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(54) Title: CLEANING DEVICE

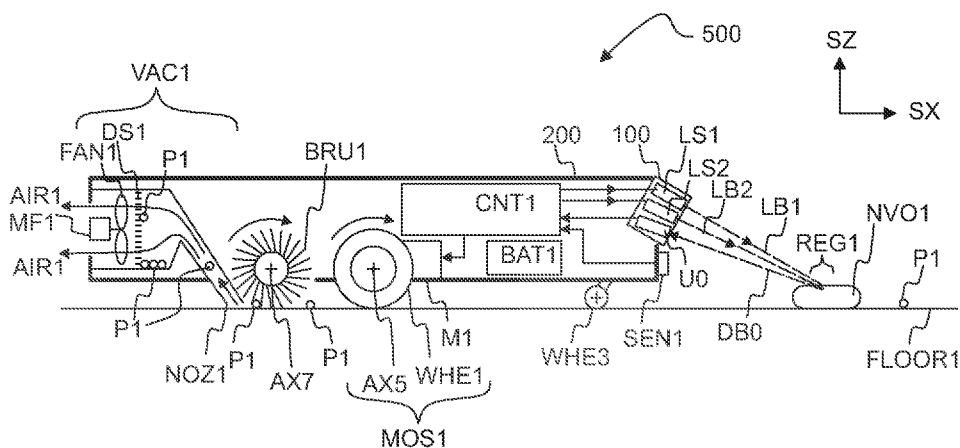


Fig. 1

(57) Abstract: An autonomous cleaning device (500), comprises:- a vacuum unit (VAC1) to remove dust particles (P1) from a floor (FLOOR1),- a motive system (MOS1) to move the cleaning device (500) on the floor (FLOOR1),- a control system (SYS1) to control movements of the cleaning device (500) based on signals obtained from one or more sensors (SEN1, 100), wherein the cleaning device (500) comprises an optical presence sensor (100) for detecting the presence of a non-vacuumable object (NVO1), the optical presence sensor (100) comprising:- a first light source (LS1) to illuminate a surveillance region (REG1) with first illuminating light (LB1), which has a first wavelength (λ_1),- a second light source (LS2) to illuminate the surveillance region (REG1) with second illuminating light (LB2), which has a second wavelength (λ_2),- one or more detectors (DET0) to gather reflected light (RL1, RL2) from the surveillance region (REG1), wherein the cleaning device (500) is arranged to form a first detector signal value (S_{DET1}) indicative of spectral intensity of gathered reflected light (RL1) at the first wavelength

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(λ_1), and to form a second detector signal value (S_{DET2}) indicative of spectral intensity of gathered reflected light (RL2) at the second-wavelength (λ_2), wherein the cleaning device (500) is arranged to determine based on the first detector signal value (S_{DET1}) and based on the second detector signal value (S_{DET2}) whether a non-vacuumable object (NVO1) is present in the surveillance region (REG1), wherein the first wavelength (λ_1) is within an optical absorption band of liquid water.

CLEANING DEVICE

FIELD

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Some embodiments relate to an autonomous cleaning device.

BACKGROUND

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An autonomous cleaning robot may comprise a brush and a suction unit to remove dust and debris from a floor. The cleaning robot is typically arranged to operate unsupervised, i.e. so that a human person does not continuously watch the cleaning robot during the operation. The cleaning robot can remove
15 dry small particles from the floor.

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Certain objects may be classified as non-vacuumable objects (NVO1). A non-vacuumable object is likely to cause problems in a situation where the cleaning robot attempts to remove the non-vacuumable object. For example, a piece of
dog feces (i.e. dog poop) may be classified as a non-vacuumable object. An attempt to use a cleaning robot to remove the non-vacuumable object from a floor is likely to cause contamination of the floor and/or contamination of the cleaning robot. A contamination due to microbes of the non-vacuumable object may be so severe that the cleaning robot needs to be replaced with a new one.

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An attempt to use a cleaning robot to remove a non-vacuumable object from a floor may also cause malfunction of the brush and/or the suction unit of the cleaning robot.

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It is known to use a combination of a camera and image recognition to identify obstacles in front of a cleaning robot.

SUMMARY

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An object is to provide an autonomous cleaning device. An object is to provide a method for cleaning.

According to an aspect, there is provided an autonomous cleaning device (500), comprising:

- a vacuum unit (VAC1) to remove dust particles (P1) from a floor (FLOOR1),
- a motive system (MOS1) to move the cleaning device (500) on the floor (FLOOR1),
- a control system (SYS1) to control movements of the cleaning device (500) based on signals obtained from one or more sensors (SEN1,100),

wherein the cleaning device (500) comprises an optical presence sensor (100) for detecting the presence of a non-vacuumable object (NVO1), the optical presence sensor (100) comprising:

- a first light source (LS1) to illuminate a surveillance region (REG1) with first illuminating light (LB1), which has a first wavelength (λ_1),
- a second light source (LS2) to illuminate the surveillance region (REG1) with second illuminating light (LB2), which has a second wavelength (λ_2),
- one or more detectors (DET0) to gather reflected light (RL1, RL2) from the surveillance region (REG1),

wherein the cleaning device (500) is arranged to form a first detector signal value (S_{DET1}) indicative of spectral intensity of gathered reflected light (RL1) at the first wavelength (λ_1), and to form a second detector signal value (S_{DET2}) indicative of spectral intensity of gathered reflected light (RL2) at the second wavelength (λ_2),

wherein the cleaning device (500) is arranged to determine based on the first detector signal value (S_{DET1}) and based on the second detector signal value (S_{DET2}) whether a non-vacuumable object (NVO1) is present in the surveillance region (REG1), wherein the first wavelength (λ_1) is within an optical absorption band of liquid water.

According to an aspect, there is provided a cleaning device according to claim 1.

Further embodiments are defined in the other claims.

The scope of protection sought for various embodiments of the invention is set out by the independent claims. The embodiments, if any, described in this specification that do not fall under the scope of the independent claims are to be interpreted as examples useful for understanding various embodiments of the invention.

The autonomous cleaning device may also be called e.g. as a cleaning robot.

The autonomous cleaning device comprises at least one presence sensor to detect the presence of a non-vacuumable object. The non-vacuumable object may be e.g. a piece of animal feces. The presence sensor may be capable of detecting animal feces in front of the cleaning device. A combined surveillance region of the presence sensor may advantageously cover at least the width of the cleaning device. One or more surveillance regions may together cover the total width of the cleaning sector of the cleaning device. Thus, the control system of the cleaning device may detect and identify a non-vacuumable object, and the control system may effectively avoid a collision with the non-vacuumable object, in an instance in which the non-vacuumable object is determined to overlap any surveillance regions of the cleaning device.

The cleaning device may be arranged to provide two infrared light beams to illuminate a region in front of the cleaning device.

The wavelength of the first illuminating infrared light beam may be selected such that the light of the first illuminating infrared light beam is highly absorbed by liquid water. The wavelength (λ_1) of the first illuminating infrared light beam may be e.g. in the range of 1400 nm to 1500 nm, advantageously in the range of 1430 nm to 1470 nm, and preferably in the range of 1440 nm to 1460 nm. The wavelength of the first illuminating infrared light beam may be e.g. substantially equal to 1450 nm.

The wavelength of the second illuminating infrared light beam may be selected such that the light of the second illuminating infrared light beam is not highly absorbed by liquid water. The wavelength of the second illuminating infrared light beam may be e.g. 980 nm or 1100 nm.

5 The presence sensor may be arranged to provide at least two beams of infrared light to illuminate a surveillance region. The presence sensor may comprise one or more detectors to detect infrared light reflected from the illuminated surveillance region. The presence sensor may comprise e.g. two light sources and a non-imaging detector unit.

10 The presence sensor may be produced at low production costs. The size of the presence sensor may be small in order to facilitate mounting of the presence sensor to the cleaning device.

15 In an embodiment, the cleaning device may be arranged to provide at least two highly divergent beams of infrared radiation, to illuminate several adjacent surveillance regions. A first illuminating beam may have a first wavelength, and a second illuminating beam may have a second wavelength. The first wavelength may be selected such that light of the first illuminating beam is highly absorbed by water. The second wavelength may be selected such that
20 light of the second illuminating beam is not highly absorbed by water. A non-vacuumable object may overlap a surveillance region such that the non-vacuumable object may reflect light of the first illuminating light beam, and the non-vacuumable object may reflect light of the second illuminating light beam. The cleaning device may provide a first detector signal indicative of spectral
25 intensity of reflected light at the first wavelength, and to provide a second detector signal indicative of spectral intensity of reflected light at the second wavelength. The cleaning device may determine the presence of the non-vacuumable object based on the detector signals.

30 The cleaning device may comprise a plurality of detectors, which may be positioned e.g. along the front perimeter of the cleaning device, so as to provide a wide combined surveillance region. The cleaning device may comprise optics to limit the field of view of each detector, so as to prevent light reflected from outside of the surveillance region of said detector from
35 propagating to said detector.

The surveillance region of a first detector unit may partly overlap with an adjacent surveillance region of a second detector unit. A series of detectors may be used along a front bumper of the cleaning device to detect reflected light from the surveillance regions. Each detector unit may have e.g. an optical aperture to prevent infrared light from outside of the viewing sector of the detector from reaching the detector element. The viewing sectors of the detectors may partly overlap.

The detector signals may be used for detecting the presence of a non-vacuatable object in front of the cleaning device. A control unit of the cleaning device may be arranged to determine an evasive action in response to the detected presence of the non-vacuatable object. The control unit may be arranged to provide a control signal to one or more driving motors of the cleaning device, so as to execute the evasive action. For example, the control unit may be arranged to cause the cleaning device to stop, to turn, or to move in a reverse direction in order to avoid collision with the detected non-vacuatable object.

Several detectors may be arranged to provide several surveillance regions. The several surveillance regions may together form a combined surveillance region, which may cover at least the width of the cleaning region of the cleaning device. The cleaning region may mean the floor area, which is cleaned by the cleaning device during a single forward movement of the cleaning device.

In an embodiment, an illuminating unit of the cleaning device may comprise beam forming optics to provide a desired vertical divergence and to provide a desired horizontal divergence. The beam forming optics may comprise e.g. reflective and/or refractive optical components. The optics may comprise e.g. a Fresnel lens to a desired vertical divergence and to provide a desired horizontal divergence. The horizontal divergence of the illuminating beam may be greater than the vertical divergence, so as to provide sufficient intensity to a wide surveillance area.

A set of detectors, for example three detectors, may be arranged to detect light reflected from the surveillance regions, which are provided in front of the cleaning device. The surveillance regions of different detectors may partly

overlap in order to provide a continuous combined surveillance area. Each detector may produce a detector signal, which is indicative of the intensity of light reflected from the surveillance region.

- 5 The illuminating light may be modulated, and the operation of the detector may be e.g. synchronized with the modulation. The modulation may improve signal-to-noise ratio of the detector signal.

