein the opening of the at least one docking station valve is electrically powered.

18. The robotic cleaning system of Claim 5, wherein the opening of the at least one docking station valve is electrically powered.

19. The robotic cleaning system of any preceding claim, wherein each of the docking station and the robot comprises one or more ports on their respective exterior;

wherein during said transfer of cleaning fluid from the at least one docking station reservoir to the at least one robot reservoir cleaning fluid proceeds through said one or more docking station ports and then through one or more robot ports.

20. The robotic cleaning system of wherein, during the docking of the robot at the docking station, the one or more docking station ports form a fluid-tight seal with the one or more robot ports.

21. The robotic cleaning system of Claim 19, when dependent upon Claim 4 and Claim 5, wherein at least a part of each docking station valve is disposed within one of the one or more docking station ports; and

wherein at least a part of each robot valve is disposed within one of the one or more robot ports.

22. The robotic cleaning system of any one of claims 4-18 and 21, wherein, at least the majority of, and preferably substantially all of, the energy for the transfer of cleaning fluid from the at least one docking station reservoir to the at least one robot reservoir, following the opening of said valves, is provided by the gravitational potential energy of the cleaning fluid within the at least one docking station reservoir.

23. The robotic cleaning system of any preceding claim, wherein each of the at least one docking station reservoir and the at least one robot reservoir defines a corresponding internal space, the internal space(s) for the at least one docking station reservoir together having a first centroid and the internal space(s) for the at least one robot reservoir together having a second centroid; and

wherein, when the robot is docked with the docking station, the first centroid is at a substantially greater vertical height than the second centroid.

24. The robotic cleaning system of Claim 23, wherein, when the robot is docked with the docking station, the first centroid is at a substantially greater vertical height than the vertically highest point of the at least one robot reservoir.

25. The robotic cleaning system of any preceding claim, wherein the cleaning robot is a window-cleaning robot and the surface that the robot moves over and cleans using said cleaning fluid is the surface of a window.

26. The robotic cleaning system of Claim 25, wherein the docking station is attachable to the window surface.

27. The robotic cleaning system of any preceding claim, wherein the capacity of the at least one docking station reservoir is greater than the capacity of the at least one robot reservoir.

28. A docking station configured for use in a robotic cleaning system according to any preceding claim.

29. A window cleaning robot comprising:

at least one processor; and

a window frame proximity sensing system, which comprises:

an electrode, disposed adjacent an exterior surface of said robot;

a voltage source, configured to apply a voltage to said electrode, which, where an object is present adjacent the robot, causes the storage of charge on the electrode and a corresponding build-up of charge of the opposite polarity on said object;

a charge sensor, operable to determine the charge stored at said electrode and connected to said at least one processor so as to provide a charge sensor output thereto;

wherein the at least one processor is programmed to determine, based on said charge sensor output, whether the robot is adjacent a frame for a window on which the robot is operating.

30. The window-cleaning robot of Claim 29, wherein the robot has a window-engaging side, which is configured to engage with a window surface to enable cleaning thereof by the robot, and a plurality of lateral sides, each of which faces in a respective direction that is generally perpendicular to the direction in which the window-engaging side faces; and

wherein said electrode is disposed on one of said lateral sides.

31. The window-cleaning robot of Claim 30, wherein the electrode is generally planar, extending in a plane generally normal to the direction in which the lateral side on which the electrode is disposed faces.

32. The window-cleaning robot of Claim 30 or Claim 31, wherein the area of the electrode is at least half of, and is preferably substantially the same as, the area of the lateral side on which it is disposed.

33. The window-cleaning robot of any one of claims 30 to 32, wherein the width of the electrode, in an electrode width direction, which is parallel to said window-engaging side and to the lateral side on which the electrode is disposed, is at least half of, and is preferably substantially the same as, the corresponding width of the robot.

34. The window-cleaning robot of any one of claims 29 to 33, wherein one of said lateral sides is a forwards side, being disposed at the forwards end of the robot, said electrode being disposed on said forwards side.

35. The window-cleaning robot of any one of claims 29 to 34, wherein said voltage source is configured to apply a known voltage to said electrode.

36. The window-cleaning robot of any one of claims 29 to 35, wherein the charge sensor comprises a reference capacitor and a voltage sensor;

wherein the window frame proximity sensing system is configured to electrically connect said electrode to said reference capacitor following the application of said voltage to said electrode, thus transferring at least a portion of, and preferably substantially all of, said charge stored at the electrode to the reference capacitor; and

wherein said charge sensor comprises a voltage sensor, which is operable to determine the voltage of the reference capacitor following said transfer of stored charge and, thereby, said charge stored at said electrode as a result of said application of said voltage to the electrode.

