

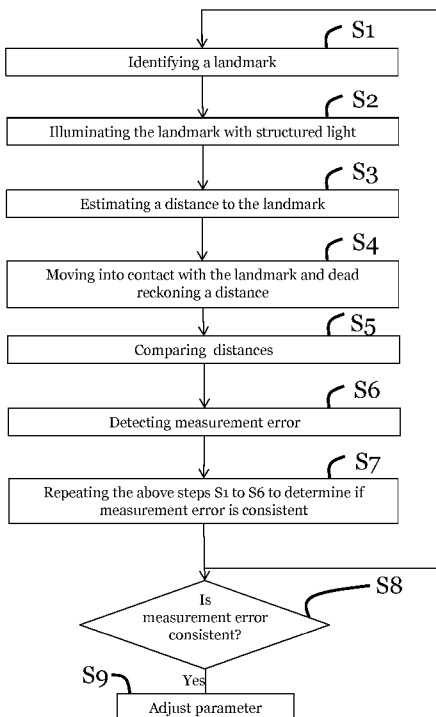


- (51) International Patent Classification:
G05D 1/02 (2006.01)
- (21) International Application Number:
PCT/EP2014/078144
- (22) International Filing Date:
17 December 2014 (17.12.2014)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
1450886-5 10 July 2014 (10.07.2014) SE
- (71) Applicant: AKTIEBOLAGET ELECTROLUX
[SE/SE]; S:t Göransgatan 143, S-10545 Stockholm (SE).
- (72) Inventor: HAEGERMARCK, Anders; Edbovägen 12, S-142 63 Trångsund (SE).
- (74) Agent: SAMZELIUS, Roger; S:t Göransgatan 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).

[Continued on next page]

(54) Title: METHOD FOR DETECTING A MEASUREMENT ERROR IN A ROBOTIC CLEANING DEVICE



(57) Abstract: The invention relates to Robotic cleaning device (10, 10') comprising a main body (11), a propulsion system (12, 13, 15a, 15b), a contact detecting portion (32) connected to the main body (11), a dead reckoning sensor (30, 30') operatively connected to the propulsion system and an obstacle detecting device comprising a camera (23) and a first structured light source (27) arranged at a distance from each other on the main body. The robotic cleaning device may further comprise a processing unit (16) arranged to control the propulsion system. The obstacle detecting device and the processing unit are arranged to estimate a distance (DC) to the landmark and to subsequently move the robotic cleaning device into contact with the landmark while measuring an actual distance (DA) to the landmark, whereby the actual distance is then compared with the distance for detection of a measurement error.

Figure 6

WO 2016/005012 A1

Published:

— *with international search report (Art. 21(3))*

METHOD FOR DETECTING A MEASUREMENT ERROR IN A ROBOTIC CLEANING DEVICE

TECHNICAL FIELD

The invention relates to a robotic cleaning device and a method for the
5 robotic cleaning device of detecting measurement errors in an obstacle
detecting device of the robotic cleaning device.

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
10 with possible obstacles.

Robotic vacuum cleaners 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 vacuum cleaners are further equipped
with intelligence in the form of microprocessor(s) and navigation means for
15 causing an autonomous behaviour such that the robotic vacuum cleaners can
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 a room, in which furniture such as tables, chairs
and other obstacles such as walls and stairs are located. These robotic
20 vacuum cleaners have navigated a room by means of using structured light,
such as e.g. line laser beams, to illuminate obstacles to be detected and
registering laser light directly reflected from the obstacles back towards the
cleaner in order to determine where the obstacles are located in the room.
Images are continuously captured by a camera of the obstacle detecting
25 device of the robotic cleaning device, and distance to the illuminated obstacle
such as a wall or a floor can be estimated by detecting the directly reflected
laser line in the captured images and using trigonometric functions based on
the known position of the cleaner, such that a 3D representation of the room
subsequently can be created relative to the robot cleaner. In order to detect a
30 distance to an illuminated object, the structured light source is usually
arranged at a known distance, a so called base line, from the camera or the

like on the robot cleaner. In addition the structured light source is preferably arranged at a known angle to make sure that the reflected light line of the structured light source is within the field of view of the camera.

For calculating or estimating distances between the robot cleaner and
5 objects/landmarks a trigonometric formula or algorithm is used, as mentioned above. In these algorithms a fixed parameter for value of the known angle at which the structured light source is arranged and a further fixed parameter for the length of the base line are used. These parameters are usually determined by tests in the factory for each robot cleaner after their
10 production. Alternatively these parameters may be pre-set in the processing unit comprising the algorithm during the production.

A problem is that the actual length of the base line and/or the actual angle at which the structured light source is arranged can change over time due to temperature changes within the robot cleaner, due to vibrations for example
15 during transport, changes in the material in which the structured light source is embedded, etc. In particular changes in the actual angle at which the structured light source is arranged may occur in errors when distances are estimated using the obstacle detecting device and a trigonometric algorithm. It follows that measurements performed by using the camera and the
20 structured light source are in some cases not accurate or they may change over time. In such a case the robot cleaner needs to be checked and verified so that the parameters can be calibrated/adjusted.