10 In an embodiment, the same detector may be arranged to detect reflected light at the first wavelength and to detect reflected light at the second wavelength. The detector may provide a primary detector signal, which is indicative of the instantaneous intensity of reflected light received by the detector. The first illuminating light beam and the second illuminating light beam may be modulated. The modulation of the first illuminating light beam may be e.g.
15 synchronized with the modulation of the second illuminating light beam. The sensor may be arranged to form a first detector signal value and a second detector signal value by demodulation from the primary detector signal.

20 The presence of a non-vacuatable object may be detected based on a ratio of the first detector signal value to the second detector signal value. This simple detection scheme may provide sufficient reliability for detecting the presence of the non-vacuatable object.

25 The presence sensor of a single surveillance region may be very simple, e.g. in order to facilitate production of the sensor and/or in order reduce production costs of the sensor. For example, the presence sensor may comprise only two light sources and only one detector. The presence sensor may comprise a first light source for providing the first illuminating light at the first wavelength, and presence sensor may comprise a second light source for providing the second
30 illuminating light at the second wavelength. The first light source may comprise a first light emitting diode (LED) to emit light at the first wavelength. The second light source may comprise a second light emitting diode to emit light at the second wavelength. The spectral selectivity of the presence sensor may be based mainly on the spectral bandwidth of the first light emitter of the first light
35 source, and on the spectral bandwidth of the second light emitter of the second light source. An object overlapping the surveillance region may form first

reflected light by reflecting the first illuminating light, and the object may form second reflected light by reflecting the second illuminating light. The intensity of the first reflected light may be proportional to the spectral reflectance of the object at the first wavelength. The intensity of the second reflected light may be proportional to the spectral reflectance of the object at the second wavelength. The same detector may be arranged to detect light at the first wavelength and at the second wavelength. The detector may form a primary signal such that the primary signal comprises contribution of the first reflected light and contribution of the second reflected light. The first emitter and the second emitter may be modulated such that a first detector signal value indicative of intensity of first reflected light and a second detector signal value indicative of intensity of second reflected light may be formed from the primary signal by demodulation.

The presence of a non-vacuumable object (NVO1) may be determined by using the first detector signal value and by using the second detector signal value. The presence of a non-vacuumable object (NVO1) may be determined by comparing measured spectral data with reference spectral data. The measured spectral data may consist of only two spectral values represented by a value of the first detector signal and by a value of the second detector signal. For example, the method may comprise comparing the ratio of the detector signal values with a predetermined limit value. For example, a non-vacuumable object may be determined to be present when the ratio of the detector signal values is smaller than the predetermined limit value. For example, the non-vacuumable object may be determined to be not present when the ratio of the detector signal values is greater than the predetermined limit value, respectively.

The cleaning device may be arranged to perform an evasive action when a non-vacuumable object is determined to be present.

In an embodiment, the control system of the cleaning device may also be arranged to recognize a material of a floor surface and/or to recognize a material of an obstacle by comparing the detector signals with reference data. The control system may be arranged use the detector signals for forming a map of the operating environment of the cleaning device. The control system

may form the map by associating the detector signals with detected locations of the cleaning device.

5 In an embodiment, a surveillance region may be arranged to overlap with the height level of the floor, so as to enable detecting e.g. the presence of a layer of an aqueous substance on the floor. The aqueous substance may be e.g. urine from an animal.

10 In an embodiment, a control system of the cleaning device may be arranged to provide an indication of the detected non-vacuumable object to a user interface. The user interface may be implemented e.g. by an application running on a smartphone.

15 The presence sensors of the cleaning device may be non-imaging sensors. Consequently, the risk of transmitting confidential or private image information may be avoided.

BRIEF DESCRIPTION OF THE DRAWINGS

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In the following examples, several variations will be described in more detail with reference to the appended drawings, in which

25 Fig. 1 shows, by way of example, in a side view, a cleaning device,

Fig. 2 shows, by way of example, a presence sensor,

30 Fig. 3a shows, by way of example, in a top view, forming an illuminated region in front of the cleaning device,

Fig. 3b shows, by way of example, in a top view, surveillance regions of the cleaning device,

35 Fig. 4 shows, by way of example, timing of illuminating light pulses, forming sensor signals by detecting reflected light, and temporal evolution of a ratio of values of the sensor signals,

- Fig. 5 shows spectral transmittance of liquid water,
- Fig. 6 shows, by way of example, spectral reflectance of a dry floor, and
5 spectral reflectance of the floor when covered with a layer of water, and
- Fig. 7a shows, by way of example, spectral reflectance of animal feces,
- 10 Fig. 7b shows, by way of example, measured spectral data, which comprises a first detector signal value and a second detector signal value,
- Figs. 7c to 7f
15 show, by way of example, determining the presence of a non-vacuumable object by using a first detector signal value and a second detector signal value,
- Fig. 8 shows, by way of example, in a side view, a presence sensor,
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- Fig. 9 shows, by way of example, a control system of the cleaning device,
- Fig. 10a shows, by way of example, in a top view, surveillance regions of
25 the cleaning device,
- Fig. 10b shows, by way of example, in a top view, a cleaning region of the cleaning device,
- 30 Fig. 11 shows, by way of example, in a side view, a presence sensor
- Fig. 12a shows, by way of example, in a side view, a non-vacuumable object located in the surveillance region of the cleaning device,
- 35 Fig. 12b shows, by way of example, in a side view, a wall located in the surveillance region of the cleaning device,

Fig. 13a shows, by way of example, temporal evolution of a first detector signal and temporal evolution of a ratio of the detector signals during a movement where the cleaning device moves close to a non-vacuumable object,

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Fig. 13b shows, by way of example, temporal evolution of the first detector signal and temporal evolution of a ratio of the detector signals during a movement where the cleaning device moves close to a wall, and

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Fig. 14 shows, by way of example, method steps for determining whether a non-vacuumable object is present in the surveillance region.

15 DETAILED DESCRIPTION

Referring to Fig. 1, a cleaning device 500 may comprise a motive system MOS1 for moving the cleaning device 500 with respect to a floor FLOOR1.

20 The cleaning device 500 may comprise a brush BRU1 and/or a vacuum unit VAC1 for removing debris and dust particles P1 from the floor FLOOR1. The vacuum unit VAC1 may comprise a particle separator DS1 to separate and collect dust particles P1. The vacuum unit VAC1 may comprise a suction fan FAN1 to cause an air flow AIR1 through the separator DS1, wherein the
25 separator DS1 may be arranged to separate the debris and dust particles P1 from the air flow AIR1. The particle separator DS1 may comprise e.g. a particle filter and/or a cyclone. The fan FAN1 may be driven by a motor MF1. The brush BRU1 may be arranged to release debris and dust particles P1 from the floor FLOOR1, before the released debris and dust particles P1 are drawn into the
30 vacuum unit VAC1 by using the air flow AIR1. The brush BRU1 may rotate e.g. around an axis AX7.

The motive system MOS1 may comprise e.g. wheels WHE1, WHE1a, WHE1b, WHE3 or (endless) continuous tracks driven by one or more motors M1a, M1b.

35 A wheel WHE1a may rotate e.g. about an axis AX5. The motive system may be arranged to move the cleaning device in the forward direction (e.g. in the

direction SX). The motive system may be arranged to stop the cleaning device 500, to turn the cleaning device 500 and/or move the cleaning device 500 backwards (e.g. in the direction -SX), in a situation where the control unit CNT1 detects the presence of a non-vacuumable object NVO1 based on detector signals obtained from a detector unit U0.

The cleaning device 500 may comprise a presence sensor 100. The presence sensor 100 may comprise a first light source LS1 to form a first illuminating light beam LB1 at a first wavelength λ_1 . The presence sensor 100 may comprise a second light source LS2 to form a second illuminating light beam LB2 at a second wavelength λ_2 . The presence sensor 100 may comprise one or more detector units U0 to gather and detect light reflected from a surveillance region REG1 of the cleaning device 500. The surveillance region REG1 may also be called e.g. as a region of interest.

The first wavelength λ_1 of the first illuminating light beam LB1 may be selected such that the light of the first illuminating light beam LB1 is highly absorbed by liquid water. The first wavelength λ_1 may be e.g. in the range of 1400 nm to 1500 nm, advantageously in the range of 1430 nm to 1470 nm, and preferably in the range of 1440 nm to 1460 nm. The first wavelength λ_1 may be e.g. substantially equal to 1450 nm.

The spectral bandwidth of the first illuminating light beam LB1 may be e.g. smaller than 50 nm. The maximum spectral intensity of the first illuminating light beam LB1 may be at the first wavelength λ_1 . The second illuminating light beam LB2 may have a maximum spectral intensity at the second wavelength λ_2 .

The first light source LS1 may be arranged to operate such that the spectral intensity of the first illuminating light beam LB1 at the second wavelength λ_2 may be low or zero. For example, the spectral intensity of the first illuminating light beam LB1 at the second wavelength λ_2 may be smaller than 1% of the maximum spectral intensity of the first illuminating light beam LB1 at the first wavelength λ_1 , when measured at the same point in the surveillance region REG1.

The second wavelength λ_2 of the second illuminating light beam LB2 may be selected such that the light of the second illuminating light beam is not highly absorbed by liquid water. The wavelength λ_2 may be e.g. in the range of 980 nm or 1100 nm. The wavelength λ_2 may be e.g. 980 nm or 1100 nm.

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The second light source LS2 may be arranged to operate such that the spectral intensity of the second illuminating light beam LB2 at the first wavelength λ_1 may be low or zero. The spectral intensity of the second illuminating light beam LB2 at the first wavelength λ_1 may be e.g. smaller than 1% of the maximum spectral intensity of the second illuminating light beam LB2 at the second wavelength λ_2 , when measured at the same point in the surveillance region REG1.

The cleaning device 500 may comprise a control unit CNT1 for controlling operation of the cleaning device 500. The control unit CNT1 may control operation of the cleaning device 500 based on one or more signals obtained from sensors SEN1, 100. The cleaning device 500 may comprise a battery BAT1 for providing operating energy for the motive system MOS1, for the vacuum unit VAC1 and/or for the control unit CNT1.

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The cleaning device 500 may comprise a housing 200. The orientation of the sensor 100 may be fixed with respect to the housing 200. The orientation of the parts of the sensor 100 may be fixed with respect to the housing 200. The detectors of the sensor 100 do not need to perform a mechanical (scanning) movement with respect to the housing 200.

SX, SY and SZ denote orthogonal directions. The floor FLOOR1 may be in a plane defined by the directions SX and SY. The cleaning device 500 may move e.g. in the direction SX immediately before detecting the presence of a non-vacuumable object NVO1.

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Referring to Fig. 2, the cleaning device 500 may comprise one or more presence sensors 100 for detecting the presence of a non-vacuumable object NVO1 in a surveillance region REG1 of a sensor 100. The cleaning device 500 may be arranged to determine whether an object (NVO1,O2) detected in the surveillance region REG1 is a non-vacuumable object NVO1 or not. The

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control system SYS1 of the cleaning device 500 may be arranged to determine whether an object detected in the surveillance region REG1 is a non-vacuumable object NVO1 or not, based on detector signals obtained from the presence sensor 100. The cleaning device 500 may be arranged to classify an object detected in the surveillance region REG1 as a non-vacuumable object NVO1 or as a harmless object O2 (see Fig. 3a).

