



- (51) **International Patent Classification:**
G05D 1/02 (2006.01)
- (21) **International Application Number:**
PCT/EP2014/077954
- (22) **International Filing Date:**
16 December 2014 (16. 12.2014)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (71) **Applicant:** AKTIEBOLAGET ELECTROLUX
[SE/SE]; S:t Goransgatan 143, S-105 45 Stockholm (SE).
- (72) **Inventors:** HAEGERMARCK, Anders; Edbovagen 12,
S-142 63 Trangsund (SE). LINDHÉ, Magnus; S:t Gorans-
gatan 143, S-105 45 Stockholm (SE).
- (74) **Agent:** WRETLAD, Eva; S:t Goransgatan 143, S-105
45 Stockholm (SE).
- (81) **Designated States** (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY,

BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

- (84) **Designated States** (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ,
TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU,
TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE,
DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU,
LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,
SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ,
GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— with international search report (Art. 21(3))



WO 2016/095966 A1

(54) **Title:** CLEANING METHOD FOR A ROBOTIC CLEANING DEVICE

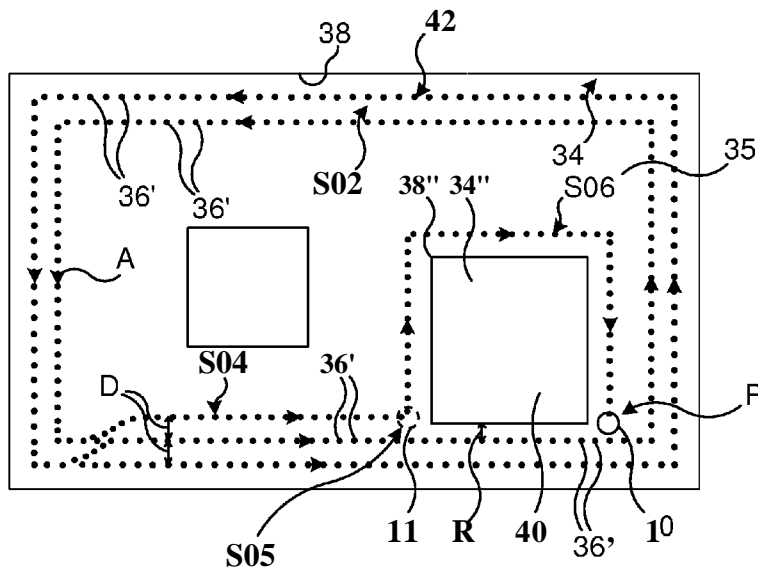


Fig. 5a

(57) **Abstract:** The invention relates to a method of operating a robotic cleaning device (10) over a surface (35, 35') to be cleaned, the method being performed by the robotic cleaning device, the method comprising the steps of: following (S02) a boundary (38, 38') of a first object (34, 34') while registering (S03) path markers (36) at intervals on the surface, the path markers comprising positional information; tracing (S04) previously registered path markers (36') at an offset (D) upon encountering one or more of the previously registered path markers; and switching (S05) from tracing the previously registered path markers to following (S06) an edge (38'') of a second object (40) upon detection of the second object.

CLEANING METHOD FOR A ROBOTIC CLEANING DEVICE

TECHNICAL FIELD

The invention relates to a robotic cleaning device and to a method of operating the robotic cleaning device for improving cleaning efficiency.

5 BACKGROUND

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

10 Robotic vacuum cleaners or robotic floor mops, further referred to as robotic cleaning devices, are known in the art and usually equipped with drive means in the form of one or more motors for moving the cleaner across a surface to be cleaned. The robotic cleaning devices may further be equipped with intelligence in the form of microprocessor(s) and navigation means for causing an autonomous behaviour such that the robotic vacuum cleaners can
15 freely move around and clean a space in the form of e.g. a room. Thus, these prior art robotic vacuum cleaners have the capability of more or less autonomously vacuum clean or mop a room, in which furniture such as tables, chairs and other objects such as walls and stairs are located.

20 There are basically two categories of robotic cleaning devices known in the prior art; - the ones which clean a surface by random motion and the ones which navigate on the surface using various sensor data.

The robotic cleaning devices, which use a random motion also look randomly for the charger. These robotic cleaning devices navigate and clean by principle of contingency. Such robotic cleaning devices may comprise a
25 collision sensor to avoid collisions when cleaning. Typically they comprise means to detect and locate the charger when they happen to pass it or when the charger comes into the field of view. This is obviously not a very efficient way of cleaning and navigating and may in particular not work very well for large surfaces or for complicated layouts.

The other type of prior art robotic cleaning devices, which navigate using sensor data deduce from the sensor data where they can safely drive without colliding with objects or obstacles. As they make assumptions about their environment based on the sensor data, which is in most cases not complete, they run a high risk of getting stuck or lost. In addition, extracting data and thus making assumptions from the sensor data additionally requires expensive electronic components.

In some cases prior art robotic cleaning devices use a stroke method to clean, which means they drive back and forth stroke by stroke in order to clean a surface. When navigating such a prior robotic cleaning device from one room to another or back to the charger, the robotic cleaning device uses sensor data to navigate. The risk of collision with objects or obstacles is then comparably high, since such robotic cleaning devices are also forced to make assumptions based on the sensor data. This may slow down the robotic cleaning device and thus reduce the efficiency of the cleaning. Additionally a stroke by stroke method may leave a substantial amount of debris or dust remaining, for example close to edges of objects or obstacles. The cleaning may not be neat.

Some known robotic cleaning devices may comprise a side brush arranged close to or at a left or right periphery of a cleaning opening in order to brush debris and dust into and in front of the cleaning opening. When a side brush, in particular only one side brush, is installed on the robotic cleaning device, the cleaning pattern needs to be adapted accordingly to make sure that the side brush is removing the debris and dust in an optimal way.

SUMMARY

An object of the present invention is to provide a method for operating a robotic cleaning device and a robotic cleaning device configured to perform the method, which method is neat, efficient and robust.

The inventors of the present invention have realized that it is possible to provide a universal method for efficiently operating a robotic cleaning device to provide a neat and tidy cleaning. The method enhances robustness of the

navigation of the robotic cleaning device and improves the overall performance of the cleaning.

Disclosed herein is a method of operating a robotic cleaning device over a surface to be cleaned, the method being performed by the robotic cleaning
5 device, the method comprising the steps of:

following a boundary of a first object while registering path markers at intervals on the surface, the path markers comprising positional information;

tracing previously registered path markers at an offset upon encountering one or more of the previously registered path markers; and

10 switching from tracing the previously registered path markers to following an edge of a second object upon detection of the second object.

This method allows the robotic cleaning device to clean according to an inward cleaning pattern or an outward cleaning pattern. The robotic cleaning device may thus start a cleaning of a surface to be cleaned by following a
15 boundary of a first object, such as a wall or the like, and move towards the inside of the surface by cleaning inwards in a spiral pattern or it may detect an second object arranged somewhere away from the boundary of the surface, thus within the surface, and start cleaning by following the edge of said second object and clean by moving outwards from the second object in a
20 spiral pattern.

The first and second objects may be furniture, walls, staircases, elevator shafts, etc. In many cases the first object may be a wall of a room and the second object may be furniture.

The intervals may either be time intervals or distance intervals.

25 The offset may be smaller than a width of the robotic cleaning device and a cleaning portion of the robotic cleaning device, respectively.

Advantageously, the robotic cleaning device is following the edge of the second object until previously registered path markers are again encountered.

When previously registered path markers are encountered, the robotic
5 cleaning device will realize that either the second obstacle was fully encircled or that one of the sides of the second obstacle was previously cleaned and will thus switch again to follow the previously deposited path markers.

This may allow the robotic cleaning device to build a map graph comprising all encountered objects during cleaning.

10 In another embodiment the robotic cleaning device may follow the edge of the second object until the second object is encircled.

Thus the robotic cleaning device may continue to follow the second object even if previously registered path markers are encountered upon doing so. As soon as the second object is entirely encircled the robotic cleaning device will
15 again follow or trace previously deposited path markers at an offset.

The steps of tracing and switching to boundary or edge following allows the robotic cleaning device to move over a surface to be cleaned in autonomous and efficient manner and moreover ensure a neat and tidy cleaning, even when objects are encountered.

20 In another preferred embodiment the method comprises the step of recognizing a loop defining an area to be cleaned upon encountering one or more of the previously registered path markers, wherein the loop comprises a plurality of the previously registered path markers.

Depending on the loop shape the cleaning pattern of the remaining surface
25 may be adapted. Upon recognition the loop may be closed. For example, only the loop that is currently followed and registered by the robotic cleaning device may be open and considered active by the robotic cleaning device.

Preferably the loop is simplified within the map graph, upon recognition for generating an efficient and simple cleaning pattern.