SUMMARY

An object of the present invention is to provide a robotic cleaning device that
25 is configured to detect measurement errors occurring in the obstacle detecting device and the processing unit, respectively.

Advantageously the robotic cleaning device is configured to autonomously calibrate parameters in an algorithm used to estimate positions of the robotic cleaning device in view of objects/landmarks.

The general idea of the robotic cleaning device and the method for detecting measurement errors performed by the robotic cleaning device is to identify a landmark, for example a flat wall, to estimate the distance to the landmark by using the obstacle detecting device and then to use dead reckoning within the
5 robotic cleaning device to determine an actual distance to the landmark by moving from the current position into contact with the landmark. The measurement error may then be determined by comparing the distance obtained by the camera, the structured light source and a processor with the actual distance obtained by dead reckoning.

10 Disclosed herein is a method for detecting measurement errors in an obstacle detecting device of a robotic cleaning device comprising the steps of estimating a distance to a landmark relative to the robotic cleaning device by illuminating the landmark with structured light and extracting information from the reflections of the structured light, moving into contact with the
15 landmark while dead reckoning an actual distance to the landmark and comparing the actual distance with the distance for detecting a measurement error in the obstacle detecting device.

In the above method the robotic cleaning device may even be configured to obtain an estimation about the location of the landmark.

20 The robotic cleaning device is thus capable of detecting measurement errors during operation. There is no need for sending the robotic cleaning device to the producer for detecting errors. The robotic cleaning device is thus very autonomous and user-friendly.

In an embodiment the method may comprise the step of repeating some or
25 all of the above steps several times by moving back away from the landmark and again in contact with the landmark.

Thereby the distances do not need to be the same at each measurement.

The landmark may preferably be a flat and immobile landmark such as a wall or the like.

In a further embodiment the method may comprise the step of determining whether the detected measurement errors are consistent.

This is advantageous since a one time measurement may not be representative as wheels of the robotic cleaning device may spin during the moving towards the landmark. Another potential problem may be that dirt on the floor affects the movement path of the robotic cleaning device when it moves into contact with the landmark. It may thus be preferred to perform the measurement several times to detect consistent measurement errors.

When a detected measurement error is discovered to be consistent over several times of performing the method, a parameter in a distance calculating algorithm may be adjusted.

This calibration step may help to provide a robotic cleaning device that is capable of continuously measure accurately over a long period of operating.

In an embodiment the parameter in the distance calculating algorithm may be a value for an angle at which the structured light source is arranged in relation to a direction of view of the camera of the obstacle detecting device.

Other parameters relating for example to a base line may be adjusted, which base line is a distance between the camera and the structured light source of the obstacle detecting device.

In an embodiment of the method some or all of the above steps may be performed after a predetermined operating time has elapsed.

In a further embodiment some or all of the above steps may be performed if a vibration and/or temperature sensor detects a temperature above or below a temperature threshold.

A high temperature within the robotic cleaning device, for example during cleaning in a well-lit room in summer or after a long period of operating, may affect the material in which the structured light source is embedded and/or

the material of the structured light source itself. A temperature threshold may prevent measurement errors originating from high or low temperatures.

Alternatively or additionally the temperature sensor may be a vibration sensor or the like that registers vibrations or shocks and that is configured to
5 initiate a measurement error detection after such a period of vibration or a shock has occurred.

In a further embodiment some or all of the above steps may be initiated if the robotic cleaning device has been in an idle mode for a predetermined period of time.

10 A long idle period, for example storage, may expose the robotic cleaning to high/low temperatures, humidity and other stresses that may affect the actual angle or the actual base line. The robotic cleaning device will thus perform some or all of the above steps once the robotic cleaning device has been idle for a predetermined period of time to provide improved accuracy.

15 Disclosed herein is further 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 connected to the propulsion system. The robotic cleaning device
20 further comprises an obstacle detecting device comprising a 3D sensor system, which may for example be a 3D camera system, a 3D laser system, etc, and a first structured light source arranged at a distance from each other on the main body and a processing unit arranged to control the propulsion system. The obstacle detecting device is arranged to position a landmark
25 relative to the robotic cleaning device by illuminating the landmark with structured light from the first structured light source. The processing unit is arranged to estimate a distance to the landmark based on a detected reflection of the structured light and subsequently moving the robotic cleaning device into contact with the landmark while measuring an actual
30 distance to the landmark via the dead reckoning sensor, whereby the actual

distance is then compared with the distance for detection of a measurement error.

The robotic cleaning device is thus advantageously configured to autonomously detect a measurement error. The actual distance as measured
5 by the dead reckoning sensor is considered to be the accurate distance.

In a further embodiment the robotic cleaning device may comprise a second structured light source.

In an embodiment the first and/or second structured light source may be arranged at an angle in relation to a front end portion of the main body of the
10 robotic cleaning device and the direction of view of a camera of the obstacle detecting device, respectively.

The angle may ensure that the projected light line from the first and/or second structured light source is actually in the field of vision of the 3D camera system.