The non-vacuumable object NVO1 may be e.g. a piece of animal feces (e.g. dog poop). The non-vacuumable object NVO1 may also be e.g. a piece of food. The non-vacuumable object NVO1 comprises soft contaminating material, which has a high relative fraction of water. An attempt to use the cleaning device 500 for removing the non-vacuumable object NVO1 from the floor FLOOR1 is likely to cause contamination of the floor FLOOR1 and/or contamination of the cleaning device 500. For example, the non-vacuumable object NVO1 may clog the brush BRU1 and/or the vacuum unit VAC1. The non-vacuumable object NVO1 may also comprise microbes, which may biologically contaminate the cleaning device 500.

The harmless object O2 is an object, which does not cause contamination of the floor FLOOR1 and/or the cleaning device 500, in a situation where the cleaning device 500 collides with the harmless object. The harmless object O2 may be e.g. a piece of furniture, a shoe, or a toy.

The optical presence sensor 100 may be arranged to provide a first illuminating light beam LB1 at a first wavelength λ_1 , and to provide a second illuminating light beam LB2 at a second wavelength λ_2 . An object (NVO1) located in a surveillance region REG1 of the optical presence sensor 100 may reflect light (RL1,RL2) at the first wavelength λ_1 and at the second wavelength λ_2 . The optical presence sensor 100 may be arranged to detect the reflected light RL1 at the first wavelength λ_1 and to detect deflected light RL2 at the second wavelength λ_2 .

The presence sensor 100 comprises a first light source LS1 to provide first illuminating light LB1 at a first wavelength λ_1 . The presence sensor 100 comprises a second light source LS2 to provide second illuminating light LB2

at a second wavelength λ_2 . The light sources LS1, LS2 may be arranged to form an illuminated region ZONE1, which is illuminated with the light LB1, LB2. The light source LS1 may comprise a light emitter LED1 to emit light, and optics LNS1 to form an illuminating light beam LB1 from the emitted light. The
5 light source LS2 may comprise a light emitter LED2 to emit light, and optics LNS2 to form an illuminating light beam LB2 from the emitted light. The emitter LED1, LED2 may be e.g. a light emitting diode or a laser diode.

An object (NVO1,O2) may form first reflected light RL1 by reflecting the first
10 illuminating light LB1, and the object (NVO1,O2) may form second reflected light by reflecting the second illuminating light LB2. The presence sensor 100 may comprise at least one detector unit U0 for detecting the reflected light RL1, RL2. The detector unit U0 may be arranged to detect light only from a spatially defined detection region DB0.

15 The spatially defined detection region DB0 may be called e.g. as a detection beam DB0 of the detector unit U0. The detector unit U0 may comprise e.g. one or more lenses LNS0 and/or optical apertures to define the detection region DB0 by limiting the field of view of the detector unit.

20 The detector unit U0 unit may comprise a detector element DET0. The detector element DET0 may be a photodetector. The photodetector DET0 may be e.g. a photodiode or a phototransistor. The photodetector DET0 may be e.g. indium gallium arsenide photodiode or a germanium photodiode. The photodetector
25 may provide a detector signal S_{DET0} by detecting the reflected light RL1, RL2.

The light sources LS1, LS2 and the detector unit U0 may together define a surveillance region REG1 of the sensor 100. The surveillance region REG1 may mean the common spatial region where the illuminating light beam LB1
30 overlaps the detection beam DB0.

The cleaning device 500 may comprise one or more detector units U0. The one or more detector units U0 may define one or more surveillance regions REG1 together with the illuminating units LS1, LS2.

The first illuminating beam LB1 may have a central axis AX1. The second illuminating beam may have a central axis SX2. The detection beam DB0 may have a central axis AX0. The axis AX0, AX1, and AX2 may pass through the surveillance region REG1. The axis AX0 may intersect the axis AX1 and/or the axis AX2 in the surveillance region REG1. In particular, the axis AX0 may intersect the axis AX1 and the axis AX2 at the same common point in the surveillance region REG1.

The detector unit U0 may be arranged to detect the first reflected light RL1 and the second reflected light RL2 selectively only from the surveillance region REG1, and only when a reflecting object (e.g. NVO1,O2) overlaps said surveillance region REG1.

The cleaning device 500 may comprise a control system SYS1. The control system SYS1 may comprise a control unit CNT1. The control system SYS1 may be arranged to control operation of the motive system MOS1 based on detector signals (S_{DET0}) obtained from one or more detector units (U0). The control system SYS1 may comprise a memory MEM1 for storing program code PROG1. The program code PROG1, when executed by the control unit CNT1, may cause the cleaning device 500 to detect the presence of a non-vacuumable object (NVO1), and to control movements of the cleaning device 500 in a situation where the presence of a non-vacuumable object (NVO1) is detected. The control system SYS1 may comprise a memory MEM2 for storing operating parameters PAR1. The operating parameters PAR1 may comprise e.g. a limit value LIM1 for determining the presence of a non-vacuumable object (NVO1).

The control unit CNT1 of the cleaning device 500 may be arranged to provide a control signal S_{LED1} for controlling operation of the first light source LS1. The control unit CNT1 may provide a control signal S_{LED2} for controlling operation of the second light source LS2. The control signal S_{LED1} may e.g. control timing and/or modulation frequency of illuminating light pulses LB1 emitted from the emitter LED1 of the first light source LS1. The control signal S_{LED2} may e.g. control timing and/or modulation frequency of illuminating light pulses LB2 emitted from the emitter LED2 of the second light source LS2.

The control unit CNT1 may provide one or more control signals S_{M1a} , S_{M1b} for controlling operation of one or more motors M1a, M1b of the motive system MOS1.

- 5 Referring to Figs. 3a and 3b, the cleaning device 500 may comprise one or more detector units U0a, U0b, U0c. The detector units U0a, U0b, U0c. may define one or more surveillance regions REG1a, REG1b, REG1c together with the illuminating units LS1, LS2. The symbol U0a may denote a detector unit U0 of the first surveillance region REG1a. The symbol U0b may denote a
 10 detector unit U0 of the second surveillance region REG1b. The symbol U0c may denote a detector unit U0 of the third surveillance region REG1c.

- The one or more surveillance regions REG1a, REG1b, REG1c may together form a combined surveillance region, wherein the width w_{TOT} of the combined
 15 surveillance region may be greater than the width w_{500} of the cleaning device 500. The one or more presence sensors 100a, 100b, 100c of the cleaning device 500 may be arranged to operate such that the total width w_{TOT} of the surveillance region of the cleaning device 500 is greater than or equal to the width w_{500} of the cleaning device 500. Consequently, the cleaning device 500
 20 may be arranged to avoid a collision with the non-vacuumable object NVO1, in a situation where the cleaning device 500 is moving in the forward direction (e.g. in the direction SX).

- The cleaning device 500 may comprise one or more first light first sources LS1
 25 to illuminate the region ZONE1 in front of the cleaning device 500 with first illuminating light LB1 at the first wavelength λ_1 . The cleaning device 500 may comprise one or more second light first sources LS2 to illuminate the region ZONE1 with second illuminating light LB2 at the second wavelength λ_2 .

- 30 The first light source LS1 may be arranged to form a first illuminating light beam LB1, which has a large horizontal divergence $\Delta\theta_H$. The horizontal divergence $\Delta\theta_H$ may be selected e.g. such that the illuminated region ZONE1 is wider than the cleaning device. The second light source LS2 may be arranged to provide a second illuminating light beam LB2, which also has a large horizontal
 35 divergence, so as to illuminate the entire region ZONE1.

The cleaning device 500 may comprise one or more detector units U0a, U0b, U0c to detect reflected light RL1, RL2. The field of view of a first detector unit U0a may define a first surveillance region REG1a together with the illuminating light beams LB1, LB2. The field of view of a second detector unit U0b may
5 define a second surveillance region REG1b. The field of view of a third detector unit U0c may define a third surveillance region REG1c. The surveillance regions REG1a, REG1b, REG1c are portions of the illuminated region ZONE1.

The light sources LS1, LS2 and the detector units U0a, U0b, U0c may be
10 arranged to operate such that the one or more surveillance regions REG1a, REG1b, REG1c of the cleaning device 500 may together form a combined surveillance region, which is wider than the cleaning device 500. w_{TOT} denotes the width of the combined surveillance region. w_{500} denotes the width of the cleaning device 500. The width w_{TOT} may be greater than the width w_{500} .
15 Consequently, the cleaning device 500 equipped with the sensor 100 may be arranged to detect and identify a non-vacuumable object NVO1 when the non-vacuumable object NVO1 overlaps any of the surveillance regions REG1a, REG1b, REG1c. Consequently, the cleaning device 500 may be arranged to avoid collision with the detected non-vacuumable object NVO1.

20 Each detector unit U0a, U0b, U0c may comprise a photodetector DET0. The first detector unit U0a may comprise a first photodetector (DET0) to detect light (RL1, RL2) reflected from the first surveillance region REG1a. The second detector unit U0b may comprise a second photodetector (DET0) to detect light
25 (RL1, RL2) reflected from the second surveillance region REG1b. The third detector unit U0c may comprise a third photodetector (DET0) to detect light (RL1, RL2) reflected from the third surveillance region REG1c. Each detector unit U0a, U0b, U0c may provide a (primary) detector signal (S_{DET0}) by detecting the reflected light (RL1, RL2). The first light source LS1 may provide first
30 illuminating light LB1 to the surveillance regions REG1a, REG1b, REG1c. The second light source LS2 may provide second illuminating light LB2 to the surveillance regions REG1a, REG1b, REG1c.

The cleaning device 500 may be optionally arranged to move close to a safe
35 object O2, e.g. in order to accurately measure the position of the safe object O2 with an auxiliary sensor SEN1. The cleaning device 500 may be optionally

arranged to allow a collision with the object O2, e.g. in order to accurately measure the position of the safe object O2 with an auxiliary sensor SEN1. The auxiliary sensor SEN1 may be e.g. an optical proximity sensor or a mechanical contact sensor. Information about the detected position and/or the determined
5 type of a detected object may be optionally updated to a map MAP1.

The cleaning device 500 may comprise one or more presence sensors 100. Each presence sensor 100 may have a surveillance region REG1a, REG1b, REG1c. In an embodiment, a first presence sensor 100 may comprise two or
10 more light sources (LS1, LS2) to provide illuminating light (LB1, LB2) to a first surveillance region REG1a, and one or more detector units (U0a) to detect light (RL1, RL2) reflected from the first surveillance region REG1a. A second presence sensor 100 may comprise two or more additional light sources (LS1, LS2) to provide illuminating light (LB1, LB2) to a second surveillance region
15 REG1b, and one or more additional detector units (U0b) to detect light (RL1, RL2) reflected from the second surveillance region REG1b.