37. The window-cleaning robot of any one of claims 29 to 36, wherein the window frame proximity sensing system is configured to carry out a plurality of transfer cycles, each transfer cycle comprising:

applying, with said voltage source, a known voltage to said electrode, thus causing the storage of charge at said electrode;

electrically connect said electrode to said reference capacitor, thus transferring substantially all of said charge stored at the electrode to the reference capacitor;

disconnecting said electrode from said reference capacitor; and

discharging said electrode.

38. The window-cleaning robot of Claim 37, wherein the charge sensor is operable to count the number of transfer cycles required for the reference capacitor to achieve a predetermined voltage, with this number being used as a measure of the charge stored at the electrode when said known voltage is applied thereto.

39. The window-cleaning robot of Claim 37, wherein the charge sensor is operable to determine the voltage of the reference capacitor after a predetermined number of transfer cycles have been carried out, with the thus-determined voltage being used as a measure of the charge stored at the electrode when said known voltage is applied thereto.

40. The window-cleaning robot of any one of claims 29 to 39, wherein the window frame proximity sensing system comprises:

a plurality of like electrodes, the plurality of like electrodes including said electrode and being distributed over the exterior of the robot;

one or more voltage sources, the one or more voltage sources including said voltage source and being configured for the application of voltage to said plurality of electrodes;

wherein the at least one sensor is configured to determine the charge stored at said plurality of electrodes as a result of said application of voltages to the plurality of electrodes.

41. The window-cleaning robot of Claim 40, when dependent upon Claim 30, wherein said plurality of electrodes are distributed over said lateral sides; and

preferably wherein each of said plurality of electrodes is disposed on a respective one of said lateral sides.

42. A window cleaning robot comprising:

a window-engaging side, which is configured to engage with a window surface to enable cleaning thereof by the robot; and

a proximity sensing system, which comprises one or more sensors and a mechanism comprising a first portion and a second portion;

wherein the mechanism is configured such that:

when the robot moves over the window surface, with said window-engaging side engaged with the window surface, and the first portion contacts an object that projects from the window surface and that obstructs the robot's movement, the object applies force to the first portion, causing the mechanism to carry out a first movement; and

when the window-engaging side approaches and engages with the window surface, the window surface contacts the second portion and applies force to it, causing the mechanism to carry out a second movement;

wherein the one or more sensors of the proximity sensing system are operable to detect if the mechanism is carrying out said first movement and thereby whether an object projecting from the window surface is in proximity to the robot; and

to detect, using the one or more sensors of the proximity sensing system are operable to detect, if the mechanism is carrying out said second movement and thereby whether the window surface is in proximity to that portion of the robot where the mechanism is located.

43. The window-cleaning robot of Claim 42, wherein said first portion comprises a first surface, which faces in a direction generally perpendicular to the direction in which the window-engaging side faces.

44. The window-cleaning robot of Claim 42 or Claim 43, wherein said second portion comprises a second surface, which faces in a direction generally parallel to the direction in which the window-engaging side faces.

45. The window-cleaning robot of any one of claims 42 to 44, wherein said first and second portions are provided at an edge of the window-engaging side of the robot.

46. The window-cleaning robot of any one of claims 42 to 45, further comprising a movement for moving the robot over the window surface, the movement system having a defined forwards direction; wherein the said first and second portions are provided at the forwards end of the robot.

47. The window-cleaning robot of any one of claims 42 to 46, wherein one of said first movement and said second movement is substantially rotational and the other is substantially translational.

48. The window-cleaning robot of any one of claims 42 to 47, wherein the mechanism is biased against at least one of, and preferably both of, said first movement and said second movement.

49. The window-cleaning robot of any one of claims 42 to 48, wherein the one or more sensors comprises a first sensor, for detecting said first movement, and a second sensor, for detecting said second movement.

50. The window-cleaning robot of any one of claims 42 to 49, wherein the one or more sensors are photo-interrupter sensors.

51. The window-cleaning robot of any one of claims 42 to 50, wherein said mechanism comprises a moveable member, said first and second portions being provided by said moveable member.

52. The window-cleaning robot of Claim 51, wherein the mechanism is configured to allow the moveable member to rotate and to translate.