15 In a further embodiment the processing unit may be configured to measure and store the measurement errors from several measurements and wherein the processing unit may detect if the measurement errors are consistent or not.

As described above, this may help to avoid that a one time error during the
20 measurement method, has an influence on the detection of a real, consistent measurement error(s).

In another embodiment the processing unit may comprise a distance calculating algorithm with a parameter representing the angle at which the first and/or second structured light source is arranged and wherein the
25 processing unit calibrates the parameter if it is detected that the measurement errors are consistent.

In an embodiment the robotic cleaning device may comprise at least one impact and/or temperature sensor, which is arranged in communication with the processing unit.

5 The impact and/or temperature sensor may register high temperatures around or within the robotic cleaning device and/or vibrations so that the processing unit may initiate the method according to some or all of the above steps.

In another embodiment the processing unit may comprises a timer.

10 The timer may be used to determine whether or not it is necessary to initiate the method according to some or all of the above steps and thus whether or not it is necessary to calibrate the robotic cleaning device.

15 The invention further relates to a computer program comprising computer-executable instructions for causing a robotic cleaning device to perform some or all of the above steps when the computer-executable instructions are executed on a processing unit included in the robotic cleaning device.

The invention further relates to a computer program product comprising a computer readable storage medium, the computer readable storage medium comprising the computer program according to the above paragraph embodied therein.

20 Generally, all terms used in the claims are to be interpreted according to their ordinary meaning in the technical field, unless explicitly defined otherwise herein. All references to "a/an/the element, device, apparatus, component, means, step, etc." are to be interpreted openly as referring to at least one instance of the element, device, apparatus, component, means, step, etc.,
25 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:

5 Fig 1 illustrates schematically an embodiment of the robotic cleaning device according to the invention in a bottom up view, whereby a bottom of a main body is illustrated transparent to show various components of the robotic cleaning device;

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

10 Fig 3 illustrates schematically a top down view onto the robotic cleaning device according to an embodiment of the invention;

Fig 4 illustrates schematically how the robotic cleaning device estimates a distance to a landmark;

15 Fig. 5 illustrates schematically how the robotic cleaning device measures an actual distance to the landmark by dead reckoning; and

Fig. 6 illustrates a method steps according to a method of the invention.

DETAILED DESCRIPTION

20 The invention will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments of the invention 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
25 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, 10' according to the invention can be mains-operated and 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 movement of the driving wheels 12, 13, such that the cleaning device 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 the surface to be cleaned. A number of different driving wheel 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 as a device having a more traditional circular-shaped main body, or a triangular-shaped main body.

As an alternative to the above described propulsion system, a track 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 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 30, 30'.

A controller 16 such as a microprocessor 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 (not shown in Figure 1a) for detecting obstacles in the form of walls, floor lamps, table legs, around which the robotic cleaning device must navigate. The dead reckoning sensors 30, 30' are connected to the controller 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 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 controller 16, which may be embodied in the form of a microprocessor or processing unit 16. The microprocessor 16 communicates with the wheel motors 15a, 15b to control movement of the wheels 12, 13 in accordance with information provided by the obstacle detecting device such that the robotic cleaning device 10 can move as desired across the surface to be cleaned. This will be described in more detail with reference to subsequent drawings.

Further, the main body 11 may optionally be arranged 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 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 controller/microprocessor 16.

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 controller 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 controller/processing unit 16 embodied in the form of one or more microprocessors is 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 controller 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 controller 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 controller 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 side 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 and in case the measurement of the obstacle
5 detecting device has to be verified, as will be described later herein, referring to figures 4 and 5.

Additionally, the robotic cleaning device 10 may comprise a vibration and/or temperature sensor 34 operatively connected to the controller 16. The vibration and/or temperature sensor 34 may be configured to register the
10 temperature within the robotic cleaning device 10 and to initiate a method for checking parameters in an algorithm when the temperature is above a certain temperature threshold, as will be described later herein. The vibration and/or temperature sensor 34 may further be used to register vibrations, which may for example occur if the robotic cleaning device collides with objects or if it
15 falls over an edge, and to initiate the method for checking parameters of the algorithm, as will be described later herein.

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
20 first and a second structured light source 27, 28, which may be horizontally or vertically oriented line lasers. Further shown is the controller 16, the main body 11, the driving wheels 12, 13, and the rotatable brush roll 17 previously discussed with reference to Figure 1. The controller 16 is operatively coupled to the camera 23 for recording images of a vicinity of the robotic cleaning
25 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. Further, the field of view of the camera 23 is preferably smaller than the space illuminated by the first and second
30 structures light source 27, 28. The camera 23 is controlled by the controller 16 to capture and record a plurality of images per second. Data from the

images is extracted by the controller 16 and the data is typically saved in the memory 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 objects of a home or room. The camera 23 is controlled by the controller 16 to capture and record images from which the controller 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 cleaning device 10 is moving across the surface to be cleaned. Thus, the controller 16 derives positional data of the robotic cleaning device 10 with respect to the surface to be cleaned from the recorded images, generates a 3D representation of the surroundings from the derived positional data and controls the driving motors 15a, 15b to move the robotic cleaning device across the surface to be cleaned in accordance with the generated 3D representation and navigation information supplied to the robotic cleaning device 10 such that the surface to be cleaned can be navigated by taking into account the generated 3D representation. Since the derived positional data will serve as a foundation for the navigation of the robotic cleaning device 10, it is important that the positioning is correct; the robotic cleaning device will otherwise navigate according to a “map” of its surroundings that is misleading.