The costs for providing an illuminating unit LS1 may be higher than the costs for providing a detector unit (U0a). The cleaning device 500 may be
20 implemented so that two or more detector units (U0a, U0b, U0c) utilize light (LB1) of the same illuminating unit (LS1), so as to reduce total costs for producing a presence sensor 100. The cleaning device 500 may comprise a first detector unit U0a to form a first surveillance region REG1a, and a second detector unit U0b to form a second surveillance region REG1b. The first light
25 source LS1 may be arranged to illuminate the first surveillance region REG1a and the second surveillance region REG1b with the first illuminating light LB1, which has the first wavelength λ_1 . The second light source LS2 may be arranged to illuminate the first surveillance region REG1a and the second surveillance region REG1b with the second illuminating light LB2, which has
30 the second wavelength λ_2 .

The cleaning device 500 may comprise a first detector unit U0a to form a first surveillance region REG1a, a second detector unit U0b to form a second surveillance region REG1b, and a third detector unit U0c to form a third
35 surveillance region REG1c. The first light source LS1 may be arranged to illuminate the surveillance regions REG1a, REG1b, REG1c with the first

illuminating light LB1. The second light source LS2 may be arranged to illuminate the surveillance regions REG1a, REG1b, REG1c with the second illuminating light LB2.

- 5 Fig. 4 shows, by way of example, obtaining a first detector signal value S_{DET1} and a second detector signal value S_{DET2} , and determining the ratio of the detector signal values. The symbol S_{DET1} may refer to the first detector signal and/or to a value of the first detector signal. The symbol S_{DET2} may refer to the second detector signal and/or to a value of the second detector signal.

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- The values of the first detector signal S_{DET1} may be indicative of spectral reflectance of an object at the first wavelength λ_1 , in a situation where the object overlaps the surveillance region REG1. The values of the second detector signal S_{DET2} may be indicative of spectral reflectance of the object at the second wavelength λ_2 . The presence of a non-vacuatable object NVO1 in the surveillance region REG1 may be detected by comparing a first detector signal value S_{DET1} with a second detector signal value S_{DET2} . For example, the presence of a non-vacuatable object NVO1 may be detected by comparing the ratio (S_{DET1}/S_{DET2}) of the detector signal values with a limit value LIM1. The limit value LIM1 may be a predetermined limit value, or the value LIM1 may be adaptively selected e.g. based on a typical spectral reflectance of floor material and safe objects in the operating environment of the cleaning device 500.

- 25 The method may comprise determining whether a non-vacuatable object NVO1 is present or not, based on the ratio (S_{DET1}/S_{DET2}) of the detector signal values. The method may comprise determining that a non-vacuatable object NVO1 is present in a situation where the ratio (S_{DET1}/S_{DET2}) is smaller than the limit value LIM1. The method may comprise determining that a non-vacuatable object NVO1 is not present in a situation where the ratio (S_{DET1}/S_{DET2}) is greater than the limit value LIM1.

- 35 The uppermost curve of Fig. 4 shows, by way of example light pulses of modulated illuminating light LB1. The second curve from the top of Fig. 4 shows, by way of example, light pulses of modulated second light LB2. The first light pulses LB1 have the first wavelength λ_1 . The second light pulses LB2 have the second wavelength λ_2 . The rising edge of the light pulses LB1 may

coincide with times $t_{1,1}$, $t_{2,1}$, $t_{3,1}$, ... The rising edge of the light pulses LB2 may coincide with times $t_{1,2}$, $t_{2,2}$, $t_{3,2}$, ... The light pulses LB1 may have a maximum intensity I_{MAX1} . The light pulses LB2 may have a maximum intensity I_{MAX2} .

- 5 The third curve from the top of Fig. 4 shows, by way of example, temporal evolution of intensity of reflected light, as detected by a detector unit. The same detector unit (U0) may be arranged to detect reflected light RL1, RL2 at the first wavelength λ_1 and at the second wavelength λ_2 . The detector unit (U0) may provide a primary detector signal S_{DET0} , which may comprise information
 10 about the intensity of reflected light RL1 at the first wavelength λ_1 , and which may comprise information about the intensity of reflected light RL2 at the second wavelength λ_2 . For example, the presence of a non-vacuumable object NVO1 in the surveillance region REG1 after the time $t_{3,1}$ may cause a change of the signal values.

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Referring to the fourth curve from the top of Fig. 4, the first detector signal S_{DET1} may be formed from the primary detector signal S_{DET0} by demodulation. Referring to the fifth curve from the top of Fig. 4, the second detector signal S_{DET2} may be formed from the primary detector signal S_{DET0} by demodulation.
 20 The first detector signal S_{DET1} may have a maximum value S_{MAX1} . The second detector signal S_{DET2} may have a maximum value S_{MAX2} .

- Referring to the lowermost curve of Fig. 4, the method may comprise calculating a ratio ($K=S_{DET1}/S_{DET2}$) of the detector signal values. The method
 25 may comprise determining the type of an object by comparing the ratio (S_{DET1}/S_{DET2}) with a limit value LIM1. When the ratio (S_{DET1}/S_{DET2}) is smaller than the limit value LIM1, this may be an indication of the presence of a non-vacuumable object NVO1 in the surveillance region REG1. For example, the value K_{FLOOR1} may denote the ratio S_{DET1}/S_{DET2} for normal dry floor FLOOR1.
 30 For example, the value K_{NVO1} may denote the ratio S_{DET1}/S_{DET2} for a non-vacuumable object NVO1 (e.g. animal feces).

- The illuminating light beams LB1, LB2 may be modulated such that the separate detector signals S_{DET1} , S_{DET2} may be formed from the primary signal
 35 S_{DET0} by demodulation. The illuminating light beams LB1, LB2 may be modulated e.g. at the same pulse frequency but with a phase difference so as

to allow forming the detector signals S_{DET1} , S_{DET2} from the primary signal S_{DET0} by time division demultiplexing. The illuminating light beam LB1 may be modulated at a first frequency, and the illuminating light beam LB2 may be modulated at a second different frequency, so as to allow forming the detector signals S_{DET1} , S_{DET2} from the primary signal S_{DET0} by band pass filtering.

The illuminating light beams LB1, LB2 may be modulated e.g. sinusoidally or by forming light pulses. The detector signals S_{DET1} , S_{DET2} may be formed from the primary signal S_{DET0} e.g. by lock-in demodulation.

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The floor FLOOR1 may sometimes be covered with a layer of water or a layer of another aqueous substance. The ratio ($S_{\text{DET1}}/S_{\text{DET2}}$) of the detector signal values may be very low in a situation where the surveillance region REG1 overlaps with a layer of water. A small value of the ratio ($S_{\text{DET1}}/S_{\text{DET2}}$) may be an indication of the presence of a water layer. LIM2 may denote a reference value for detecting a layer of aqueous substance. The device 500 may be arranged to determine the presence of a layer of an aqueous substance by comparing the ratio ($S_{\text{DET1}}/S_{\text{DET2}}$) with the reference value LIM2. The device 500 may be arranged to determine that a layer of an aqueous substance is present if the ratio ($S_{\text{DET1}}/S_{\text{DET2}}$) is smaller than the reference value LIM2.

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In an embodiment, the signal values of both detector signals S_{DET1} , S_{DET2} may be substantially equal to zero in a situation where the surveillance region REG1 does not overlap any object (NVO1, O2, O3) or the floor (FLOOR1). The cleaning device 500 may be arranged to determine that no object is present in the surveillance region in a situation where both detector signals S_{DET1} , S_{DET2} are substantially equal to zero.

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Fig. 5 shows spectral transmittance ($I_T(\lambda)/I_0(\lambda)$) of liquid water, for the layer thickness of 1 mm. The symbol $I_0(\lambda)$ may denote initial spectral intensity of light impinging on the layer. The symbol $I_T(\lambda)$ may denote spectral intensity of light transmitted through the layer.

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Water has high spectral absorbance in the vicinity of the wavelength 1450 nm. The wavelength 1450 nm is substantially at the center of an absorption band of water. The first wavelength λ_1 of the first illuminating light LB1 may be

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selected such that the first wavelength λ_1 is within an absorption band of water. The second wavelength λ_2 may be selected such that water has low or negligible spectral absorbance at the second wavelength λ_2 . The second wavelength λ_2 may be e.g. substantially equal to 980 nm or 1100 nm.

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Fig. 6 shows, by way of example, the spectral reflectance curve of dry floor, and the spectral reflectance curve of the same floor, when covered with a layer of water. The presence sensor 100 may interact with the wet floor so that illuminating light LB1 is first transmitted through the water layer, the light is reflected from the floor, and the reflected light RL1 is transmitted through the water layer again before it propagates to the detector unit U0. The reflection may include optical scattering. Diffuse reflection may include optical scattering. The presence of a water layer on the floor may be detected by comparing the measured spectral reflectance $R(\lambda_1)$ at the first wavelength λ_1 with the measured spectral reflectance $R(\lambda_2)$ at the second wavelength λ_2 . The water layer may be a non-vacuumable object NVO1. Also an aqueous substance, e.g. animal urine may be interpreted to be a non-vacuumable object NVO1. The method may comprise determining whether a non-vacuumable object is present or not by comparing a first detector signal value (S_{DET1}) with a second detector signal value (S_{DET2}). The method may comprise determining that a non-vacuumable object is present when the ratio (S_{DET1}/S_{DET2}) of the detector signal values is lower than a predetermined value (e.g. LIM1).

The first detector signal value S_{DET1} may be substantially equal to zero, wherein the second detector signal value S_{DET2} may be substantially greater than zero e.g. in a situation where the floor FLOOR1 is covered with a thick layer of water. For example, the first detector signal value S_{DET1} may be smaller than 5% of the maximum value (S_{MAX1}) in a situation where the thickness of the water layer is greater than 1 mm. For example, the ratio $R(\lambda_1)/R(\lambda_2)$ of the spectral reflectance values $R(\lambda_1)$ and $R(\lambda_2)$ may be smaller than 0.05 in a situation where the thickness of the water layer is greater than 1 mm.

Fig. 7a shows, by way of example, the spectral reflectance curve of animal feces. A non-vacuumable object (NVO1) may be e.g. a piece of feces. The feces may have significant absorption in the vicinity of the absorption bands of water. The feces may have significant spectral absorbance in the vicinity of the

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wavelength 1450 nm. The presence of a non-vacuumable object NVO1 may be detected by comparing the measured spectral reflectance $R(\lambda_1)$ at the first wavelength λ_1 with the measured spectral reflectance $R(\lambda_2)$ at the second wavelength λ_2 . The method may comprise determining whether a non-vacuumable object (NVO1) is present or not by comparing a first detector signal (S_{DET1}) with a second detector signal (S_{DET2}). The method may comprise determining that a non-vacuumable object is present when the ratio (S_{DET1}/S_{DET2}) of the detector signals is lower than a predetermined value (LIM1).