53. The window-cleaning robot of Claim 51 or Claim 52, wherein the first movement and the second movement correspond to respective movements of the moveable member.

54. The window-cleaning robot of any one of claims 51 to 53, wherein the first movement corresponds to one of a substantially translational movement of the moveable member and a substantially rotational movement of the moveable member; and

wherein the second movement corresponds to the other of a substantially translational movement of the moveable member and a substantially rotational movement of the moveable member.

55. The window-cleaning robot of any one of claims 51 to 54, wherein the first movement corresponds to a substantially translational movement of the moveable member and the second movement corresponds to a substantially rotational movement of the moveable member.

56. The window-cleaning robot of any one of claims 51 to 55, wherein the moveable member comprises a main body and an elongate portion extending from the main body, the first and second portions being provided on the main body and the one or more sensors being configured to detect movement of the elongate portion.

57. A window-cleaning robot comprising:

a main body;

a cleaning pad mounting member, upon which a cleaning pad may be mounted;

a linkage having a first end, at which the linkage is mounted on said main body, and a second end, on which said cleaning pad mounting member is mounted;

a motor, configured to cause vibrational movements of said linkage, which as a result contacts said cleaning pad mounting member, causing vibrational movements thereof and of said cleaning pad;

wherein the robot has a window-engaging side, which is configured to engage with a window surface to enable cleaning thereof by the robot, said cleaning pad being disposed on the window-engaging side of the robot; and

wherein the linkage is moveably mounted on the main body so as to permit movement of the cleaning pad mounting member relative to the main body within a plane parallel to said window-engaging side.

58. The window-cleaning robot of Claim 57, wherein the linkage is moveably mounted on the main body so as to permit movement of the cleaning pad mounting member relative to the main body along a path lying in a plane parallel to said window-engaging side.

59. The window-cleaning robot of Claim 58, wherein the linkage is moveably mounted so that it is permitted to move alone a path lying in a plane parallel to said window-engaging side, the linkage path and the cleaning pad mounting member path being substantially the same shape.

60. The window-cleaning robot of any one of claims 57 to 59, further comprising a sliding member, the linkage being moveably mounted on the main body by way of said sliding member.

wherein at least one of said sliding member and said main body comprises one or more rail portions

61. The window-cleaning robot of any one of claims 58 to 60, wherein said cleaning pad mounting member path is a straight line.

62. The window-cleaning robot of Claim 61, wherein the robot has a forwards direction and wherein said straight line extends perpendicular to said forwards direction.

63. The window-cleaning robot of any one of claims 57 to 62, wherein said motor is disposed within said linkage.

64. The window-cleaning robot of Claim 63, wherein said motor drives the movement of a weight disposed within said linkage, thereby causing said vibrational movements of said linkage.

65. The window-cleaning robot of Claim 64, wherein said motor drives the rotation of a shaft, said weight being eccentrically disposed on said shaft.

66. The window-cleaning robot of any one of claims 57 to 65, wherein the linkage has a longitudinal axis, which extends from said first end to said second end, and which is oriented perpendicular to said window-engaging side.

67. The window-cleaning robot of any one of claims 57 to 66, wherein said cleaning pad mounting member is elongate in cleaning pad length direction, which is perpendicular to said window-engaging side.

68. The window-cleaning robot of Claim 66, wherein the robot has a forwards direction and said cleaning pad length direction is perpendicular to said forwards direction.

69. The window-cleaning robot of Claim 66 or Claim 67, wherein the extent of the cleaning pad mounting member is substantially equal to or greater than the extent of the main body in said cleaning pad length direction.

70. The window-cleaning robot of any one of claims 66 to 68, when dependent upon Claim 61, wherein said straight line path is parallel to said cleaning pad length direction.

71. The window-cleaning robot of any one of claims 57 to 70, wherein said cleaning pad mounting member is configured to allow a cleaning pad to be removably mounted thereupon.

72. The window-cleaning robot of any one of claims 57 to 71, wherein vibrational movements of the linkage are in random directions lying in a plane parallel to the window-engaging side.

73. The window-cleaning robot of any one of claims 57 to 72, further comprising a cleaning pad module, which comprises said cleaning pad mounting member and a housing, on which the cleaning pad mounting member is moveably mounted.

74. The window-cleaning robot of Claim 73, wherein said cleaning pad module comprises one or more polishing pads.

75. The window-cleaning robot of Claim 73 or Claim 74, wherein the mass of said cleaning pad module is substantially greater than the mass of the cleaning pad mounting member.