The 3D representation generated from the images recorded by the 3D camera system 22 thus facilitates detection of obstacles in the form of walls, floor lamps, table legs, around which the robotic cleaning device 10 must navigate as well as rugs, carpets, doorsteps, etc., that the robotic cleaning device 10 must traverse. The robotic cleaning device 10 is hence configured to learn about its environment or surroundings by operating/cleaning.

With respect to Figure 2, for illustrational purposes, the 3D camera system 22 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
5 minimize the height of the robotic cleaning device 10, thereby allowing it to pass under obstacles, such as e.g. a sofa.

Figure 3 illustrates a top down view onto a robotic cleaning device 10' according to another embodiment of the invention, whereby the 3D camera system 22 comprises only the first structured light source 27 which is
10 arranged at an angle α to a main direction of view V of the camera 23 as illustrated in figure 3. As described above, there may be two structured light sources 27, 28 arranged on the robotic cleaning device 10. In figure 3 a base line b is further illustrated. The base line b corresponds to the distance between the camera 23 and the structured light source 27, as measured
15 perpendicular to the main direction of view V of the camera 23. The camera 23 and the structured light source 27 may be embedded in the material of the main body 11. Over time the angle α and/or the actual value of the base line b may change, for example due to material shrinkage, material aging, humidity, vibrations, temperature, etc., affecting the measurement and estimation of
20 distances performed by the 3D camera system 23 and the obstacle detecting device, respectively. Figures 4 to 6 illustrate a method to verify and calibrate the above parameters, which represent values for the angle α and the base line b, in a distance calculating algorithm.

Figure 4 illustrates how the robotic cleaning device 10' identifies S1 (c.f.
25 figure 6) a landmark 36, such as for example a flat wall, illuminates S2 (c.f. figure 6) the landmark 36 with light from the structured light source 27 and estimates S3 (c.f. figure 6) a distance DC to the landmark 36 by analysing the reflected light originating from the structured light source 27. During the identification S1 of the landmark 36 the robotic cleaning device 10' may
30 rotate essentially on the spot in order to produce a map of the landmark 36, in case the landmark 36 is not already stored in an internal map of the robotic cleaning device 10'. The distance DC may preferably be a distance

which is the shortest distance to the landmark 36; it does however not need to be the shortest distance. As previously described, the distance DC is obtained via an algorithm that is on the controller or microprocessor 16 using trigonometric functions and fixed parameters which represent the base line b and the angle α (c.f. figure 3).

In order to detect a measurement error during the estimation S3 of the distance DC the actual distance DA has to be determined. This may be done according to figure 5. After estimating S3 the distance DC, the robotic cleaning device 10' moves S4 (c.f. figure 6) into contact with the landmark 36, as illustrated in figure 5, and measures the actual distance DA by using dead reckoning and the dead reckoning sensors 30, 30', respectively. Contact with the landmark 36 will be registered as soon as the contact detecting portion 32 (c.f. figure 1) detects physical contact with the landmark 36.

By comparing S5 (c.f. figure 6) the distance DC with the actual distance DA a measurement error resulting from the parameters representing the angle α and/or the base line b in the algorithm may be detected S6 (c.f. figure 6). As the angle α is the most sensitive parameter in the algorithm, thus the parameter with highest influence on the estimation S3, the measurement error is in most cases originating in a wrong parameter representing this angle α . Thus in case there is a measurement error, the parameter representing the angle α is in most cases the source of the error. Therefore a measurement error means that the parameter representing the angle α does not correspond any longer with the actual angle α , because the actual angle α changed since the last calibration or since the production of the robotic cleaning device 10, 10'.

Figure 6 illustrates the steps S1 to S6. The measurement error of one single measurement performed according to steps S1 to S6 may be a once-off, as previously described. To prevent once-off measurement errors in measuring the actual distance DA having a high influence on the measurement error detection S6, the steps of identifying S1 the landmark 36, illuminating S2 the landmark 36, estimating S3 a distance DC to the landmark 36, moving S4

into contact with the landmark 36, comparing S5 the distance DC with the actual distance DA and detecting S6 a measurement error to determine whether or not the measurement error is actually consistent or not, may be repeated S7, several times. This may for example be done by performing a
5 number of repetitive measurements and statistically analyse the standard deviation of the detected measurement errors, if any. This can be done automatically in the controller/microprocessor 16. In order to repeat steps S1 to S6 the robotic cleaning device 10, 10' moves back away from the landmark 36 and repeats the steps S1 to S6. The actual distance DA as illustrated in
10 figure 5, does thereby not need to be the same for each measurement (steps S1 to S6).