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Fig. 7b shows, by way of example, measured spectral data SPEC1, which comprises a first detector signal value S_{DET1} and a second detector signal value S_{DET2} . The measured spectral data SPEC1 may be represented e.g. by a graphical plot which comprises two or more measured points. The measured spectral data SPEC1 may also be called e.g. as a spectrum. The detector signal values S_{DET1} , S_{DET2} may be obtained when the non-vacuumable object (NVO1) of Fig. 7a is present in the surveillance region REG1 of the detector unit U0. The measured spectral data SPEC1 may comprise or consist of the first detector signal value S_{DET1} and the second detector signal value S_{DET2} . The detector signal values may be optionally normalized e.g. such that a detector signal value of 100% corresponds to a spectral reflectivity of 100%.

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Figs. 7c to 7f show determining the presence a non-vacuumable object NVO1 by based on the first detector signal value S_{DET1} and based on the second detector signal value S_{DET2} .

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The presence a non-vacuumable object NVO1 may be determined by measuring spectral data SPEC1, and by comparing the measured spectral data SPEC1 with reference spectral data. In particular, the measured spectral data SPEC1 may consist of only two spectral values represented by the first detector signal value S_{DET1} and the second detector signal value S_{DET2} .

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Figs. 7c to 7f show determining the presence a non-vacuumable object NVO1 by measuring spectral data SPEC1, and by comparing the measured spectral data SPEC1 with reference spectral data. Figs. 7c to 7e show using measured

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spectral data SPEC1, which consists of only two spectral signal values (S_{DET1} , S_{DET2}).

The detector signal values S_{DET1} , S_{DET2} may be obtained e.g. from a detector unit (U0, U0a, U0b, U0c) by demodulation. The first detector signal values S_{DET1} may be indicative of the intensity of the first reflected light RL1 at the first wavelength λ_1 . The second detector signal values S_{DET2} may be indicative of the intensity of the second reflected light RL2 at the second wavelength λ_2 . The first detector signal values S_{DET1} may be substantially proportional to the intensity of the first reflected light RL1 at the first wavelength λ_1 . The second detector signal values S_{DET2} may be substantially proportional to the intensity of the second reflected light RL2 at the second wavelength λ_2 .

Referring to Fig. 7c, a first detector signal value S_{DET1} may be obtained (method step 710), and a second detector signal value S_{DET2} may be obtained (step 720). A predetermined limit value LIM1 may be retrieved from a memory (step 730). The method may comprise calculating the ratio $K=S_{\text{DET1}}/S_{\text{DET2}}$ of the detector signal values (step 740), and determining whether the calculated ratio K is smaller or greater than the limit value LIM1 (step 750). For example, the non-vacuumable object NVO1 may be determined to be present when the ratio K is smaller than the limit value LIM1 (step 780). For example, the non-vacuumable object NVO1 may be determined to be not present when the ratio K is greater than the limit value LIM1 (step 770). The cleaning device 500 may perform an evasive action when the non-vacuumable object NVO1 is determined to be present. The cleaning device 500 may continue normal movement when the non-vacuumable object NVO1 is determined to be not present.

Referring to Fig. 7d, detector signal values S_{DET1} , S_{DET2} and the limit value LIM1 may be obtained (steps 710, 720, 730). An auxiliary value AUX1 may be calculated from the first detector signal value S_{DET1} (step 741). For example, the auxiliary value AUX1 may be equal to the ratio of the first detector signal value S_{DET1} to the limit value LIM1. The auxiliary value AUX1 may be compared with the second detector signal value S_{DET2} (step 751). For example, the non-vacuumable object NVO1 may be determined to be present when the auxiliary value AUX1 is smaller than the second detector signal value S_{DET2} (step 780).

For example, the non-vacuumable object NVO1 may be determined to be not present when the auxiliary value AUX1 is greater than the second detector signal value S_{DET2} (step 770).

- 5 Referring to Fig. 7e, detector signal values S_{DET1} , S_{DET2} and the limit value LIM1 may be obtained (steps 710, 720, 730). An auxiliary value AUX2 may be calculated from the second detector signal S_{DET2} (step 742). For example, the auxiliary value AUX2 may be equal to the second detector signal value S_{DET2} multiplied by the limit value LIM1. The auxiliary value AUX2 may be compared
10 with the first detector signal value S_{DET1} (step 752). For example, the non-vacuumable object NVO1 may be determined to be present when the first detector signal value S_{DET1} is smaller than the auxiliary value AUX2 (step 780). For example, the non-vacuumable object NVO1 may be determined to be not present when the first detector signal value S_{DET1} is greater than the auxiliary
15 value AUX2 (step 780).

- Referring to Fig. 7f, detector signal values S_{DET1} , S_{DET2} may be obtained (steps 710, 720). A third detector signal value S_{DET3} may be obtained (step 725), see also Fig. 11. An auxiliary value AUX3 may be calculated from two or more
20 detector signal values S_{DET2} , S_{DET3} . For example, the auxiliary value AUX3 may be e.g. equal to the average of the detector signal values (S_{DET2} , S_{DET3}) multiplied by the limit value LIM1. For example, the non-vacuumable object NVO1 may be determined to be present when the first detector signal value S_{DET1} is smaller than the auxiliary value AUX2 (step 780). For example, the
25 non-vacuumable object NVO1 may be determined to be not present when the first detector signal value S_{DET1} is greater than the auxiliary value AUX2 (step 780).

- Referring to Fig. 8, the light sources LS1, LS2 of the presence sensor 100 may
30 optionally comprise one or more spectral filters FIL1, FIL2 to define a spectral bandwidth of illuminating light LB1, LB2. The spectral filters FIL1, FIL2 may provide improved spectral selectivity.

- However, implementing the light sources LS1, LS2 without the spectral filters
35 FIL1, FIL2 may significantly reduce manufacturing costs. The light sources LS1, LS2 may comprise light emitting diodes (LED1, LED2), wherein the

spectral bandwidth of light emitted from a light emitting diode (LED1, LED2) may provide sufficient spectral selectivity for reliable detection of the non-vacuumable object (NVO1).

- 5 The light sources LS1, LS2 may comprise optics LNS1, LNS2 for defining dimensions of illuminating light beams LB1, LB2. The optics LNS1, LNS2 may comprise e.g. one or more lenses, reflectors and/or optical apertures to define dimensions of the illuminating light beams LB1, LB2. For example, the light source LS1 may comprise a Fresnel lens LNS1 for forming an illuminating light beam LB1, which has large horizontal divergence $\Delta\theta_H$. For example, the light source LS1 may comprise a cylindrical lens LNS1 for forming an illuminating light beam LB1, which has large horizontal divergence $\Delta\theta_H$.

- 15 A detector unit U1, U2 may comprise one or more spectral filters FIL3, FIL4 to define a spectral bandwidth for detecting reflected light RL1, RL2.

- For example, a first detector unit U1 may comprise a spectral filter FIL3 to provide improved spectral selectivity. The spectral filter FIL3 may reject light, which outside the passband of the spectral filter FIL3. The spectral filter FIL3 may be arranged to pass light at the first wavelength λ_1 , and to reject light at the second wavelength λ_2 .

- For example, a second detector unit U2 may comprise a spectral filter FIL4 to provide improved spectral selectivity. The spectral filter FIL4 may reject light, which outside the passband of the spectral filter FIL4. The spectral filter FIL3 may be arranged to pass light at the second wavelength λ_2 , and to reject light at the first wavelength λ_1 .

- 30 The illuminating light beam LB1 may have a central axis AX1. The illuminating light beam LB2 may have a central axis AX2. The detection beam DB1 may have a central axis AX3. The detection beam DB2 may have a central axis AX4.

- 35 The detector unit U1 may comprise a detector element DET1 for converting optical intensity into a first detector signal S_{DET1} . The detector unit U2 may comprise a detector element DET2 for converting optical intensity into a

second detector signal S_{DET2} . Thanks to the spectral filter FIL3, the detector unit U1 may provide the detector signal S_{DET1} also without a need to separate the first signal S_{DET1} from the second signal S_{DET2} by signal processing (demodulation).

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The first light source LS1 may provide the first illuminating light beam LB1, which may have a central axis AX1. The second light source LS2 may provide the second illuminating light beam LB2, which may have a central axis AX2. The first detector unit U1 may be arranged to gather first reflected light RL1 only from a region defined by a first detector beam DB1. The second detector unit U2 may be arranged to gather second reflected light RL2 only from a region defined by a second detector beam DB2. The illuminating light beams LB1, LB2 and the detector beams DB1, DB2 may together define a common surveillance region REG1.

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Referring to Fig. 9, the cleaning device 500 comprises control system SYS1. The control system SYS1 may comprise a control unit CNT1. The control unit CNT1 may be arranged to control operation of the motive system MOS1 based on one or more sensor signals obtained from the sensors (SEN1, 100) of the cleaning device 500.

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The control unit CNT1 may be arranged to control operation of the motive system MOS1 based on one or more sensor signals obtained from the presence sensor 100, so as to avoid collision with a non-vacuumable object NVO1.

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The presence sensor 100 may comprise e.g. the first light source LS1, the second light source LS2, and one or more detector units U0a, U0b, U0c.

A first detector unit U0a of a first surveillance region REG1a may provide a signal S_{DET0a} , S_{DET1} , and/or S_{DET2} . Signals S_{DET1} , S_{DET2} may be formed from the primary signal S_{DET0a} by demodulation, wherein the first detector signal S_{DET1} may represent light (RL1) reflected from the first surveillance region REG1a at the first wavelength λ_1 , and the second detector signal S_{DET2} may represent light (RL2) reflected from the first surveillance region REG1a at the second wavelength λ_2 .

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A second detector unit U0b of a second surveillance region REG1b may provide a signal S_{DET0b} , S_{DET1} , and/or S_{DET2} . Signals S_{DET1} , S_{DET2} may be formed from the primary signal S_{DET0b} by demodulation, wherein the first detector signal S_{DET1} may represent light (RL1) reflected from the second surveillance region REG1b at the first wavelength λ_1 , and the second detector signal S_{DET2} may represent light (RL2) reflected from the second surveillance region REG1b at the second wavelength λ_2 .

10 A third detector unit U0c of a third surveillance region REG1c may provide a signal S_{DET0c} , S_{DET1} , and/or S_{DET2} . Signals S_{DET1} , S_{DET2} may be formed from the primary signal S_{DET0c} by demodulation, wherein the first detector signal S_{DET1} may represent light (RL1) reflected from the third surveillance region REG1c at the first wavelength λ_1 , and the second detector signal S_{DET2} may represent light (RL2) reflected from the third surveillance region REG1c at the second wavelength λ_2 .

Alternatively, the presence sensor 100 may comprise one or more first detector units (U1) to detect first reflected light (RL1) reflected from the first surveillance region REG1a at the first wavelength λ_1 , and the presence sensor 100 may comprise one or more second detector units (U2) to detect second reflected light (RL2) reflected from the first surveillance region REG1a at the second wavelength λ_2 .