This may improve the navigation and the efficiency of the cleaning of the robotic cleaning device since already cleaned areas may be avoided and
5 multiple cleaning of the same areas, for example in corridors or bottlenecks, can be avoided.

The simplification may comprise the step of closing and/ or splitting the loop into a plurality of loops defining a plurality of areas to be cleaned, so that the robotic cleaning device can clean the areas one after the other.

10 When a surface to be cleaned for instance comprises two rooms being interconnected by a corridor, the loop may be divided, when a first long along the boundaries of the two rooms has been completed, into two loops, one for each room. Each loop may define an area to be cleaned and the robotic cleaning device may clean the two areas one after the other.

15 Such a simplification avoids multiple strokes over an area that was previously cleaned, in the above case for example the corridor, and it reduces complexity for the robotic cleaning device.

The simplification may alternatively comprise a completion of a loop, if it is safe to assume that there is no object or obstacle involved in the completion.

20 Additionally the simplification may involve the splitting up of a surface to be cleaned after a first loop has been completed by guiding the robotic cleaning device along a borderline that separates the surface, when it is detected that the surface is larger than a threshold value.

In an embodiment a first area of the plurality of areas may be considered
25 clean when the robotic cleaning device is encountering previously registered path markers when moving in any direction without being able to establish the offset to any of the previously registered path markers.

When all path markers of the previously registered path markers around a currently registered path marker are closer to the robotic cleaning device than the offset, it is safe to assume that the first area has been entirely cleaned and thus finished.

- 5 If the above is not the case the robotic cleaning device will move towards the area where previously registered path markers are still spaced apart more than the offset and continue cleaning.

Further, the method may comprise the step of avoiding entering areas where the distance between previously registered path markers is less than the
10 offset.

When the first area to be cleaned from the area of the plurality of areas may be considered finished, the robotic cleaning device may move to a second area to be cleaned of the plurality of areas and starting to trace previously registered path markers of the loop defining the second area to be cleaned.

- 15 The robotic cleaning device may thus work step by step by finishing each area until no area is left.

In a preferred embodiment path markers may be registered at a left or right periphery of the robotic cleaning device or the cleaning opening of the robotic cleaning device, as seen in a direction of movement of the robotic cleaning
20 device.

In another embodiment the robotic cleaning device may follow the left or right path markers with a right or left periphery of the robotic cleaning device or the cleaning portion of the robotic cleaning device, as seen in a direction of movement of the robotic cleaning device.

- 25 In particular, if a side brush is installed on the robotic cleaning device, the robotic cleaning device may follow the path markers with the side brush when encountering previously registered path markers.

In a further embodiment the robotic cleaning device may follow the boundary or the edge of the first and second object so that the path markers are registered on the periphery of the robotic cleaning device or the cleaning portion of the robotic cleaning device that is located away from the boundary or the edge.

The above may apply depending if the robotic cleaning device is cleaning counter-clockwise or clockwise and if a side brush is installed or not. If a side brush is installed it is advantageous if the side brush is following the boundary or edge of the first or second object. The robotic cleaning device may thus be configured to change the cleaning pattern to counter-clockwise or clockwise to ensure that the side brush is following the edge or boundary of the object when an object is encountered.

The registering of path markers may be started when a corner of the first object is detected.

This may somewhat simplify the cleaning pattern, as described later herein.

Herein is also disclosed a robotic cleaning device comprising a main body, a propulsion system arranged to move the robotic cleaning device, a contact detecting portion connected to the main body and arranged to detect if the robotic cleaning device is in contact with an object and a dead reckoning sensor operatively connected to the propulsion system. The robotic cleaning device may further comprise a processing unit arranged to control the propulsion system, whereby the processing unit may be connected to the dead reckoning sensor and configured to perform the method comprising any of the previously described steps and/ or features.

Disclosed herein is further a computer program comprising computer-executable instructions for causing a robotic cleaning device to perform the method comprising any of the previously described steps and/ or features, when the computer-executable instructions are executed on a processing unit included in the robotic cleaning device.

Disclosed is further a computer program product comprising a computer readable storage medium, the computer readable storage medium having the computer program according to the above embodied therein.

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

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is now described, by way of example, with reference to the accompanying drawings, in which:

15 Fig 1 schematically illustrates a top down view onto an embodiment of a robotic cleaning device according to the invention;

Fig 2 schematically illustrates a front view onto a robotic cleaning device according to an embodiment of the invention;

20 Fig. 3a schematically illustrates the registering of path markers when starting inward cleaning according to a method of the invention;

Fig. 3b schematically illustrates the registering of path markers when starting outward cleaning according to a method of the invention;

Fig. 4 schematically illustrates how a loop is recognized and potentially closed;

25 Fig. 5a schematically illustrates the switching from tracing path markers to following an edge of an object upon encountering of an object;

Fig. 5b schematically illustrates a similar view as figure 5a; in this case the object is entirely encircled prior to switching back to path markers tracing;

Fig. 5c schematically illustrates a similar view as figure 5a and 5b; in this case the object is not entirely encircled prior to switching back to path markers
5 tracing;

Fig. 6a schematically illustrates outward cleaning;

Fig. 6b schematically illustrates how loops are simplified in an environment according to figure 6a;

Fig. 7 schematically illustrates how the robotic cleaning device is moving
10 from a first area to a second area after the first area is clean; and

Fig. 8 illustrates the method steps of the present invention.

DETAILED DESCRIPTION

The invention will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments of the invention
15 are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like
20 elements throughout the description.

The invention relates to robotic cleaning devices, or in other words, to automatic, self-propelled machines for cleaning a surface, e.g. a robotic vacuum cleaner, a robotic sweeper or a robotic floor washer. The robotic cleaning device 10 according to the invention can be mains-operated and
25 have a cord, be battery-operated or use any other kind of suitable energy source, for example solar energy.

Figure 1 shows a robotic cleaning device 10 according to an embodiment of the present invention in a bottom view, i.e. the bottom side of the robotic

cleaning device 10 is shown. The arrow indicates the forward direction of the robotic cleaning device. The robotic cleaning device 10 comprises a main body 11 housing components such as a propulsion system comprising driving means in the form of two electric wheel motors 15a, 15b for enabling
5 movement of the driving wheels 12, 13, such that the robotic cleaning device 10 can be moved over a surface to be cleaned. Each wheel motor 15a, 15b is capable of controlling the respective driving wheel 12, 13 to rotate independently of each other in order to move the robotic cleaning device 10 across a surface to be cleaned. A number of different driving wheel
10 arrangements, as well as various wheel motor arrangements, may be envisaged. It should be noted that the robotic cleaning device 10 may have any appropriate shape, such circular-shaped main body 11 as illustrated, or a triangular-shaped main body.

As an alternative to the above described propulsion system, a track
15 propulsion system may be used or even a hovercraft propulsion system.

The propulsion system is further connected to two dead reckoning sensors 30, 30', one assigned to each driving wheel 12, 13, as illustrated in figure 1. The dead reckoning sensors 30, 30' are configured to independently measure distances travelled by the robotic cleaning device 10 by observing the
20 movement and turns, respectively, of the driving wheels 12, 13, in order to help to position the robotic cleaning device 10, for example within a room.

The embodiment of the robotic cleaning device 10 as illustrated in figure 1 comprises two dead reckoning sensors 30, 30', it is however possible to envisage robotic cleaning devices comprising only one dead reckoning sensor
25 30, 30'.

A controller such as processing unit 16 controls the wheel motors 15a, 15b to rotate the driving wheels 12, 13 as required in view of information received from an obstacle detecting device (shown in figure 2) for detecting obstacles in the form of walls, floor lamps, table legs, around which the robotic
30 cleaning device must navigate. The dead reckoning sensors 30, 30' are

connected to the processing unit 16, for example via the electric wheel motors 15a, 15b, as illustrated in figure 1.

The obstacle detecting device may be embodied in the form of infrared (IR) sensors and/ or sonar sensors, a microwave radar, a 3D sensor system
5 registering its surroundings, implemented by means of e.g. a 3D camera, a camera in combination with lasers, a laser scanner, etc. for detecting obstacles and communicating information about any detected obstacle to the processing unit 16. The processing unit 16 communicates with the wheel motors 15a, 15b to control movement of the wheels 12, 13 in accordance with
10 information provided by the obstacle detecting device.

In figure 1 the width W of the robotic cleaning device 10 is further illustrated. As the main body 11 has a round shape, the width W corresponds to a diameter of the main body. In general terms, the width W may be defined as the widest part or largest dimension of the robotic cleaning device 10 as
15 measured in a forward direction M.