76. The window-cleaning robot of any one of claims 73 to 75, wherein the cleaning pad module comprises one or more reservoirs containing for storing a cleaning fluid, the one or more reservoirs being fluidically connected to said cleaning pad so as to wet the cleaning pad with said cleaning fluid.

77. A window-cleaning robot comprising:

one or more reservoirs for storing a cleaning fluid;

one or more cleaning pads, configured to be wetted with the cleaning fluid and to contact a window surface so as to remove debris therefrom with the aid of the cleaning fluid, the robot having a window-engaging side, which is configured to engage with the window surface to enable cleaning thereof by the robot, said one or more cleaning pads being disposed on said window-engaging side;

one or more conduits for conveying said cleaning fluid, at least some of said conduits being supply conduits, each of which provides at least part of one or more fluid supply paths, each fluid supply path extending from one of the one or more reservoirs to one of the one or more cleaning pads, a high-impedance region being located within the supply conduit(s) for each of said fluid supply paths;

at least one air pump, configured to apply an air pressure differential across each high-impedance region;

wherein, for each fluid supply path, the corresponding high impedance region presents sufficient impedance to the flow of cleaning fluid along the fluid supply path in question that, in the absence of said air pressure differential, cleaning fluid accumulates in the vicinity of said high-impedance region within the supply conduit(s) for the fluid supply path; and

wherein said air pressure differential is sufficient to force the cleaning fluid accumulated in the vicinity of each high-impedance region through the high-impedance region in question and to the one or more cleaning pads.

78. The window-cleaning robot of Claim 77, further comprising one or more filter members, each filter member being disposed within one of the one or more high-impedance regions and contributing to the impedance presented by that high-impedance region;

optionally wherein each filter is wettable by the cleaning fluid.

79. The window-cleaning robot of Claim 78, wherein each filter member is elongate in the same direction as the supply conduit(s) in which it is disposed.

80. The window-cleaning robot of Claim 78 or Claim 79, wherein each filter member is formed substantially of polymeric material.

81. The window-cleaning robot of any one of claims 78 to 80, wherein each filter member is formed substantially of a porous or fibrous material.

82. The window-cleaning robot of any one of claims 78 to 80, wherein each filter member comprises a plurality of apertures, through which the cleaning fluid moves when said pressure differential is applied;

preferably wherein each filter member is generally planar and extends normal to the supply conduit in which it is disposed.

83. The window-cleaning robot of any one of claims 78 to 82, wherein each filter member contributes at least the majority of the impedance presented by the corresponding high-impedance region.

84. The window-cleaning robot of any one of claims 77 to 83, wherein the at least one air pump is configured to generate within each supply conduit an increase in the pressure of the air on the same side of the high-impedance region as the one or more reservoirs, the increase in pressure being sufficiently abrupt to force cleaning fluid through the high-impedance region and to the corresponding cleaning pad.

85. The window-cleaning robot of any preceding claim, further comprising an attachment system, configured to attach the robot to the surface of the window; and

wherein the at least one air pump forms a part of said attachment system.

86. The window-cleaning robot of any one of claims 77 to 85, wherein, the part of each fluid supply path between the corresponding reservoir and the corresponding high-impedance region is shaped such that, when the robot is oriented with the window-engaging side facing vertically downwards, at least a portion of that part of the fluid supply path is vertically higher than the corresponding reservoir , thus providing a barrier to the passage of cleaning fluid from the corresponding reservoir to the corresponding high-impedance region.

87. The window-cleaning robot of any one of claims 77 to 86, wherein said one or more conduits comprise one or more transfer conduits;

wherein said one or more reservoirs comprise a first reservoir and a second reservoir;

wherein each transfer conduit provides at least part of one or more transfer fluid paths, each transfer fluid path extending between said first reservoir and said second reservoir.

88. The window-cleaning robot of Claim 87, wherein said one or more supply conduits comprise one or more combining supply conduits, each combining supply conduit providing at least part of a fluid supply path extending from said first reservoir and at least part of a fluid supply path extending from said second reservoir.

89. The window-cleaning robot of Claim 88, wherein each transfer conduit is fluidically connected at at least one fluid junction located along its length to one of said combining conduits.

90. The window-cleaning robot of Claim 89, when dependent upon Claim 78, wherein a portion of each filter member is disposed within a corresponding one of said fluid junctions.