25 The control system SYS1 may comprise a memory MEM1 for storing computer program code PROG1. The code PROG1, when executed by one or more data processors of the control unit CNT1, may cause the cleaning device 500 to detect whether an object (O2, NVO1) is present in a surveillance region (REG1a, REG1b, REG1c), to determine whether the detected object is a non-vacuumable object (NVO1) or not, and to avoid collision with an object, which is determined to be a non-vacuumable object (NVO1). For example, the control unit CNT1 may be arranged to stop, turn, and/or move the cleaning device in a reverse direction when a non-vacuumable object (NVO1) is detected to overlap with at least one surveillance region (REG1a, REG1b, REG1c).

The control system SYS1 may comprise a memory MEM2 for storing operating parameters PAR1. The operating parameters PAR1 may comprise e.g. a limit value LIM1, which may be used as criterion for detecting the presence of a non-vacuatable object (NVO1).

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The control system SYS1 may comprise a memory MEM3 for storing a map MAP1 of the operating environment of the cleaning device 500. The map MAP1 may comprise information about the locations of walls, carpets, furniture, charging station, and non-vacuatable objects (NVO1). The map
10 MAP1 may also be updated during operation of the cleaning device 500.

The control system SYS1 may comprise a user interface UIF1 for receiving commands from a human user and/or for providing information to a human user.

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The control system SYS1 may comprise a communication unit RXTX1 for receiving data and/or for transmitting data. For example, the cleaning device 500 may send and/or receive data about the locations of walls, carpets, furniture, charging station, and non-vacuatable objects (NVO1). For example,
20 the cleaning device 500 may send and/or receive data regarding the map MAP1. The communication unit RXTX1 may be arranged to communicate e.g. with one or more auxiliary devices UNIT2. COM1 may denote communication of data. The communicated data may comprise e.g. map data, measured data, command data, alarm data and/or user input. The auxiliary device UNIT2 may
25 also comprise a control unit CNT2, a memory MEM21 for storing computer program code PROG2, a memory MEM22 for storing map data MAP1. A communication unit RXTX2, and/or a user interface UIF2. The auxiliary device UNIT2 may be e.g. a charging station, a smartphone of a human user, or an internet server.

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The cleaning device 500 may be arranged to operate unsupervised.

In an embodiment, the cleaning device 500 may improve the reliability of identifying an object e.g. by observing the object from different directions. The
35 cleaning device 500 may perform a sequence of movements in the vicinity of the object in order to gather more signal data about the object. The cleaning

device 500 may be arranged to turn in order to change the relative positions of the one or more surveillance regions REG1a, REG1b, REG1c with respect to an object (O2, NVO1). The motive system MOS1 may be arranged to turn the device 500. The cleaning device 500 may be arranged to record the detector
5 signal values S_{DET1} , S_{DET2} as a function of orientation of the cleaning device 500. The cleaning device 500 may comprise e.g. an electronic compass and/or a gyroscope for detecting the orientation of the cleaning device 500 with respect to a reference direction (e.g. with respect to the direction north or south). The cleaning device 500 may be arranged to determine position and/or
10 width of an object by analyzing the detector signals, which were recorded as a function of the orientation of the cleaning device 500. The cleaning device 500 may be arranged to turn when encountering an object in order to determine position and/or width of the object more accurately. The cleaning device 500 may be arranged to gather more data by turning when encountering an object
15 in order to improve the reliability of identifying said object.

The cleaning device 500 may be arranged to move backwards and forwards when encountering an object, in order to gather more signal data about the object, in order to improve the reliability of identifying the object.

20 The detector units (U0a, U0b, U0c) may be fixed to a body or housing 200 of the cleaning device 500. The detector units (U0a, U0b, U0c) may be stationary with respect to the (moving) cleaning device 500. Turning of the cleaning device 500 may allow monitoring a region, which is wider than the width W_{TOT}
25 of the combined surveillance region of the cleaning device 500.

In an embodiment, the cleaning device 500 may be arranged to detect a layer of water on the floor FLOOR1 based on the detector signals S_{DET1} , S_{DET2} . The layer of water (or aqueous liquid) may be caused e.g. due to a leaking water
30 tube or due to an urinating animal. The cleaning device 500 may be arranged to detect a layer of water on the floor FLOOR1 by comparing the detector signal values S_{DET1} , S_{DET2} with reference data. The cleaning device 500 may be arranged to detect a layer of water on the floor FLOOR1 by comparing the ratio of the signals S_{DET1}/S_{DET2} with a predetermined reference value (LIM2).

35

In an embodiment, the cleaning device 500 may be arranged to provide an indication of a detected water layer to a user interface (e.g. UIF2). For example, the cleaning device 500 may be arranged to send an alarm signal to a human user when the cleaning device 500 detects a layer of water on the floor.

In an embodiment, the cleaning device 500 may be arranged to provide an indication of the detected water layer to a user interface (e.g. UIF2) only when the layer is detected to cover a large area of the floor FLOOR1. As a criterion, the cleaning device 500 may be arranged to determine that the layer is large e.g. when the layer overlaps at least two adjacent surveillance regions (e.g. the surveillance regions REG1a and REG1b).

In an embodiment, the cleaning device 500 may be arranged to determine that an object is a non-vacuumable object only if the ratio of the signals S_{DET1}/S_{DET2} indicates that the object is a non-vacuumable object and if an additional criterion is fulfilled. The additional criterion may be e.g. that the object does not simultaneously overlap with three surveillance regions (REG1a, REG1b, REG1c) of the cleaning device 500. In an embodiment, an object which overlaps three surveillance regions is so large, that it can be logically deduced that said object cannot be a non-vacuumable object (NVO1).

Referring to Fig. 10a, the cleaning device 500 may have an effective transverse width w_{EFF} defined e.g. by the wheels WHE1a, WHE1b of the device 500. The combined width w_{TOT} of the surveillance regions (REG1, REG1a, REG1b, REG1c) may be e.g. greater than or equal to the effective width w_{EFF} , so as to prevent contaminating the wheels WHE1a, WHE1b and/or the nozzle NOZ1. The effective width w_{EFF} may be e.g. in the range of 60% to 80% of the width w_{500} of the cleaning device 500. The combined width w_{TOT} of the surveillance regions (REG1, REG1a, REG1b, REG1c) may be e.g. greater than or equal to 80% of the total width w_{500} of the cleaning device 500.

Referring to Fig. 10b, the risk of contaminating the cleaning system (BRU1, VAC1) of the cleaning device 500 may be significantly reduced if the combined width w_{TOT} of the surveillance regions (REG1, REG1a, REG1b, REG1c) is selected to be greater than or equal to the width w_{CLEAN} of the cleaning region

CREG1 of the cleaning device 500. The cleaning device 500 may move in a forward direction at a velocity VEL1. The cleaning region CREG1 may mean an area of the floor FLOOR1, which is cleaned by the cleaning device during a single linear forward movement of the cleaning device 500, e.g. in the direction SX.

Referring to Fig. 11, the cleaning device 500 may comprise a third light source LS3 to provide third illuminating light LB3 at a third wavelength λ_3 . The third wavelength λ_3 may be different from the first wavelength λ_1 , and the third wavelength λ_3 may be different from the second wavelength λ_2 . An object (NVO1, O2, O3) located in the surveillance region (REG1, REG1a, REG1b, REG1c) may provide third reflected light RL3 by reflecting the third illuminating light LB3. The cleaning device 500 may comprise a detector unit (U0) for gathering and detecting the third reflected light RL3. The cleaning device 500 may be arranged to form a third detector signal value (S_{DET3}) indicative of spectral intensity of gathered reflected light RL3 at the third wavelength λ_3 . For example, the third detector signal value S_{DET3} may be formed from a primary detector S_{DET0} of the detector unit U0 by demodulation. For example, the cleaning device 500 may be arranged to modulate the illuminating light beams LB1, LB2, LB3, and the cleaning device 500 may be arranged to form the first detector signal S_{DET1} , the second detector signal S_{DET2} , and the third detector signal S_{DET3} from the primary detector signal S_{DET0} by demodulation. The illuminating light beams LB1, LB2, LB3 may be modulated such that the separate detector signals S_{DET1} , S_{DET2} , S_{DET3} may be formed by demodulation.

The cleaning device 500 may be arranged to identify an object (NVO1, O2, O3) located in the surveillance region (REG1, REG1a, REG1b, REG1c) based on the three detector signals S_{DET1} , S_{DET2} , S_{DET3} . For example, measured spectral data SPEC1 may comprise or consist of detector signal values S_{DET1} , S_{DET2} , S_{DET3} .

For example, the cleaning device 500 may be arranged to identify an object (NVO1, O2, O3) by comparing the measured spectral data SPEC1 with reference spectral data. The reference data may comprise e.g. information about spectral reflectance values of several different materials. The cleaning device may be arranged to provide three or more detector signals by gathering

reflected light from the surveillance region, and the cleaning device may be arranged to identify an object by comparing the detector signals with reference data. Each detector signal may be indicative of spectral reflectance of the object at a different wavelength. The object O3 may be e.g. a carpet, which is made of cotton fibers or plastic fibers. For example, the cleaning device may be arranged to detect whether an object overlapping the surveillance region is a carpet or not, based on the three or more detector signals. For example, the cleaning device may be arranged to determine whether an object (O3) located in the surveillance region is a piece of textile, a piece of wood, a piece of plastic, or a non-vacuumable object, by comparing the measured spectral data SPEC1 with reference data. In an embodiment, the measured spectral data SPEC1 may also comprise three or more detector signal values S_{DET1} , S_{DET2} , S_{DET3} .

However, using only the two detector signals S_{DET1} , S_{DET2} may allow determining, with a sufficient degree of reliability, whether an object (NVO1, O2, O3) overlapping the surveillance region (REG1a, REG1b, REG1c) is a non-vacuumable object (NVO1) or not. The cleaning device 500 may be implemented so that the cleaning device 500 is not arranged to illuminate the surveillance region with third illuminating light (LB3), which has a third wavelength (λ_3).

The presence sensor 100 of the cleaning device 500 is a non-imaging sensor, so as to ensure privacy of the operating environment of the cleaning device 500. The control system SYS1 of the cleaning device 500 does not need to capture and/or analyze images in order to determine whether the detected objects are non-vacuumable or not. Consequently, the risk of sending private photographs of the interior to the internet may be avoided.

Referring to Fig. 12a, the width and/or height of a non-vacuumable object NVO1 may be so small that the non-vacuumable object NVO1 may only partly cover a surveillance region REG1 (REG1a, REG1b, REG1c). Typically, the non-vacuumable object NVO1 may only partly overlap with a surveillance region REG1 (REG1a, REG1b, REG1c). The intensity of reflected light RL1, RL2 propagating from the non-vacuumable object NVO1 to the detector unit may be low due to the low coverage.