The main body 11 may optionally be provided with a cleaning member 17 for removing debris and dust from the surface to be cleaned in the form of a rotatable brush roll arranged in an opening 18 at the bottom of the robotic cleaner 10. Thus, the rotatable brush roll 17 is arranged along a horizontal
20 axis in the opening 18 to enhance the dust and debris collecting properties of the cleaning device 10. In order to rotate the brush roll 17, a brush roll motor 19 is operatively coupled to the brush roll to control its rotation in line with instructions received from the processing unit 16. Optionally the robotic cleaning device 10 comprises a side brush (not shown) in order to optimize
25 the cleaning. The side brush may be arranged at or close to a periphery of the opening 18 so that debris and dust is brushed into the brush roll 17 in front of the opening. In the examples illustrated in figures 3a to 7, it may be assumed that a side brush (not shown) is arranged at the right periphery of the opening 18 of the robotic cleaning device 10 although the invention is not
30 depending on this, which means the method according to the invention also works without a side brush.

Moreover, the main body 11 of the robotic cleaner 10 comprises a suction fan 20 creating an air flow for transporting debris to a dust bag or cyclone arrangement (not shown) housed in the main body via the opening 18 in the bottom side of the main body 11. The suction fan 20 is driven by a fan motor 21 connected to the processing unit 16 from which the fan motor 21 receives instructions for controlling the suction fan 20. It should be noted that a robotic cleaning device 10 having either one of the rotatable brush roll 17 and the suction fan 20 for transporting debris to the dust bag may be envisaged. A combination of the two will however enhance the debris-removing capabilities of the robotic cleaning device 10 .

Alternatively, the robotic cleaning device 10 may comprise a mop (not shown) and/ or a rotating floor brush (not shown).

With further reference to Figure 1, the processing unit 16 may be embodied in the form of one or more microprocessors arranged to execute a computer program 25 downloaded to a suitable storage medium 26 associated with the microprocessor, such as a Random Access Memory (RAM), a Flash memory or a hard disk drive. The processing unit 16 is arranged to carry out a method according to embodiments of the present invention when the appropriate computer program 25 comprising computer-executable instructions is downloaded to the storage medium 26 and executed by the processing unit 16. The storage medium 26 may also be a computer program product comprising the computer program 25. Alternatively, the computer program 25 may be transferred to the storage medium 26 by means of a suitable computer program product, such as a digital versatile disc (DVD), compact disc (CD) or a memory stick. As a further alternative, the computer program 25 may be downloaded to the storage medium 26 over a network. The processing unit 16 may alternatively be embodied in the form of a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), a complex programmable logic device (CPLD), etc.

In figure 1 is further a contact detecting portion 32 illustrated. The contact detecting portion 32 is arranged at a front end of the robotic cleaning device 10 as seen in a direction of movement. The contact detecting portion 32 may extend over the whole front part of the robotic cleaning device 10, similar to a park distance sensor of a modern car. Alternatively, the contact detecting portion 32 may only extend over the front extremity of the robotic cleaning device 10, as illustrated in figure 1. The contact detecting portion 32 is arranged in order to detect whether or not the robotic cleaning device 10 is in contact with an object or landmark. This may be useful when a collision with obstacles has to be avoided.

Figure 2 shows a front view of the robotic cleaning device 10 according to an embodiment illustrating the previously mentioned obstacle detecting device in the form of a 3D camera system 22 comprising at least a camera 23 and a first and a second structured light source 27, 28, which may be horizontally or vertically oriented line lasers. Further illustrated is the processing unit 16, the main body 11, the driving wheels 12, 13, and the rotatable brush roll 17 previously discussed with reference to Figure 1. The processing unit 16 is operatively coupled to the camera 23 for recording images of a vicinity of the robotic cleaning device 10. The first and second structured light sources 27, 28 may preferably be vertical line lasers and are arranged lateral of the camera 23 configured to illuminate a height and a width that is greater than the height and width of the robotic cleaning device 10. The camera 23 is controlled by the processing unit 16 to capture and record a plurality of images per second. Data from the images is extracted by the processing unit 16 and the data is typically saved in the storage medium 26 along with the computer program 25.

The first and second structured light sources 27, 28 are configured to scan, preferably in a vertical orientation, the vicinity of the robotic cleaning device 10, normally in the direction of movement of the robotic cleaning device 10. The first and second structured light sources 27, 28 are configured to send out laser beams, which illuminate furniture, walls and other obstacles of a home or room. The camera 23 is controlled by the processing unit 16 to

capture and record images from which the processing unit 16 creates a representation or layout of the surroundings that the robotic cleaning device 10 is operating in, by extracting features from the images and by measuring the distance covered by the robotic cleaning device 10, while the robotic
5 cleaning device 10 is moving across the surface to be cleaned. Thus, the processing unit 16 may derive positional data of the robotic cleaning device 10 with respect to the surface to be cleaned from the recorded images, to generate a 3D representation of the surroundings in particular the obstacles.

The 3D representation generated from the images recorded by the 3D camera
10 system 22 thus facilitates detection of obstacles in the form of walls, floor lamps, table legs, etc. around which the robotic cleaning device 10 must navigate as well as rugs, carpets, doorsteps, etc., that the robotic cleaning device 10 must traverse.

With respect to Figure 2, for illustrational purposes, the 3D camera system 22
15 is separated from the main body 11 of the robotic cleaning device 10 .

However, in a practical implementation, the 3D camera system 22 is likely to be integrated with the main body 11 of the robotic cleaning device 10 to minimize the height of the robotic cleaning device 10, thereby allowing it to pass under obstacles, such as e.g. a sofa.

20 The robotic cleaning device 10 has now been described comprising an obstacle detecting device having a 3D camera 23 and first and second structured light sources 27, 28, as this provides for an efficient and rather quick navigation of the robotic cleaning device. However, in its simplest form the robotic cleaning device 10 may only comprise the contact detecting
25 portion 32, since this contact detecting portion 32 enables the robotic cleaning device 10 to navigate around detected objects and obstacles. For the method as illustrated herein, it is sufficient that the robotic cleaning device 10 comprises the contact detecting portion 32, the obstacle detecting device is not essential to perform the method described herein.

In the following figures 3a to 7, the robotic cleaning device 10 is illustrated in the figures by a solid line showing its current position, while earlier positions 11 of the robotic cleaning device 10 are illustrated in a dashed line.

Additionally, the arrows A in the figures 3a to 7 illustrate the direction of movement of the robotic cleaning device 10, thus how the robotic cleaning device 10 has been driving in the different illustrated map graphs or cleaning patterns outlined by path markers 36.

Although it is illustrated in figures 3a to 7 that the path markers 36 are registered centrally in relation to the robotic cleaning device 10, the path markers may be registered at a left or right periphery of the robotic cleaning device 10 or the cleaning opening 18 of the robotic cleaning device 10, as seen in a direction of movement of the robotic cleaning device 10.

Referring now to figures 3a and 3b which illustrate how the robotic cleaning device 10 is detecting so 1 a first object 34, 34' either being part of a surface 35 to be cleaned or surrounding the surface 35. The first object may be in the form of a wall 34 of a room or furniture 34' arranged on the surface 35. The first object may for example also be a chimney, an elevator shaft, stairs, a carpet etc. The robotic cleaning device 10 detects so 1 the first object 34, 34' and moves so 1 towards it. As soon as the first object 34, 34' is reached, the robotic cleaning device 10 starts with following so 2 a boundary or edge of the first object 34, 34' while registering so 3 path markers 36 at intervals on the surface 35.

Figure 3a illustrates how the robotic cleaning device 10 detects so 1 the first object 34, which is embodied as a wall of a room. The robotic cleaning device 10 moves towards the first object 34 until a boundary 38, in the illustrated case the wall, is reached. When the robotic cleaning device 10 observes that the boundary 38 is reached, for example via detection by the obstacle detecting device or the contact detecting portion 32, the processing unit 16 starts to register so 3 the path markers 36 at intervals and stores them for example on the storage medium 26, while following so 2 the boundary 38 using the contact detecting portion 32 or the obstacle detecting device. Figure

3a illustrates how the robotic cleaning device 10 starts with an outer boundary 38 by inward cleaning, which will be described later on referring to figures 4 to 5c and 7. The boundary 38 in figure 3a is represented the wall and may thus be considered as an outer boundary 38.

5 Figure 3b on the other hand illustrates how the robotic cleaning device 10 detects and moves S01 to the first object 34' arranged within the surface 35. As previously described, the robotic cleaning device 10 is detecting and moving S01 towards the first object 34' arranged within the surface 35, for example represented by a table or a cabinet. As soon as the first object 34' is
10 reached, the robotic cleaning device 10 starts to follow S02 the edge 38' while the processing unit 16 continuously registers S03 path markers 36 at intervals. The robotic cleaning device 10 thus performs an outward cleaning in figure 3b. This will be further explained when referring to figures 6a and 6b.

15 It is preferred that the robotic cleaning device 10 only starts registering S03 path markers when the robotic cleaning device 10 has started to follow the edge 38' or boundary 38, as illustrated in figures 3a and 3b.