If it is discovered S8, after the number of repetitive measurements that the measurement errors are consistent, the parameter representing the angle α and/or the parameter representing the base line b in the distance calculating
15 algorithm may be adjusted S9, as illustrated in figure 6.

The above described method may be performed after a predetermined operating time of the robotic cleaning device 10, 10' has passed and/or after the vibration and/or temperature sensor 34 has registered a vibration and/or after the vibration and/or temperature sensor 34 has registered a
20 temperature within or around the robotic cleaning device 10, 10' that is above or below a predetermined temperature threshold.

In case the robotic cleaning device 10 (not shown in figures 3 to 5) comprises the first and the second structured light source 27, 28, the parameter representing both angles, the angle α and the angle at which the second
25 structured light source 28 is arranged in view of direction of view V of the camera, may be adjusted.

In a further embodiment it may be possible to check or verify the two angles described in the previous paragraph independently from each other. In another embodiment the two angles may be checked depending on each other
30 by using average values. Preferably the angle α at which the first structured

light source 27 is arranged and the angle (not illustrated in the figures) at which the second structured light source 28 is arranged are the same, which makes it easier to verify and increase accuracy, as described above.

During the whole method the actual distance DA is considered to be accurate.

- 5 Although for example a spin of one of the driving wheels 12, 13 may result in an inaccurate actual distance DA, the repetitive measurements according to above described steps S1 to S6 may exclude or at least reduce the influence of such a once-off error coming from a wrongly measured actual distance. In principle, error measurements that are found by the controller to be wrong
10 (due to deviation from a pattern of measurements) can be ignored or discarded when determining consistent errors.

- 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
15 within the scope of the invention, as defined by the appended patent claims.

CLAIMS

1. A method for detecting measurement errors in an obstacle detecting device of a robotic cleaning device (10, 10') comprising the steps of:
 - estimating (S3) a distance (DC) to a landmark (36) by illuminating the landmark with structured light and extracting information from the reflections of the structured light;
 - moving (S4) into contact with the landmark while dead reckoning an actual distance (DA) to the landmark; and
 - comparing (S5) the actual distance (DA) with the distance for detecting (S6) a measurement error in the obstacle detecting device.
2. Method according to claim 1, comprising the step of repeating (S7) the above steps (S1, S3, S5, S6) several times by moving back away from the landmark and again in contact with the landmark.
3. Method according to claim 2, comprising the step of determining (S8) whether detected measurement errors are consistent.
4. Method according to claim 3, comprising the step of adjusting (S9) a parameter in a distance calculating algorithm, if it is detected that the measurement errors are consistent.
5. Method according to claim 4, wherein the parameter in the distance calculating algorithm is a value for an angle (α) at which a structured light source is arranged in relation to direction of view (V) of the obstacle detecting device.
6. Method according to any of the previous claims, wherein some or all of the above steps (S3, S4, S5, S6, S7, S8, S9) are performed after a predetermined operating time of the robotic cleaning device has elapsed.

7. Method according to any of the previous claims 1 to 6, wherein some or all of the above steps (S3, S4, S5, S6, S7, S8, S9) are performed if a vibration and/or temperature sensor (34) detects a temperature above or below a temperature threshold.
- 5 8. Method according to any of the previous claims 1 to 7, wherein some or all of the above steps (S3, S4, S5, S6, S7, S8, S9) are initiated if the robotic cleaning device has been in an idle mode for a predetermined period of time.
9. Robotic cleaning device (10, 10') comprising:
- 10 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
15 an object;
a dead reckoning sensor (30, 30') operatively connected to the propulsion system;
an obstacle detecting device comprising a camera (23) and a first structured light source (27) arranged at a distance from each other on
20 the main body; and
a processing unit (16) arranged to control the propulsion system;
wherein the obstacle detecting device is arranged to position a landmark (36) relative to the robotic cleaning device by illuminating the landmark with structured light from the first structured light
25 source, wherein the processing unit is arranged to estimate a distance (DC) to the landmark based on a detected reflection of the structured light and subsequently moving the robotic cleaning device into contact with the landmark while measuring an actual distance (DA) to the landmark via the dead reckoning sensor, whereby the actual distance
30 is then compared with the distance for detection of a measurement error.

10. The robotic cleaning device according to claim 9, wherein the first structured light source (27) is arranged at an angle (α) in relation to a direction of view (V) of the camera of the robotic cleaning device.
- 5 11. The robotic cleaning device according to claim 9 or 10, wherein the processing unit is configured to measure and store the measurement errors from several measurements and wherein the processing unit detects if the measurement errors are consistent or not.
- 10 12. The robotic cleaning device according to claim 11, wherein the processing unit comprises a distance calculating algorithm with a parameter representing the angle and wherein the processing unit calibrates the parameter if it is detected that the measurement errors are consistent.
- 15 13. The robotic cleaning device according to any of the previous claims 9 to 12, comprising at least one vibration and/or temperature sensor (34), which is arranged in communication with the processing unit.
14. The robotic cleaning device according to any of the previous claims 9 to 13, wherein the processing unit (16) comprises a timer.
- 20 15. A computer program (25) comprising computer-executable instructions for causing a robotic cleaning device (10, 10') to perform the steps recited in any one of claims 1-8 when the computer-executable instructions are executed on a processing unit (16) included in the robotic cleaning device (10, 10').
- 25 16. 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 15 embodied therein.