The surface SRF1 of the non-vacuumable object NVO1 may have inclined portions and/or substantially horizontal portions, which may direct most of the reflected light away from the detector unit. The intensity of reflected light RL1, RL2 propagating from the non-vacuumable object NVO1 to the detector unit may be low due to the orientations of the surface portions of the non-vacuumable object NVO1.

Thus, a non-vacuumable object NVO1 does not typically cause a high value of a detector signal S_{DET1} and/or S_{DET2} , due to the size and the orientations of the surface SRF1. In an embodiment, a high value of a detector signal S_{DET1} and/or S_{DET2} may be used as an indication that an object detected in the surveillance region REG1 (REG1a, REG1b, REG1c) is not a non-vacuumable object NVO1.

Low values of the detector signal S_{DET1} and/or S_{DET2} may be used as a further indication about the presence of a non-vacuumable object NVO1 in the surveillance region REG1, in a situation where the ratio S_{DET1}/S_{DET2} of the detector signals is smaller than the limit value LIM1.

A surveillance region REG1 (REG1a, REG1b, REG1c) of the cleaning device 500 may extend to a monitoring distance L_{SUR} from the cleaning device 500, so as to allow early detection of a non-vacuumable object NVO1. The surveillance region REG1 may extend to the front of the cleaning device 500 by the distance L_{SUR} in the horizontal direction. The monitoring distance L_{SUR} may be e.g. greater than 0.1 m, greater than 0.2 m, or even greater than 0.5 m. Consequently, the moving cleaning device 500 may have sufficient time for determining the presence of the cleaning device 500 in advance, and for performing an evasive action (e.g. stopping, turning, and/or reversing), so as to avoid a collision with the non-vacuumable object NVO1. The detector signals S_{DET1} , S_{DET2} may be formed mainly by optical back-scattering from the object, which is located in the surveillance region. A non-vacuumable object NVO1 may typically have a low back-scattering cross section.

However, some safe objects O4 may have a large back-scattering cross section, which may cause high detector signal values S_{DET1} and/or S_{DET2} .

Referring to Fig. 12b, a safe object O4 may have a large substantially vertical surface SRF4. The safe object O4 may be e.g. a wall of a room or a leg of a furniture. During normal operation, the cleaning device 500 should move and perform cleaning also close to the safe object O4, so as to maximize the cleaned area of the floor FLOOR1. In an embodiment, the cleaning device 500 may even intentionally collide with the safe object O4, e.g. in order to accurately measure the position of the safe object O4 and/or in order to gather position information for determining a map of the room. A collision with the safe object O4 does not cause contamination of the cleaning device 500.

The large vertical surface SRF4 of the safe object O4 may cause high detector signals S_{DET1} and/or S_{DET2} . In an embodiment, one or more high detector signal values S_{DET1} and/or S_{DET2} may be used as an indication that an object detected in the surveillance region is a safe object O4. One or more high detector signal values S_{DET1} and/or S_{DET2} may be used as an indication that an object detected in the surveillance region is not a non-vacuatable object NVO1.

Fig. 13a shows, by way of example, temporal evolution of the first detector signal S_{DET1} , and temporal evolution of the ratio S_{DET1}/S_{DET2} of the detector signals, during a movement where the cleaning device 500 moves close to a non-vacuatable object NVO. In this example, the non-vacuatable object NVO1 is a layer of water on the floor.

The ratio S_{DET1}/S_{DET2} is lower than the first limit LIM1 between times t_{10} , t_{11} , and between times t_{20} , t_{21} , indicating the presence of the non-vacuatable object NVO1 in the surveillance region REG1.

In this example, the orientation of the light-reflecting surface SRF1 of the non-vacuatable object NVO is mainly horizontal, and the non-vacuatable object NVO may reflect most of the light (RL1, RL2) away from the detector unit U0. The detector signal S_{DET1} remains lower than the auxiliary limit LIM3 between the times t_{10} , t_{11} , and between the times t_{20} , t_{21} .

The low detector signal S_{DET1} may be used as a further indication that the object which causes the low ratio $S_{\text{DET1}}/S_{\text{DET2}}$ is a non-vacuatable object NVO1.

- 5 The first limit LIM1 may be e.g. smaller than or equal to 0.95 times a reference value of the ratio $S_{\text{DET1}}/S_{\text{DET2}}$. The reference value of the ratio $S_{\text{DET1}}/S_{\text{DET2}}$ may represent e.g. the ratio $S_{\text{DET1}}/S_{\text{DET2}}$ of a clean floor FLOOR1.

- The auxiliary limit LIM3 may be a predetermined limit value. The auxiliary limit
 10 LIM3 may be e.g. greater than 1.3 times a reference value REF1 of the detector signal S_{DET1} . The auxiliary limit LIM3 may be e.g. greater than 1.7 times a reference value REF1 of the detector signal S_{DET1} . The reference value REF1 may represent e.g. the detector signal S_{DET1} or S_{DET2} from a clean floor FLOOR1. The "low" detector signal $S_{\text{DET1}}, S_{\text{DET2}}$ may mean a detector signal,
 15 which is smaller than the auxiliary limit LIM3, and the "high" detector signal $S_{\text{DET1}}, S_{\text{DET2}}$ may mean a detector signal, which is greater than or equal to the auxiliary limit LIM3.

- Fig. 13b shows, by way of example, the temporal evolution of the first detector
 20 signal S_{DET1} , and the temporal evolution of the ratio $S_{\text{DET1}}/S_{\text{DET2}}$ of the detector signals, during a movement where the cleaning device 500 moves close to a wall, i.e. a safe object O4, which has a large vertical surface SRF4.

- In this example, the safe object O4 significantly overlaps with the surveillance
 25 region REG1 between the times t_{30}, t_{31} . The ratio $S_{\text{DET1}}/S_{\text{DET2}}$ is lower than the first limit LIM1, and the detector signal S_{DET1} is higher than the auxiliary limit LIM3 between the times t_{30}, t_{31} .

- The safe object O4 may sometimes cause a low value of the ratio $S_{\text{DET1}}/S_{\text{DET2}}$
 30 e.g. due to different spatial intensity distributions of the illuminating light beams LB1, LB2. For example, the light sources LS1, LS2 may form the illuminating light beams LB1, LB2 such that the spatial intensity distribution of the first illuminating light beam LB1 is slightly different from the spatial intensity distribution of the first illuminating light beam LB1. The light sources LS1, LS2
 35 may form the illuminating light beams LB1, LB2 e.g. such that the first illuminating light beam LB1 does not completely overlap with the second

illuminating light beam LB2. The safe object O4 may cause a low value of the ratio $S_{\text{DET1}}/S_{\text{DET2}}$ also e.g. due to a non-linearity of the detector unit U0 at high signal levels.

- 5 The high value of the detector signal S_{DET1} may be used as an indication that an object which causes the low ratio $S_{\text{DET1}}/S_{\text{DET2}}$ is not a non-vacuumable object NVO1.

One or more high detector signal values S_{DET1} and/or S_{DET2} may be used as
10 an indication of a false alarm. Even if the low ratio $S_{\text{DET1}}/S_{\text{DET2}}$ of the detector signals would indicate the presence of a non-vacuumable object NVO1 in the surveillance region REG1 (i.e. an alarm), then the high value of the detector signal value S_{DET1} and/or S_{DET2} may override said alarm. A high detector signal S_{DET1} and/or S_{DET2} may override an indication of presence, which is based on
15 a low ratio $S_{\text{DET1}}/S_{\text{DET2}}$ of the detector signals. The method may comprise determining based on at least one high detector signal that no non-vacuumable object is present in the surveillance region, despite the measured ratio $S_{\text{DET1}}/S_{\text{DET2}}$ of the detector signals.

- 20 The cleaning device 500 may be arranged to check whether at least one detector signal value $S_{\text{DET1}}, S_{\text{DET2}}$ is greater than or equal to an auxiliary limit value LIM3, wherein the cleaning device 500 may be arranged to determine that a non-vacuumable object NVO1 is not present in the surveillance region REG1 in a situation where said at least one detector signal value $S_{\text{DET1}}, S_{\text{DET2}}$
25 is greater than or equal to the auxiliary limit value LIM3.

The control system SYS1 may be arranged to check whether at least one detector signal value $S_{\text{DET1}}, S_{\text{DET2}}$ is greater than or equal to an auxiliary limit value LIM3, wherein the control system SYS1 may be arranged to determine
30 that a non-vacuumable object NVO1 is not present in the surveillance region REG1 in a situation where said at least one detector signal value $S_{\text{DET1}}, S_{\text{DET2}}$ is greater than or equal to the auxiliary limit value LIM3.

- 35 The method may comprise checking whether at least one detector signal value $S_{\text{DET1}}, S_{\text{DET2}}$ is greater than or equal to an auxiliary limit value LIM3, and determining that a non-vacuumable object NVO1 is not present in the

surveillance region REG1 in a situation where said at least one detector signal value S_{DET1}, S_{DET2} is greater than or equal to the auxiliary limit value LIM3.

Fig. 14 shows, by way of example, method steps for determining whether a
5 non-vacuatable object is present in the surveillance region. A first detector
signal value S_{DET1} may be obtained (method step 710), and a second detector
signal value S_{DET2} may be obtained (step 720). A predetermined limit value
LIM1 may be retrieved from a memory (step 730). The method may comprise
calculating the ratio $K = S_{DET1}/S_{DET2}$ of the detector signal values (step 740), and
10 determining whether the calculated ratio K is smaller or greater than the limit
value LIM1 (step 750). For example, the non-vacuatable object NVO1 may
be determined to be not present when the ratio K is greater than the limit value
LIM1 (step 770).

15 An auxiliary detector signal value S_{AUX3} may be determined from one or more
measured detector signal values S_{DET1} and/or S_{DET2} (step 830). For example,
the auxiliary detector signal value S_{AUX3} may be equal to the first detector
signal value S_{DET1} or equal to the second detector signal value S_{DET2} . For
example, the auxiliary detector signal value S_{AUX3} may be equal to the average
20 value $(S_{DET1} + S_{DET2})/2$ of the detector signals S_{DET1}, S_{DET2} . For example, the
auxiliary detector signal value S_{AUX3} may be equal to the sum $S_{DET1} + S_{DET2}$ of
the detector signals S_{DET1}, S_{DET2} .

The method may comprise comparing the auxiliary detector signal value S_{AUX3}
25 with the auxiliary limit value LIM3 (in step 850). For example, the non-
vacuatable object NVO1 may be determined to be present when the auxiliary
detector signal value S_{AUX3} is smaller than the auxiliary limit value LIM3 (step
780). For example, the non-vacuatable object NVO1 may be determined to
be not present when the auxiliary detector signal value S_{AUX3} is not smaller
30 than the auxiliary limit value LIM3 (step 770).

For example, the non-vacuatable object NVO1 may be determined to be
present when the ratio K is smaller than the limit value LIM1 (step 780). The
cleaning device 500 may perform an evasive action when the non-vacuatable
35 object NVO1 is determined to be present. The cleaning device 500 may

continue normal movement when the non-vacuumable object NVO1 is determined to be not present.