The method described herein thus works for inward cleaning as illustrated in figures 3a and 4 to 7 and for outward cleaning as illustrated in figures 3b, 6a
20 and 6b.

The intervals between the registered S03 path markers 36 may be time intervals or distance intervals. Thus the path markers 36 may be dropped or registered S03 at time intervals of for example 1 to 30 seconds, preferably 3 to 20 seconds and more preferably from 5 to 15 seconds or at distance
25 intervals of for example 1 to 20cm, preferably 5 to 15cm and more preferably in the range of 7 to 13cm.

Alternatively the distance intervals may be in the range of 1% to 100% of the largest dimension of the robotic cleaning device 10, more preferably 20% to 50% of the largest dimension of the robotic cleaning device 10, which is in the

illustrated case the diameter or width W but may in other cases be a length or width of the robotic cleaning device 10 .

In figures 3a and 3b the path markers 36 are illustrated with a rather big distance in between, this is mainly for illustrative purposes. In figures 4 to 7,
5 the path markers 36 are illustrated as dotted lines, in which every dot represents a path marker 36. The size relation between the robotic cleaning device 10 and the intervals/ distance between path markers 36 is only to be understood illustrative and not absolute.

Figure 4 illustrates how the robotic cleaning device 10 is following $S02$ the
10 boundary 38 until previously registered $S03$ path markers 36' are encountered. When the robotic cleaning device 10 encounters previously registered path markers 36' it starts tracing $S04$ the previously registered path markers 36' while continuing to register $S03$ path markers 36 at intervals, at an offset D . In the illustrated case in figure 4, the robotic
15 cleaning device 10 performs a full loop 42 along the boundary 38 of the object 34 until it encounters previously registered path markers 36'.

Again, as previously mentioned the robotic cleaning device may trace $S04$ the previously registered path markers 36' with a right or left periphery of the robotic cleaning device or the cleaning opening 18 of the robotic cleaning
20 device 10, as seen in a direction of movement of the robotic cleaning device 10 . The previously registered path markers 36' may have been registered themselves at a left or right periphery of the robotic cleaning device or the cleaning opening 18.

Additionally, in case the path markers 36, 36' are registered at a left or right
25 periphery of the cleaning opening 18 or the robotic cleaning device 10, the robotic cleaning device 10 may follow the boundary 38, 38' of the first object 34, 34' or the edge 38" of the first and second object 40 so that the path markers 36 are registered on the periphery of the robotic cleaning device 10 or the cleaning opening 18 of the robotic cleaning device 10 that is located
30 away from the boundary 38, 38'.

In case a side brush (not shown) is installed on the robotic cleaning device 10 for example on the right side of the cleaning opening 18, as seen in a moving direction of the robotic cleaning device 10, the robotic cleaning device 10 may be configured to always follow S02 the boundary 38, 38' or edge 40 of the first object 34, 34' or the second object 40 so that the side brush is following the boundary 38, 38' or edge 40 while registering S03 path markers 36 on the left side of the cleaning opening 18 as seen in the direction of movement of the robotic cleaning device.

The offset D is preferably less than the width of the opening 18 (c.f. figure 1) of the robotic cleaning device 10. This may ensure a proper cleaning. In some cases the offset D may be larger, for example in case a side brush or two side brushes are used. The offset D may then be less than a sphere of action of the cleaning opening 18 and the side brush. Although in the figures the distance towards the boundary 38, 38' is illustrated as being similar to the offset D, it is clear that in practice this distance corresponds at least approximately to half of the offset D, as the robotic cleaning device 10 is following the boundary 38, 38'.

Optionally the processing unit 16 may be configured to recognize S07 and close the loop 42 of figure 4, as there will normally be a small gap where no path markers 36 are registered when the robotic cleaning device switches from the following S02 and registering S03 to tracing S04 previously registered path markers 36'. The processing unit 16 may thus close this small gap and represent the loop 42 as a closed loop in a map graph stored on the storage medium 26.

Figure 5a illustrates how the robotic cleaning device 10 may encounter a second object 40 while tracing S04 of previously deposited path markers 36'. As illustrated in figure 5a, the robotic cleaning device 10 encountered the second object 40 at the previous position 11. As soon as the robotic cleaning device 10 detects and identifies the second object 40, it switches S05 to following S06/ following mode and follows S06 the second object 40 along the edge 38". The robotic cleaning device 10 may only switch S05 to

boundary 38, 38' or edge 38" following S06 when it cannot pass the second object 40 thus when it would need to change direction for navigating around the second object. In other words it may only switch S05 when it drives directly towards and thus basically into the second object 40.

- 5 Figure 5a further illustrates a distance R as measured perpendicular to a sequence of previously registered path markers 36' being arranged closest to an edge part 44 of the second obstacle 40 and the edge part 44. The distance R may determine future decisions of the robotic cleaning device 10, as described referring to figures 5b and 5c.
- 10 When the robotic cleaning device 10 reaches the current position P, as shown in figure 5a, it will again encounter previously registered path markers 36' and has then two possibilities to proceed. The two possibilities are illustrated in figures 5b and 5c, respectively.

Figure 5b illustrates how the robotic cleaning device 10 will continue to
15 follow S06 the edge 38" of the second object 40 upon encountering previously registered path markers 36' until the processing unit 16 detects that the second object 40 has been fully encircled. When the processing unit 16 detects that the second object was fully encircled, the robotic cleaning device 10 is switching back to tracing S04 of previously registered path
20 markers 36' at the offset D. As can be seen in figure 5b such a full circle around the second object may lead to double cleaning of a specific region, in the illustrated case a region close to the lower edge part 44 of the second object 40. A full encircling of the second object 40 may provide information to the robotic cleaning device 10 regarding the exact shape and
25 position/ extension of the second object 40.

Still referring to figure 5b, the robotic cleaning device 10 may decide to fully encircle the second object 40 if it is detected that the distance R is larger than half of the offset D. This may for example be detected by the processing unit 16 by continuously analysing the map graph. When the distance R is larger
30 than half of the offset D a region close to the lower edge part 44 is not entirely

clean and thus the robotic cleaning device 10 may decide to fully encircle the second object 44 to clean this region.

On the other hand if the processing unit 16 detects that the distance R is smaller or approximately the same as half of the offset D, the robotic cleaning device 10 may switch back to tracing S04 previously deposited path markers 36' as soon as previously deposited path markers 36' are encountered when following the edge 38" of the second obstacle 44, as illustrated in figure 5c. In figure 5c previously registered path markers 36' are encountered when the robotic cleaning device 10 reaches position S. Thus at position S, the robotic cleaning device 10 may switch back from following S06 to tracing S04 previously registered path markers.

Referring now to figure 6a and 6b, which illustrates the step of simplifying S08 a loop 42 by closing and splitting the loop 42 to form two loops 42', 42", the loop 42 will only be closed and split S08a if certain conditions apply, which will be explained below. The simplifying S08 of loops 42 is illustrated by an outward cleaning example, as previously described. The arrow between figures 6a and 6b illustrates schematically the simplification S08 step.

Figure 6a illustrates how the robotic cleaning device 10 cleans the surface 35 by starting following S02 the boundary 38' of the second object 34' being arranged within the surface 35 to be cleaned and performing outward cleaning by tracing S04 previously registered path markers 36'. The dashed position 11 again illustrates a previous position 11 of the robotic cleaning device 10 which was in the illustrated case the starting point of the cleaning. From following S02 the second object 34' the robotic cleaning device 10 has moved outwards until it encountered the outer, first object 34 in the form of the boundary 38 where it switched S05 to wall following S06 the boundary 38 of the outer, first object 34.

Figure 6a thus illustrates that the robotic cleaning device 10 can start with an object 34', 40 being arranged within the surface 35 to be cleaned. Thus the

method works fine when the robotic cleaning device 10 for example starts the cleaning at the second object 34', 40, as illustrated in figures 5a to 5c.

Figure 6b illustrates how the loop 42 may be closed and split s08a into a plurality of loops 42', 42'', which define a plurality of areas 46', 46''. In order to simplify s08 the cleaning the processing unit 16 closes and splits s08a the
5 current closed loop 42 into a first and a second loop 42', 42''. This may for example be done when the robotic cleaning device 10 reached its current position P. The simplification comprises adding bridge sequences 48 at the positions indicated in figure 6b. These bridge sequences 48 may comprise
10 virtually added path markers 36 which may be traced S04 by the robotic cleaning device 10 when the latter is cleaning the first area 46' and the second area 46'' to be cleaned, respectively.

The bridge sequences 48 may have length L1, L2 that is smaller than the offset D, as otherwise the bridge sequences 48 will be based on the
15 assumption that there are no objects 34, 34', 40 or obstacles where the bridge sequences are added. Thus there is no assumption made. The bridge sequences 48 are based on the knowledge that there are no objects or obstacles where these bridge sequences 48 are added.