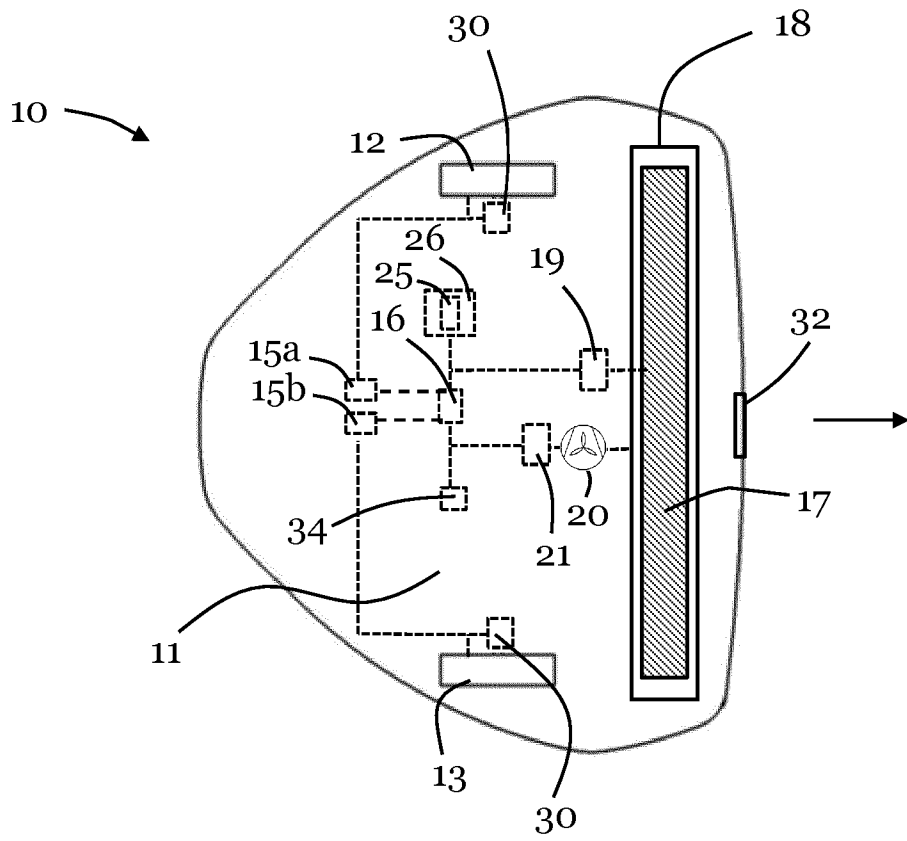


Figure 1

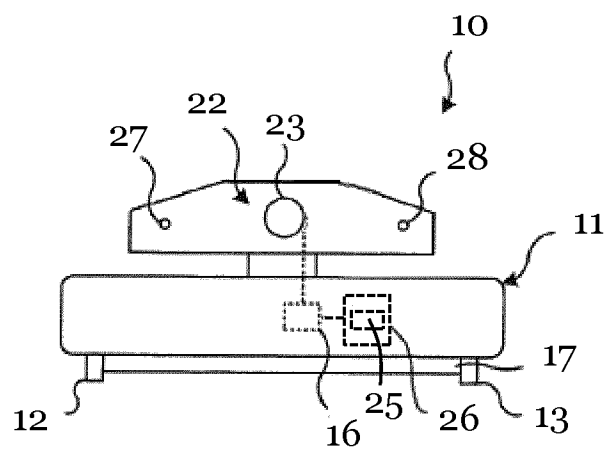


Figure 2

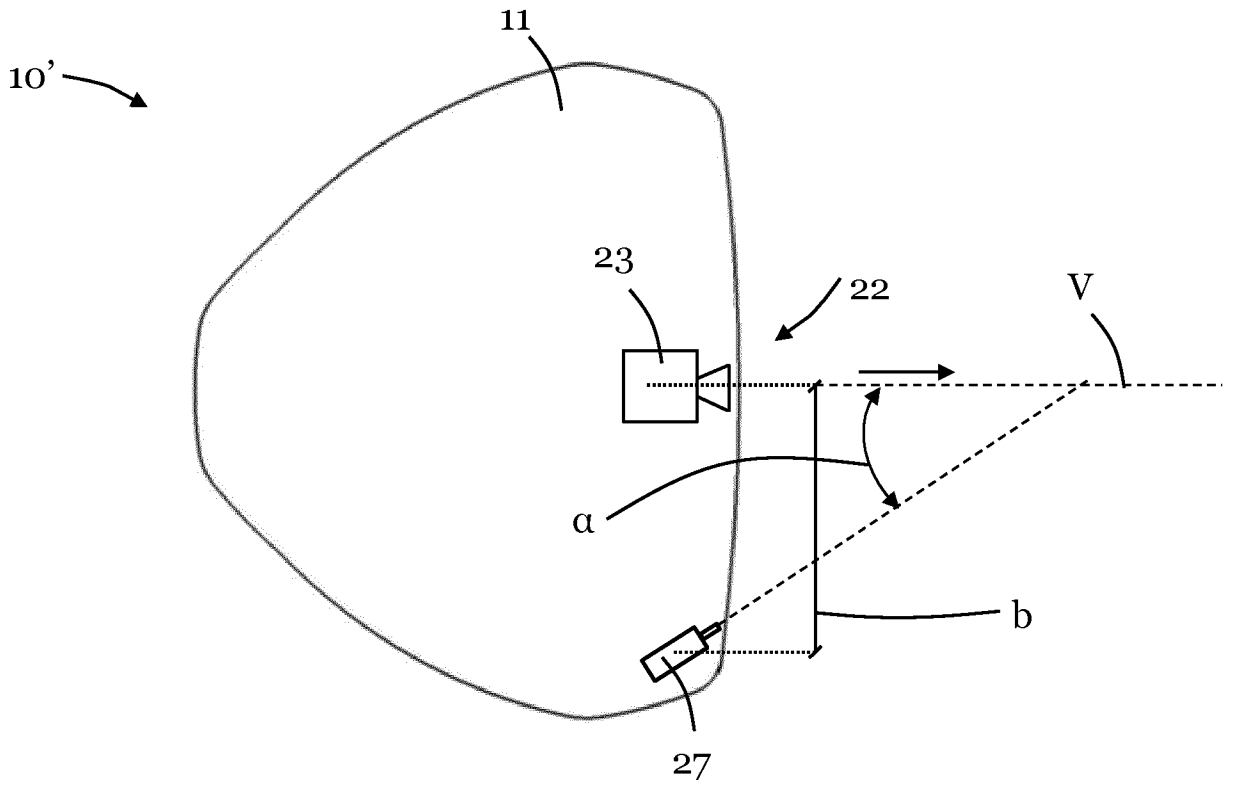


Figure 3

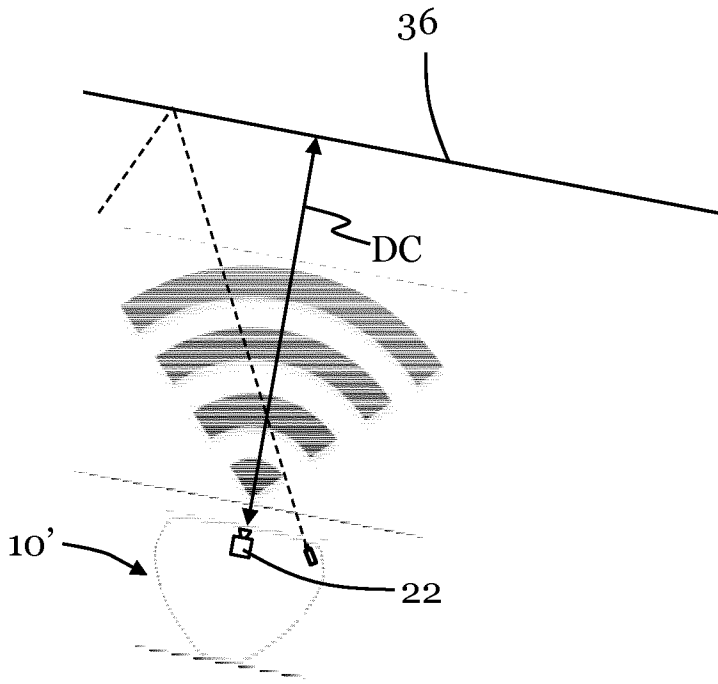


Figure 4

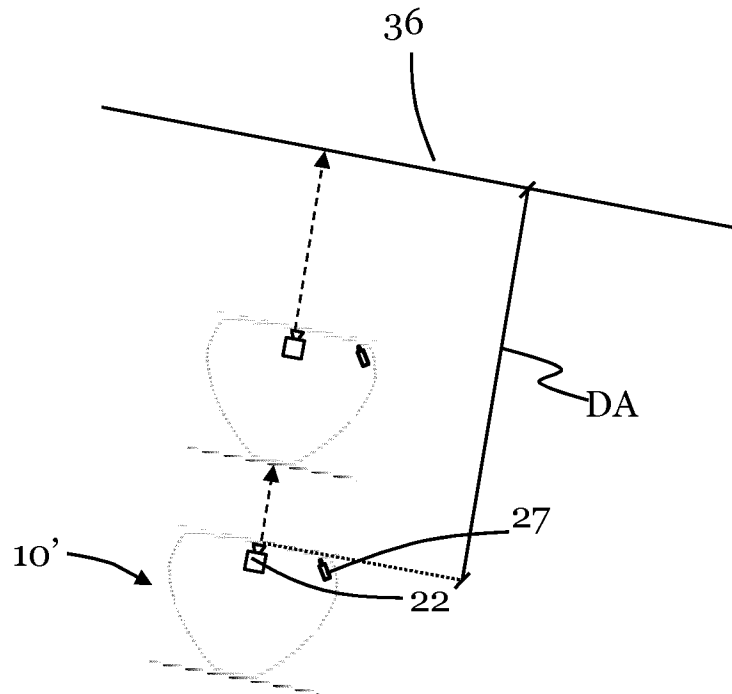


Figure 5

5/5

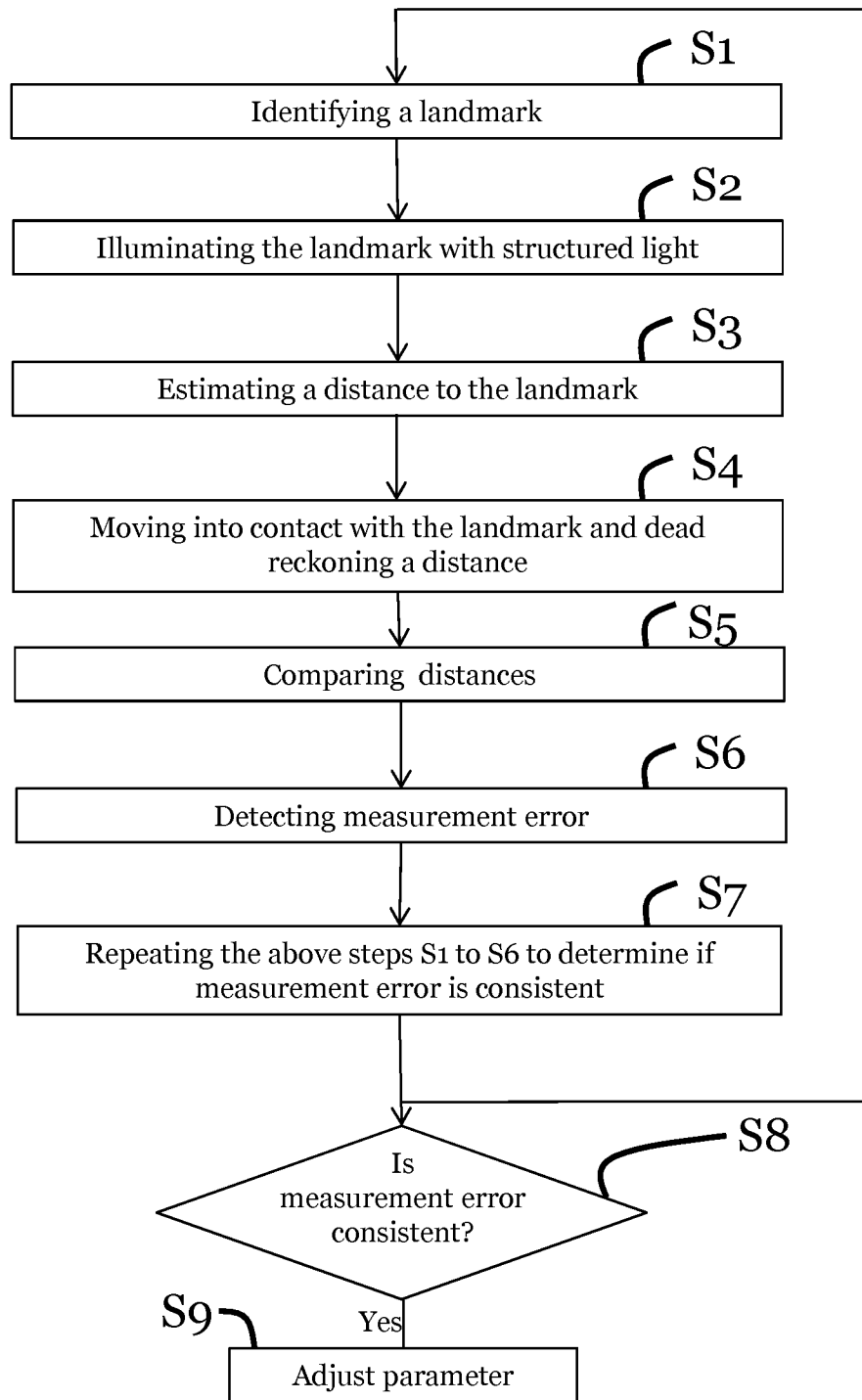


Figure 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/078144

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

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2006 231477 A (MITSUBISHI HEAVY IND LTD) 7 September 2006 (2006-09-07) the whole document	1-16
A	JP 2008 290184 A (FUJITSU LTD) 4 December 2008 (2008-12-04) the whole document	1-16

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
7 April 2015

Date of mailing of the international search report
15/04/2015

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
Pöllmann, H

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2014/078144

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2006231477 A	07-09-2006	NONE	

JP 2008290184 A	04-12-2008	JP 4811347 B2	09-11-2011
		JP 2008290184 A	04-12-2008