91. The window-cleaning robot of any one of claims 87 to 89, wherein each transfer conduit has a first end, which is fluidically connected to said first reservoir, and a second end, which is fluidically connected to said second reservoir.

92. The window-cleaning robot of any one of claims 88 to 91, wherein there are a plurality of said combining conduits disposed side-by-side in an array.

93. The window-cleaning robot of any one of claims 88 to 92, wherein each combining conduit extends parallel to a first direction.

94. The window-cleaning robot of any one of claims 88 to 93, wherein the window-engaging side faces in said first direction.

95. The window-cleaning robot of any one of claims 87 to 93, wherein there is a plurality of said transfer conduits, disposed side-by-side in an array.

96. The window-cleaning robot of any one of claims 87 to 95, wherein the array of transfer conduits is located between said first reservoir and said second reservoir.

97. The window-cleaning robot of any one of claims 87 to 96, wherein each transfer conduit extends parallel to a second direction.

98. The window-cleaning robot of Claim 97, wherein the first reservoir and the second reservoir extend perpendicular to said second direction.

99. The window-cleaning robot of any one of claims 87 to 98, wherein said second direction is parallel to said window-engaging side.

100. The window-cleaning robot of one of claims 87 to 99, wherein each transfer conduit extends in a direction parallel to said window-engaging side.

101. The window-cleaning robot of any one of claims 87 to 100, wherein the first reservoir and the second reservoir extend parallel to one another.

102. The window-cleaning robot of any one of claims 87 to 101, wherein each of the first reservoir and the second reservoir extends in a direction parallel to said window-engaging side.

103. The window-cleaning robot of any one of claims 77 to 102, wherein each high-impedance region presents sufficient impedance to the passage of said cleaning fluid that, in the absence of said pressure differential, the cleaning fluid is substantially prevented from passing through each high-impedance region from the one or more reservoirs to the one or more cleaning pads, regardless of the orientation of the robot with respect to the vertical direction.

104. The window-cleaning robot of any one of claims 77 to 103, wherein said one or more supply conduits comprise one or more outlet supply conduits, each outlet supply conduit having a first end, at which it receives fluid from said one or more reservoirs, and a second end, at which there is an outlet, each outlet being located adjacent the corresponding cleaning pad, so that the outlet supply conduit can provide cleaning fluid thereto via said outlet.

105. The window-cleaning robot of Claim 104, when dependent upon Claim 88, wherein each combining supply conduit is an outlet supply conduit.

106. The window-cleaning robot of Claim 104, further comprising, for each outlet supply conduit, a respective nozzle portion, which provides the outlet for the outlet supply conduit in question and which is shaped so as to direct the cleaning fluid emanating from said outlet towards the corresponding one of the one or more cleaning pads.

107. The window-cleaning robot of any one of claims 104 to 106, further comprising, for each outlet supply conduit, a respective cup-shaped portion, which is located adjacent the

corresponding cleaning pad, the cup-shaped portion receiving cleaning fluid from the outlet supply conduit in question and holding the cleaning fluid adjacent the cleaning pad in question so as to wet that cleaning pad with the cleaning fluid.

108. The window cleaning robot of any one of claims 77 to 107, further comprising a main body and a cleaning pad module, which is moveably mounted on the main body;

wherein said one or more cleaning pads and said one or more conduits are provided within said cleaning pad module.

109. The window cleaning robot of Claim 108, wherein said one or more reservoirs are provided within said cleaning pad module.

110. A window-cleaning robot comprising:

one or more reservoirs for storing a cleaning fluid;

one or more cleaning pads, configured to be wetted with the cleaning fluid and to contact a window surface so as to remove debris therefrom with the aid of the cleaning fluid;

one or more supply conduits, each providing at least part of one or more fluid supply paths, each fluid supply path extending from one of the one or more reservoirs to one of the one or more cleaning pads;

wherein the robot has a supporting side, which stably supports the robot when the robot is placed on a horizontal surface with said supporting side in contact with the horizontal surface;

wherein the one or more reservoirs and the one or more supply conduits are configured such that, at least when the robot is oriented with the supporting side facing generally vertically downwards, cleaning fluid is substantially prevented from travelling from said one or more reservoirs to said one or more cleaning pads via said fluid supply paths.

111. The window-cleaning robot of Claim 110, wherein said one or more reservoirs and said one or more supply conduits are configured such that, regardless of the orientation of the robot with respect to the vertical direction, the cleaning fluid in the one or more reservoirs has insufficient hydrostatic pressure to reach the one or more cleaning pads.