The distances R1, R2, illustrated in figure 6b are measured in a direction
20 perpendicular to a moving direction A of the robotic cleaning device 10 in between two neighbouring sequence sections, each sequence section comprising a plurality of registered path markers 36, 36'. The distances R1, R2 must be smaller than the offset D, otherwise the processing unit 16 will not add the bridge sequences 48, as described above.

25 The described closing and splitting s08a of loops may be applied in many situations such as for example also in the map graph illustrated in figure 5c. A bridge sequence 48' may for example be added at position B in figure 5c, in case the determined distance R, R1, R2 between the current sequence sections and neighbouring sequence section is smaller than the offset D, for
30 simplifying the current loop 42.

When the robotic cleaning device 10 is done with the first area 46' the second area 46" will be cleaned by tracing S04 the previously registered path markers 36' of the second loop 42".

Figure 7 illustrates another surface 35' to be cleaned consisting of two rooms interconnected by a door opening, for example. In figure 7, the robotic cleaning device 10 has already cleaned the first area 46' to be cleaned and the loop 42 has been simplified by adding two bridge sequences 48 so that the loop 42 is simplified into two loops 42', 42". The starting position 11 illustrates where the robotic cleaning device 10 started its cleaning by following S02 the boundary 38 of the object 34 while registering S03 path markers 36 at regular intervals. When the robotic cleaning device 10 reaches its current position P, it will detect that it cannot trace S04 any previously registered path markers 36' any longer with establishing an offset D to anyone of the previously registered path markers 36' and will therefore register that the first area 46' has been entirely cleaned.

The robotic cleaning device 10 will then move S09 to the second area 46" to be cleaned and finish this second area 46" by tracing S04 previously registered path markers 36' of the second loop 42".

As schematically illustrated in figure 7, it may be beneficial to start the cleaning in a corner 50 of the first object 34, 34' as this simplifies the map graph and thus the shape of the loops 42', 42".

Figure 8 illustrates the method steps according to the present invention in a flow diagram. Steps S02 to S08 may be repeated whenever previously registered path markers 36' or a second, third, fourth, etc. object 40 is encountered or if loops 42 need to be simplified.

Although the invention has now been described by various examples, the invention is not limited to those specific examples. The method according to the invention is versatile and universal and may be applied to many potential surfaces to be cleaned having simple or very complicated layouts.

Further in the above described path markers 36, 36' are continuously registered S03 from the beginning of following S02 a boundary 38, 38' until the cleaning is done.

5 Additionally although not illustrated in the figures, the robotic cleaning device 10 and the processing unit 16, respectively, may decide if a surface 35 to be cleaned is too big by splitting that surface 35 into two or more surfaces. In such a case the robotic cleaning device 10 may be configured to follow a borderline or border bridge sequence in between the two surfaces in order to close the loop of the big surface and in order to ensure that there is no
10 obstacle along that border bridge sequence. A border bridge sequence may even be longer than the offset D and thus it needs to be verified if the assumption that no object is arranged along the border bridge sequence can be made. This splitting of a big surface may thus also be part of the simplification step.

15 The invention has mainly been described above with reference to a few embodiments. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible within the scope of the invention, as defined by the appended patent claims.

CLAIMS

1. A method of operating a robotic cleaning device (10) over a surface (35, 35') to be cleaned, the method being performed by the robotic cleaning device (10), the method comprising the steps of:
 - 5 following (S02) a boundary (38, 38') of a first object (34, 34') while registering (S03) path markers (36) at intervals on the surface, the path markers comprising positional information;

tracing (S04) previously registered path markers (36') at an offset (D) upon encountering one or more of the previously registered path markers;
10 and

switching (S05) from tracing the previously registered path markers to following (S06) an edge (38") of a second object (40) upon detection of the second object.
 2. The method according to claim 1, wherein the robotic cleaning device is
15 following the edge (38") of the second object (40) until previously registered path markers (36') are again encountered.
 3. The method according to claim 1, wherein the robotic cleaning device is following the edge (38") of the second object (40) until the second object is encircled.
 - 20 4. The method according to any of the previous claims, comprising the step of recognizing (S07) a loop (42) defining an area to be cleaned upon encountering one or more of the previously registered path markers (36'), wherein the loop comprises a plurality of the previously registered path markers.
 - 25 5. The method according claim 4, comprising the step of simplifying (S08) the loop (42) for generating an efficient cleaning pattern.

6. The method according to claim 5, wherein the simplifying comprises the step of closing and/ or splitting (S08a) the loop (42) into a plurality of loops (42', 42'') defining a plurality of areas (46', 46'') to be cleaned, so that the robotic cleaning device can clean the areas one after the other.
- 5 7. The method according to claim 6, wherein a first area (46') of the plurality of areas is considered to be clean when the robotic cleaning device is encountering previously registered path markers when moving in any direction without being able to establish the offset (D) to any of the previously registered path markers (36').
- 10 8. The method according to claim 7, comprising the step of moving (S09) from the first area (46') to a second area (46'') to be cleaned of the plurality of areas and trace (S04) previously registered path markers (36') of a loop (42'') defining the second area to be cleaned.
- 15 9. Method according to any of the previous claims, wherein the path markers (36) are registered at a left or right periphery of the robotic cleaning device or a cleaning opening (18) of the robotic cleaning device, as seen in a direction of movement of the robotic cleaning device.
- 20 10. Method according to claim 9, wherein the robotic cleaning device is tracing S04 the left or right previously registered path markers (36') with a right or left periphery of the robotic cleaning device or the cleaning opening (18) of the robotic cleaning device, as seen in a direction of movement of the robotic cleaning device.
- 25 11. Method according to claim 9 or 10, wherein the robotic cleaning device is following (S02, S06) the boundary (38, 38') of the first object (34, 34') or the edge (38'') of the second object (34, 34', 40) so that the path markers are registered on the periphery of the robotic cleaning device or the cleaning opening (18) of the robotic cleaning device that is located away from the boundary (38, 38') or the edge (38'').

12. Method according to any of the previous claims, wherein the registering (SO 3) of path markers (36, 36') is started when a corner of the first object is detected.

13. Robotic cleaning device (10) comprising:

5 a main body (11);

a propulsion system (12, 13, 15a, 15b) arranged to move the robotic cleaning device;

a contact detecting portion (32) connected to the main body (11) and arranged to detect if the robotic cleaning device is in contact with an object;

10 a dead reckoning sensor (30, 30') operatively connected to the propulsion system;

a processing unit (16) arranged to control the propulsion system; wherein the processing unit (16) is connected to the dead reckoning sensor and configured to perform the method according to any of claims 1 to 12.

15 14. A computer program (25) comprising computer-executable instructions for causing a robotic cleaning device (10) to perform the steps recited in any one of claims 1-12, when the computer-executable instructions are executed on a processing unit (16) included in the robotic cleaning device (10).

20 15. A computer program product comprising a computer readable storage medium (26), the computer readable storage medium (26) having the computer program (25) according to claim 14 embodied therein.

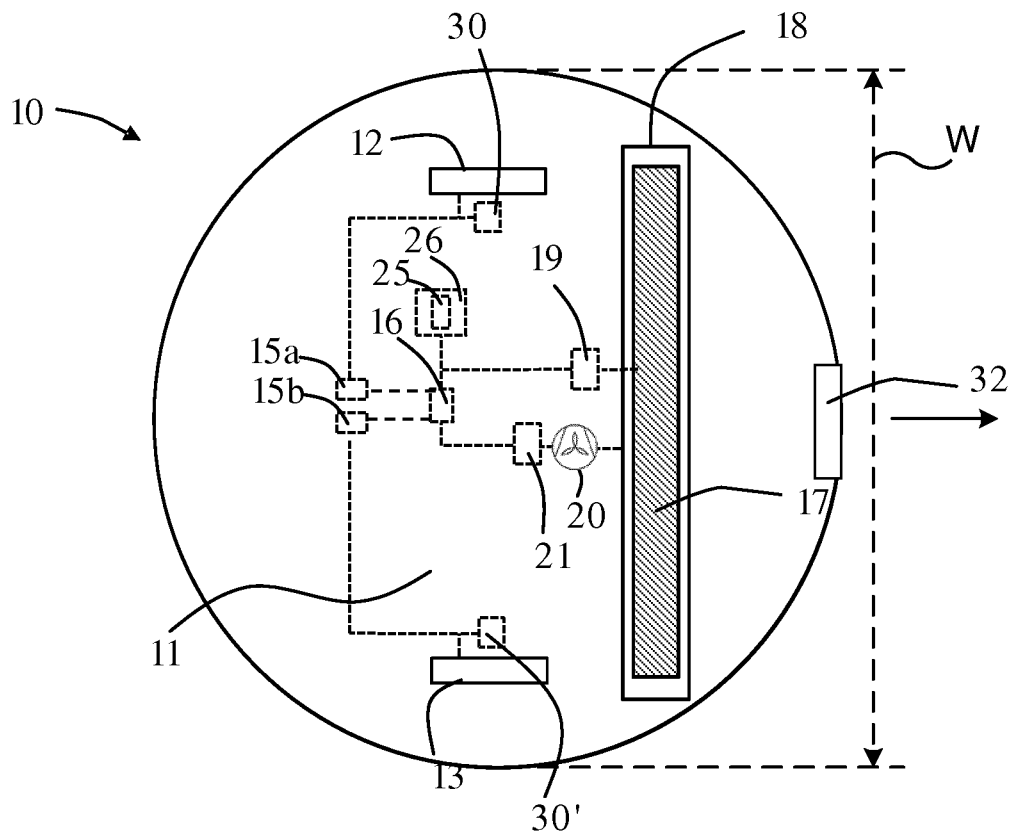


Fig. 1

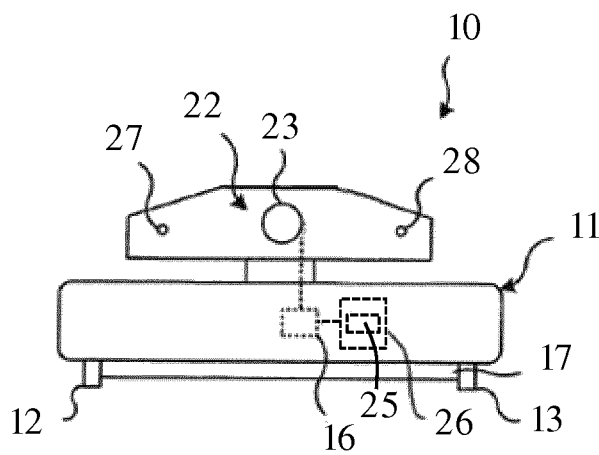


Fig. 2

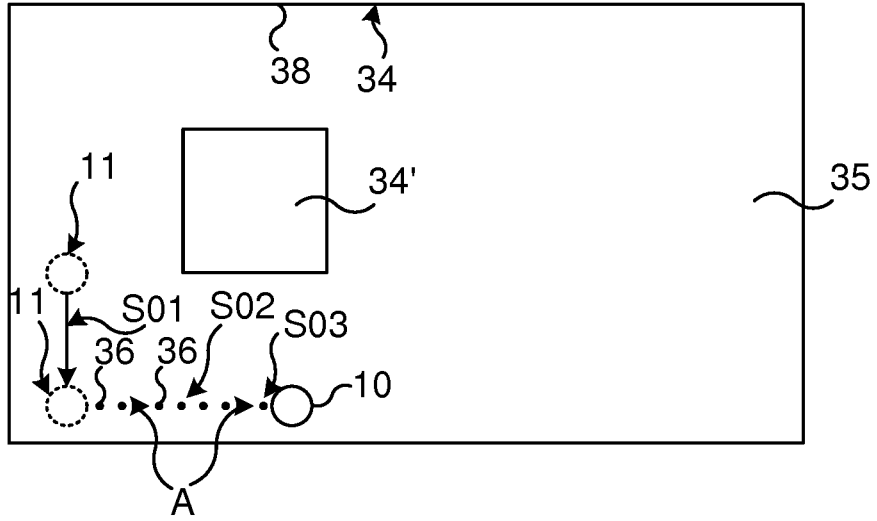


Fig. 3a

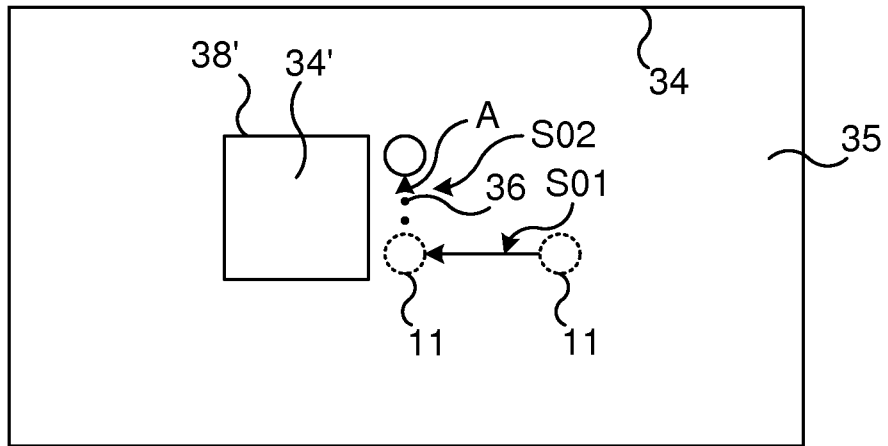


Fig. 3b

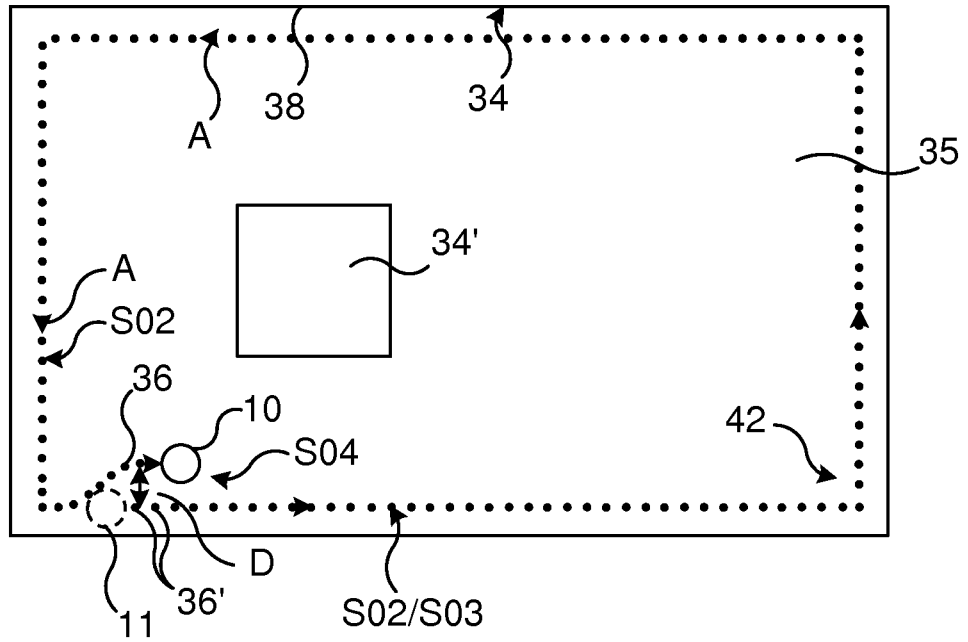


Fig. 4

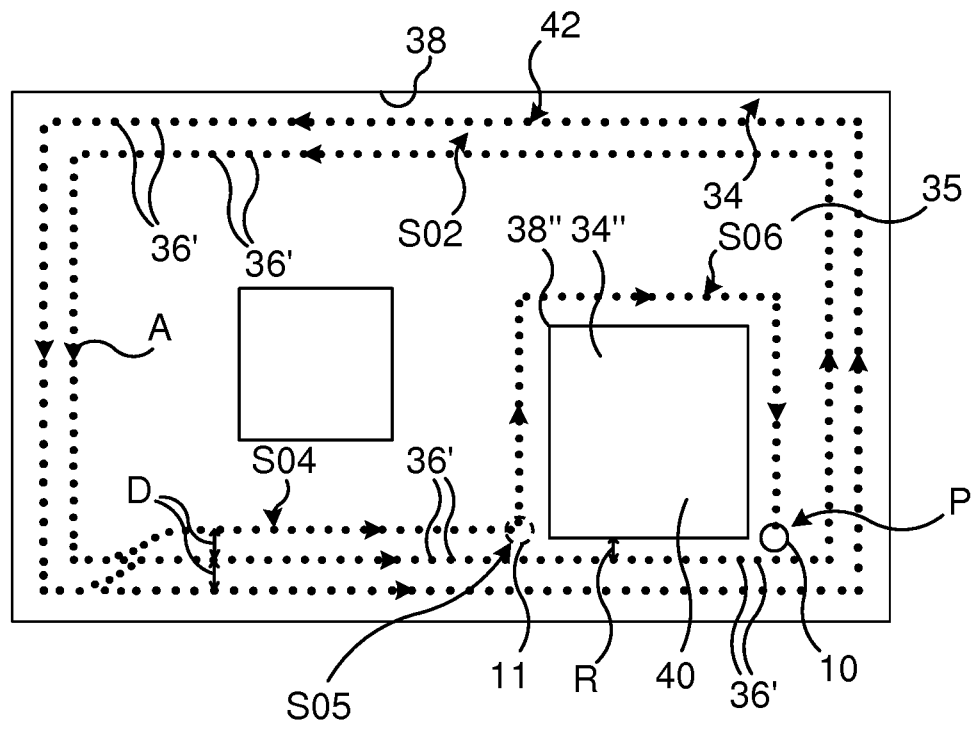


Fig. 5a

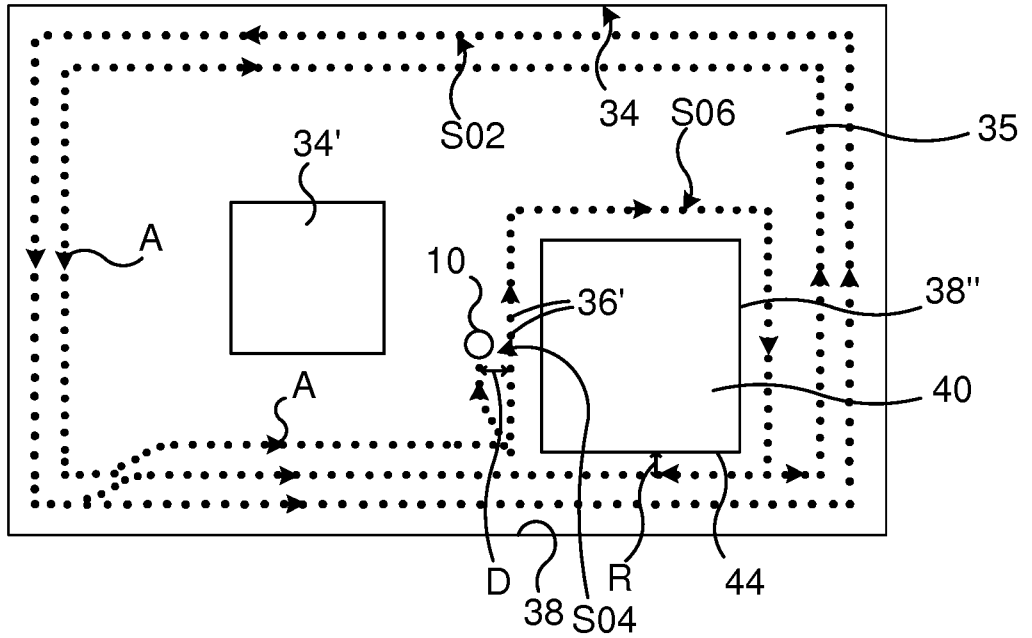


Fig. 5b

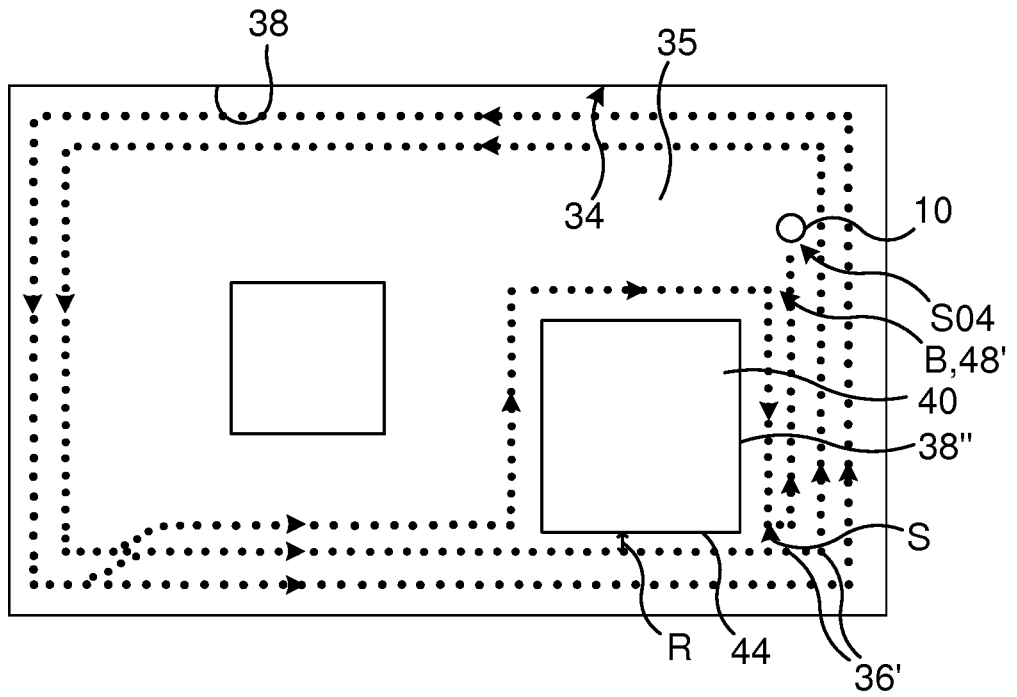


Fig. 5c

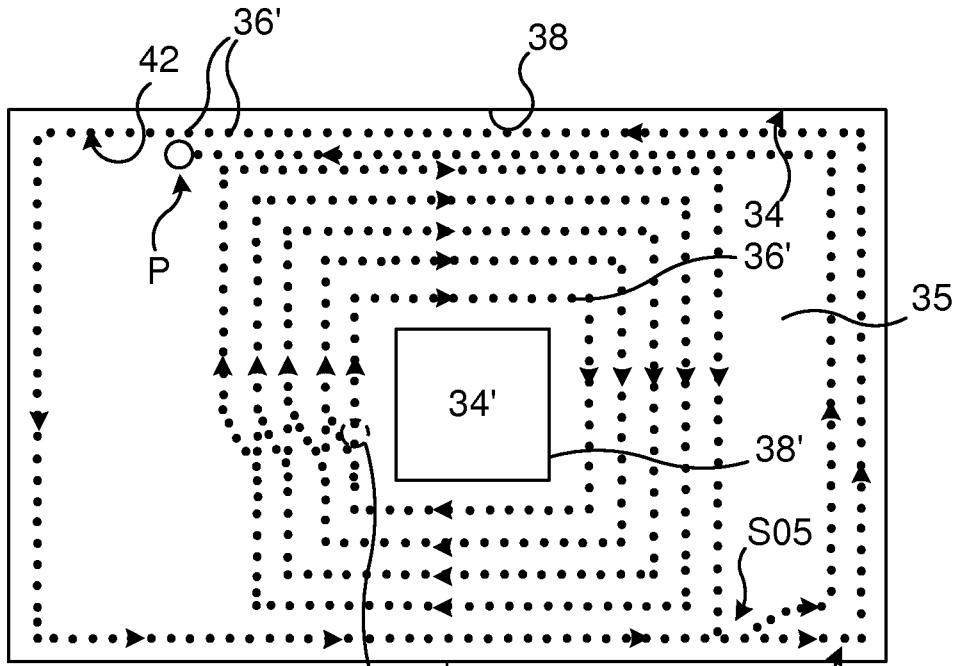


Fig. 6a

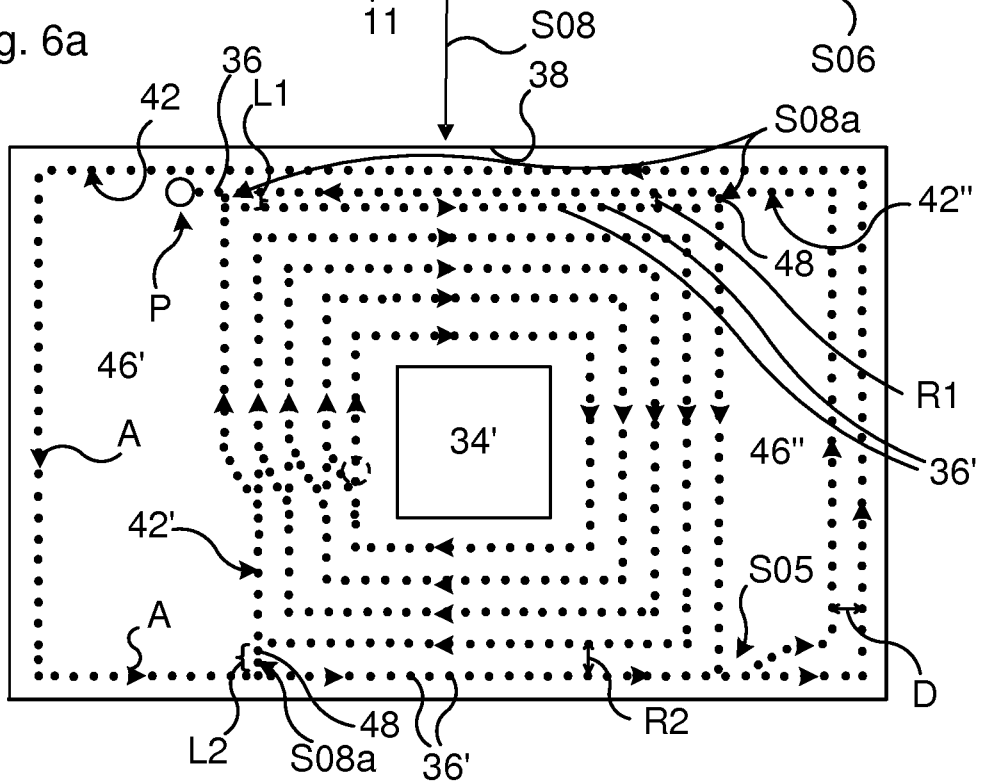


Fig. 6b

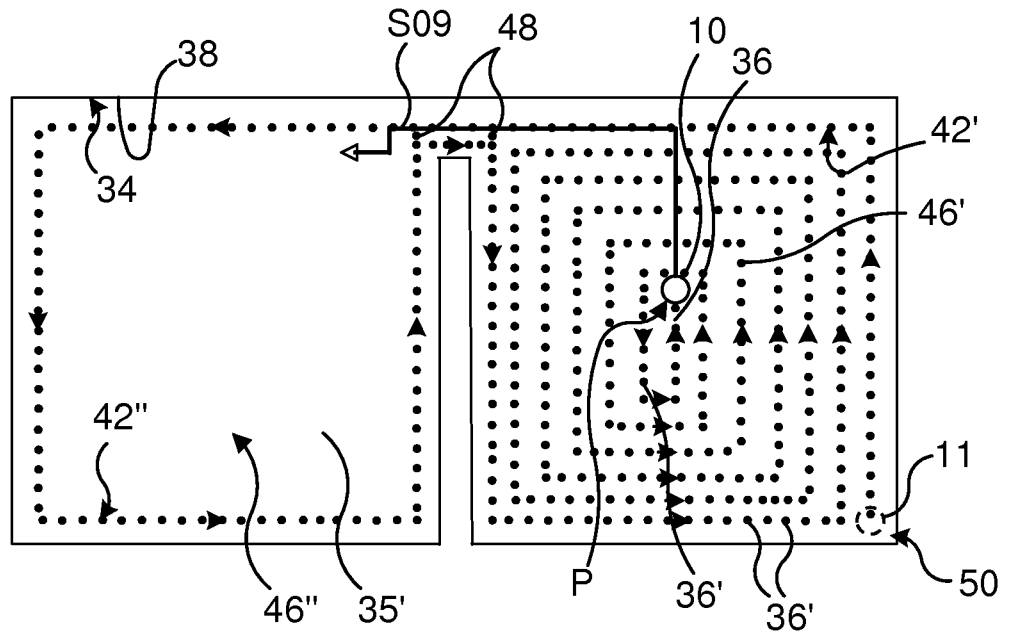


Fig. 7

7/7

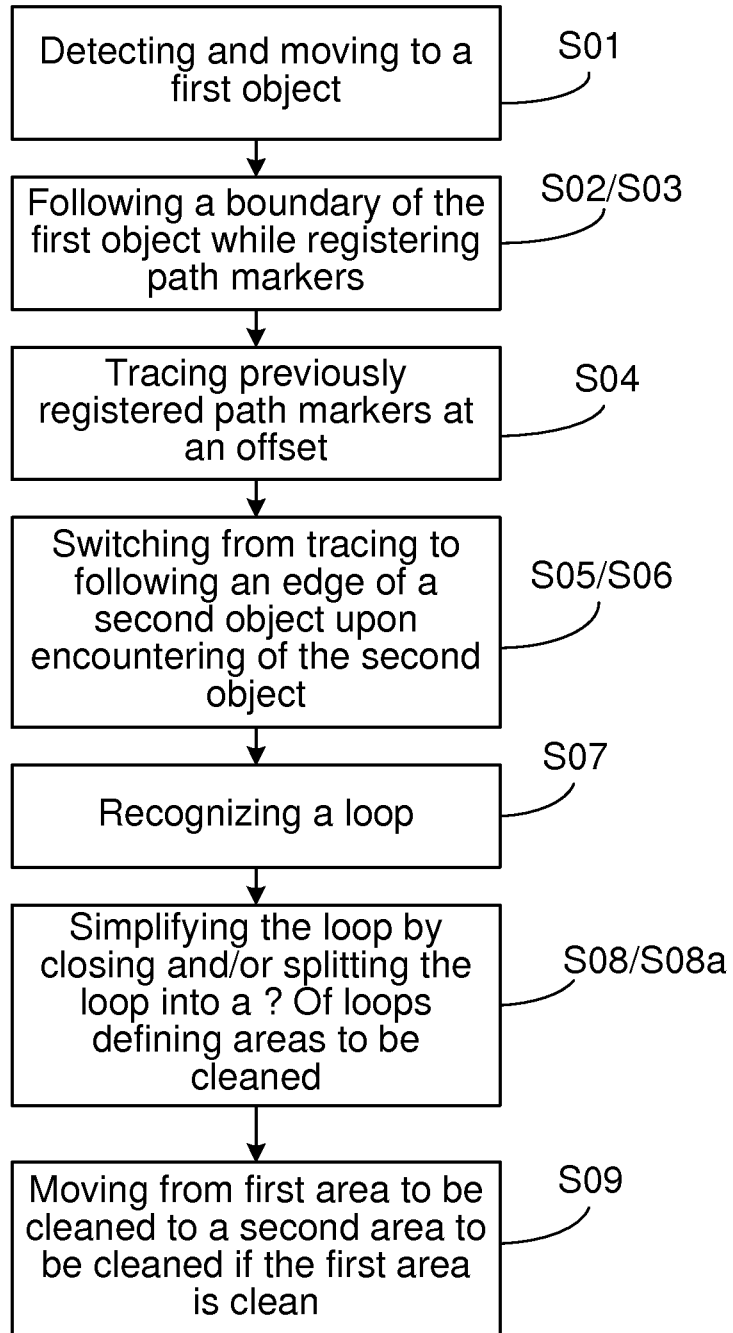


Fig. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/077954

A. CLASSIFICATION OF SUBJECT MATTER
INV. G05D1/02
 ADD.
 According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
 Minimum documentation searched (classification system followed by classification symbols)
G05D G01S

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 605 156 B1 (CLARK ALAN GERARD [GB] ET AL) 12 August 2003 (2003-08-12)	1, 14, 15