112. The window-cleaning robot of Claim 110, wherein said one or more reservoirs and said one or more supply conduits are configured such that, a necessary condition for cleaning fluid from the one or more reservoirs to reach the one or more cleaning pads by the action of hydrostatic pressure alone is that the supporting side faces in a direction that subtends an angle with the vertically downwards direction that is greater than 30 degrees.

113. The window-cleaning robot of any one of claims 110 to 112, wherein said one or more reservoirs and said one or more supply conduits are arranged such that, when the robot is oriented with the supporting side facing vertically downwards, at least a portion of each fluid supply path is vertically higher than the corresponding reservoir, thus providing a barrier to the passage of cleaning fluid from the corresponding reservoir to the corresponding one or more cleaning pads.

114. The window-cleaning robot of any one of claims 110 to 113, wherein a high impedance region is located within the supply conduit(s) for each fluid supply path, each high impedance region being configured to present impedance to the flow of cleaning fluid along the corresponding fluid supply path.

115. The window-cleaning robot of Claim 114, wherein the impedance presented by each high impedance region is sufficient to cause cleaning fluid to accumulate within the vicinity of said high-impedance region.

116. The window-cleaning robot of Claim 115, additionally comprising at least one pump, configured to force the cleaning fluid accumulated in the vicinity of said high-impedance region through the high-impedance region and to the at least one cleaning pad.

117. The window-cleaning robot of Claim 116, wherein the at least one pump is an air pump and is configured to apply an air pressure differential across each high-impedance region that is sufficient to force the cleaning fluid accumulated in the vicinity of said high-impedance region through the high-impedance region and to the at least one cleaning pad.

118. The window-cleaning robot of Claim 117, further comprising an attachment system, configured to attach the robot to the surface of the window; and

wherein the at least one air pump forms a part of said attachment system.

119. The window-cleaning robot of any one of claims 116 to 118, further comprising one or more filter members, each filter being disposed at least partly within the one of the one or more high-impedance regions and contributing to the impedance presented by that high-impedance region;

optionally wherein each filter member is wettable by the cleaning fluid.

120. The window-cleaning robot of Claim 119, wherein each filter member is elongate in the same direction as the supply conduit in which it is disposed.

121. The window-cleaning robot of Claim 119 or Claim 120, wherein each filter member is formed substantially of polymeric material.

122. The window-cleaning robot of any one of claims 119 to 121, wherein each filter member is formed substantially of a porous or fibrous material.

123. The window-cleaning robot of any one of claims 119 to 121, wherein each filter member comprises a plurality of apertures, through which the cleaning fluid moves when said pressure differential is applied;

preferably wherein each filter member is generally planar and extends normal to the supply conduit in which it is disposed.

124. The window-cleaning robot of any one of claims 119 to 123, wherein each filter member contributes at least the majority of the impedance presented by the corresponding high-impedance region.

125. The window-cleaning robot of any one of claims 110 to 124, wherein said supporting side is a window-engaging side and is configured to engage with a window surface to enable

cleaning thereof by the robot, said one or more cleaning pads being disposed on the window-engaging side.

126. The window-cleaning robot of any one of claims 110 to 125, additionally comprising a plurality of support surfaces, which are located on the supporting side of the robot and lie in a common plane, which faces in the same direction as the supporting side.

Intellectual Property Office

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Claims searched:	1-28	**Date of search:**	17 August 2017

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1, 2, 4-24, 27, 28	CN 105149155 A (Jiangsu) all figures and WPI abstract accession number 2015-832288.
X	1, 3-5, 17-28	JP 2007190305 A (NEC) all figures and WPI abstract accession number 2007-851225.
X	1, 3-5, 17-22, 28	US 2016/0227975 A1 (Afrouzi) paragraph 0017.
X	1, 3-5, 17-21, 28	US 5959423 A (Nakanishi) all figures and line 36 of column 11 to line 5 of column 12.
X	1, 3-5, 17-19, 21, 22, 27, 28	US 2007/0051757 A1 (Lim) figure 4 and paragraphs 0093-0097.
X	1, 3-5, 17-22, 28	US 9114440 B1 (Colucci) all figures and lines 42-55 of column 6.

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The following online and other databases have been used in the preparation of this search report

WPI, EPODOC

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International Classification:

Subclass	Subgroup	Valid From
A47L	0001/02	01/01/2006
A47L	0009/28	01/01/2006
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