Y	column 5, line 40 - column 6, line 49	2-5 ,9-13
A	figure 5	6-8
Y	DE 10 2010 000174 A1 (VORWERK CO INTERHOLDING [DE]) 28 July 2011 (2011-07-28)	2-5 ,9-13
A	paragraphs [0030] - [0037] figures 4-5	6-8
Y	US 2005/085947 A1 (ALDRED MICHAEL D [GB] ET AL) 21 April 2005 (2005-04-21)	2-5 ,9-13
A	Abstract paragraphs [0051] - [0053] , [0059] - [0060] , [0073] - [0074] figures 2,4,5 ,6,9 ,13	6-8
	----- -/- .	

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

5 October 2015

Date of mailing of the international search report

12/10/2015

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
 NL - 2280 HV Rijswijk
 Tel. (+31-70) 340-2040,
 Fax: (+31-70) 340-3016

Authorized officer

Roberts , Nei I

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/077954

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2014/033055 A1 (ELECTROLUX AB [SE]) 6 March 2014 (2014-03-06)	13
A	page 11, lines 3-13 page 12, lines 19-32 figure 5 -----	6-8

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No PCT/EP2014/077954
--

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6605156	BI	12-08-2003	AT 237275 T 15-05-2003
		AU 761745 B2	12-06-2003
		AU 6005800 A	13-02-2001
		DE 60002209 DI	22-05-2003
		DE 60002209 T2	04-03-2004
		EP 1198192 AI	24-04-2002
		ES 2197105 T3	01-01-2004
		JP 4426145 B2	03-03-2010
		JP 2003505127 A	12-02-2003
		US 6605156 BI	12-08-2003
		Wo 0106904 AI	01-02-2001

DE 102010000174	AI	28-07-2011	NONE

US 2005085947	AI	21-04-2005	AT 363679 T 15-06-2007
		AU 2002337343 B2	30-11-2006
		DE 60220435 T2	31-01-2008
		EP 1440354 AI	28-07-2004
		JP 4249624 B2	02-04-2009
		JP 4846686 B2	28-12-2011
		JP 2005508540 A	31-03-2005
		JP 2008077670 A	03-04-2008
		US 2005085947 AI	21-04-2005
		wo 03040845 AI	15-05-2003

Wo 2014033055	AI	06-03-2014	CN 104487864 A 01-04-2015
		EP 2888603 AI	01-07-2015
		KR 20150048093 A	06-05-2015
		US 2015185322 AI	02-07-2015
		wo 2014033055 AI	06-03-2014