5 The method may comprise determining the presence of the non-vacuumable object (NVO1) by comparing measured spectral data (SPEC1) with reference spectral data (LIM1), wherein said measured spectral data (SPEC1) comprises the first detector signal value (S_{DET1}) and the second detector signal value (S_{DET2}).

- 10 The method may comprise:
- determining an auxiliary detector signal value (S_{AUX3}) from the first detector signal value (S_{DET1}) and/or from the second detector signal value (S_{DET2}),
 - comparing the auxiliary detector signal value (S_{AUX3}) with a predetermined auxiliary limit value (LIM3), and
- 15 - using a result of said comparison as an additional criterion for determining whether the non-vacuumable object (NVO1) is present in the surveillance region (REG1).

The method may comprise:

- 20 - checking whether at least one of the detector signal values (S_{DET1}, S_{DET2}) is greater than or equal to a predetermined auxiliary limit value (LIM3),
- determining that a non-vacuumable object (NVO1) is not present in the surveillance region (REG1) in a situation where said at least one detector signal value (S_{DET1}, S_{DET2}) is greater than or equal to the auxiliary limit value
- 25 (LIM3).

Various aspects are illustrated by the following examples:

Example 1. An autonomous cleaning device (500), comprising:

- 30 - a vacuum unit (VAC1) to remove dust particles (P1) from a floor (FLOOR1),
- a motive system (MOS1) to move the cleaning device (500) on the floor (FLOOR1),
 - a control system (SYS1) to control movements of the cleaning device (500) based on signals obtained from one or more sensors (SEN1,100),

wherein the cleaning device (500) comprises an optical presence sensor (100) for detecting the presence of a non-vacuumable object (NVO1), the optical presence sensor (100) comprising:

- a first light source (LS1) to illuminate a surveillance region (REG1) with first illuminating light (LB1), which has a first wavelength (λ_1),
 - a second light source (LS2) to illuminate the surveillance region (REG1) with second illuminating light (LB2), which has a second wavelength (λ_2),
 - one or more detectors (DET0) to gather reflected light (RL1, RL2) from the surveillance region (REG1),
- wherein the cleaning device (500) is arranged to form a first detector signal value (S_{DET1}) indicative of spectral intensity of gathered reflected light (RL1) at the first wavelength (λ_1), and to form a second detector signal value (S_{DET2}) indicative of spectral intensity of gathered reflected light (RL2) at the second wavelength (λ_2),
- wherein the cleaning device (500) is arranged to determine based on the first detector signal value (S_{DET1}) and based on the second detector signal value (S_{DET2}) whether a non-vacuumable object (NVO1) is present in the surveillance region (REG1), wherein the first wavelength (λ_1) is within an optical absorption band of liquid water.

Example 2. The device (500) of example 1, wherein the first wavelength (λ_1) is in the range of 1400 nm to 1500 nm, advantageously in the range of 1430 nm to 1470 nm, preferably in the range of 1440 nm to 1460 nm.

Example 3. The device (500) of example 1 or 2, wherein the first light source LS1 comprises a light emitting diode (LED1).

Example 4. The device (500) according to any of the examples 1 to 3, comprising a first detector unit (U0a) to form a first surveillance region (REG1a), and a second detector unit (U0b) to form a second surveillance region (REG1b), wherein the first light source (LS1) is arranged to illuminate the first surveillance region (REG1a) and the second surveillance region (REG1b) with the first illuminating light (LB1), which has the first wavelength (λ_1).

Example 5. The device (500) according to any of the examples 1 to 4, comprising one or more detector units (U0a, U0b), wherein each detector unit (U0a, U0b) defines a surveillance region (REG1a, REG1b), wherein the combined width (w_{TOT}) of the surveillance regions (REG1a, REG1b) of the one or more detector units (U0a, U0b) is greater than the width (w_{CLEAN}) of a cleaning region (CREG1) of the cleaning device (500), the cleaning region (CREG1) being the floor area, which is cleaned by the cleaning device (500) during a single forward movement of the cleaning device (500).

Example 6. The device (500) according to any of the examples 1 to 5, comprising one or more detector units (U0a, U0b), wherein each detector unit (U0a, U0b) defines a surveillance region (REG1a, REG1b), wherein the combined width (w_{TOT}) of the surveillance regions (REG1a, REG1b) of the one or more detector units (U0a, U0b) is greater than 80% of the width (w_{500}) of the cleaning device (500).

Example 7. The device (500) according to any of the examples 1 to 6, wherein the light sources (LS1, LS2) are arranged to modulate the first illuminating light (LB1) and the second illuminating light (LB2), wherein the same detector unit (D0) is arranged to detect first reflected light (RL1) at the first wavelength (λ_1), and to detect second reflected light (RL2) at the second wavelength (λ_2), wherein the first detector signal value (S_{DET1}) and the second detector signal value (S_{DET2}) are formed by demodulation.

Example 8. The device (500) according to any of the examples 1 to 7, wherein the presence sensor (100) is a non-imaging sensor, so as to ensure privacy of the operating environment of the cleaning device (500).

Example 9. The device (500) according to any of the examples 1 to 8, wherein the device (500) is arranged to determine the presence of the non-vacuatable object (NVO1) by comparing measured spectral data (SPEC1) with reference spectral data (LIM1), wherein said measured spectral data (SPEC1) comprises the first detector signal value (S_{DET1}) and the second detector signal value (S_{DET2}).

Example 10. The device (500) according to any of the examples 1 to 9, wherein the device (500) is arranged to determine the presence of the non-vacuatable object (NVO1) by comparing a ratio (S_{DET1}/S_{DET2}) of the detector signals with a predetermined limit value (LIM1).

5

Example 11. A method for cleaning a floor (FLOOR1) with an autonomous cleaning device (500), the cleaning device (500) comprising:

- a vacuum unit (VAC1) to remove dust particles (P1) from a floor (FLOOR1),
- a motive system (MOS1) to move the cleaning device (500) on the floor (FLOOR1),

10

- a control system (SYS1) to control movements of the cleaning device (500) based on signals obtained from one or more sensors (SEN1,100),

wherein the cleaning device (500) comprises an optical presence sensor (100) for detecting the presence of a non-vacuatable object (NVO1), the optical presence sensor (100) comprising:

15

- a first light source (LS1) to illuminate a surveillance region (REG1) with first illuminating light (LB1), which has a first wavelength (λ_1), the first wavelength (λ_1) being within an optical absorption band of liquid water,

- a second light source (LS2) to illuminate the surveillance region (REG1) with second illuminating light (LB2), which has a second wavelength (λ_2),

20

- one or more detectors (DET0) to gather reflected light (RL1, RL2) from the surveillance region (REG1),

the method comprising:

- moving the cleaning device (500),

25

- forming a first detector signal value (S_{DET1}) indicative of spectral intensity of gathered reflected light (RL1) at the first wavelength (λ_1),

- forming a second detector signal value (S_{DET2}) indicative of spectral intensity of gathered reflected light (RL2) at the second wavelength (λ_2),

- determining based on the first detector signal value (S_{DET1}) and based on the second detector signal value (S_{DET2}) whether a non-vacuatable object (NVO1) is present in the surveillance region (REG1),

30

wherein the first wavelength (λ_1) is within an optical absorption band of liquid water.

35

For the person skilled in the art, it will be clear that modifications and variations of the devices and methods according to the present invention are perceivable.

The figures are schematic. The particular embodiments described above with reference to the accompanying drawings are illustrative only and not meant to limit the scope of the invention, which is defined by the appended claims.

CLAIMS

1. An autonomous cleaning device (500), comprising:
- a vacuum unit (VAC1) to remove dust particles (P1) from a floor (FLOOR1),
 - 5 - a motive system (MOS1) to move the cleaning device (500) on the floor (FLOOR1),
 - a control system (SYS1) to control movements of the cleaning device (500) based on signals obtained from one or more sensors (SEN1,100),
- wherein the cleaning device (500) comprises an optical presence sensor (100)
- 10 for detecting the presence of a non-vacuumable object (NVO1), the optical presence sensor (100) comprising:
- a first light source (LS1) to illuminate a surveillance region (REG1) with first illuminating light (LB1), which has a first wavelength (λ_1),
 - a second light source (LS2) to illuminate the surveillance region (REG1) with
 - 15 second illuminating light (LB2), which has a second wavelength (λ_2),
 - one or more detectors (DET0) to gather reflected light (RL1, RL2) from the surveillance region (REG1),
- wherein the cleaning device (500) is arranged to form a first detector signal value (S_{DET1}) indicative of spectral intensity of gathered reflected light (RL1) at
- 20 the first wavelength (λ_1), and to form a second detector signal value (S_{DET2}) indicative of spectral intensity of gathered reflected light (RL2) at the second wavelength (λ_2),
- wherein the cleaning device (500) is arranged to determine based on the first detector signal value (S_{DET1}) and based on the second detector signal value
- 25 (S_{DET2}) whether a non-vacuumable object (NVO1) is present in the surveillance region (REG1), wherein the first wavelength (λ_1) is within an optical absorption band of liquid water.
- 30 2. The device (500) of claim 1, wherein the device (500) is arranged to determine the presence of the non-vacuumable object (NVO1) by comparing measured spectral data (SPEC1) with reference spectral data (LIM1), wherein said measured spectral data (SPEC1) comprises the first detector signal value (S_{DET1}) and the second detector signal value (S_{DET2}).
- 35 3. The device (500) of claim 1 or 2, wherein the device (500) is arranged to determine the presence of the non-vacuumable object (NVO1) by comparing

a ratio (S_{DET1}/S_{DET2}) of the detector signals with a predetermined limit value (LIM1).

4. The device (500) according to any of the claims 1 to 3, wherein the cleaning
5 device (500) is arranged to:

- determine an auxiliary detector signal value (S_{AUX3}) from the first detector signal value (S_{DET1}) and/or from the second detector signal value (S_{DET2}),
- compare the auxiliary detector signal value (S_{AUX3}) with a predetermined auxiliary limit value (LIM3), and

10 - use a result of said comparison as an additional criterion for determining whether the non-vacuatable object (NVO1) is present in the surveillance region (REG1).

5. The device (500) according to any of the claims 1 to 4, wherein the cleaning
15 device (500) is arranged to check whether at least one of the detector signal values (S_{DET1}, S_{DET2}) is greater than or equal to a predetermined auxiliary limit value (LIM3), wherein the cleaning device (500) is arranged to determine that a non-vacuatable object (NVO1) is not present in the surveillance region (REG1) in a situation where said at least one detector signal value
20 (S_{DET1}, S_{DET2}) is greater than or equal to the auxiliary limit value (LIM3).

6. The device (500) according to any of the claims 1 to 5, wherein the first
wavelength (λ_1) is in the range of 1400 nm to 1500 nm, advantageously in the range of 1430 nm to 1470 nm, preferably in the range of 1440 nm to 1460 nm.

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7. The device (500) according to any of the claims 1 to 6, wherein the first light source LS1 comprises a light emitting diode (LED1).

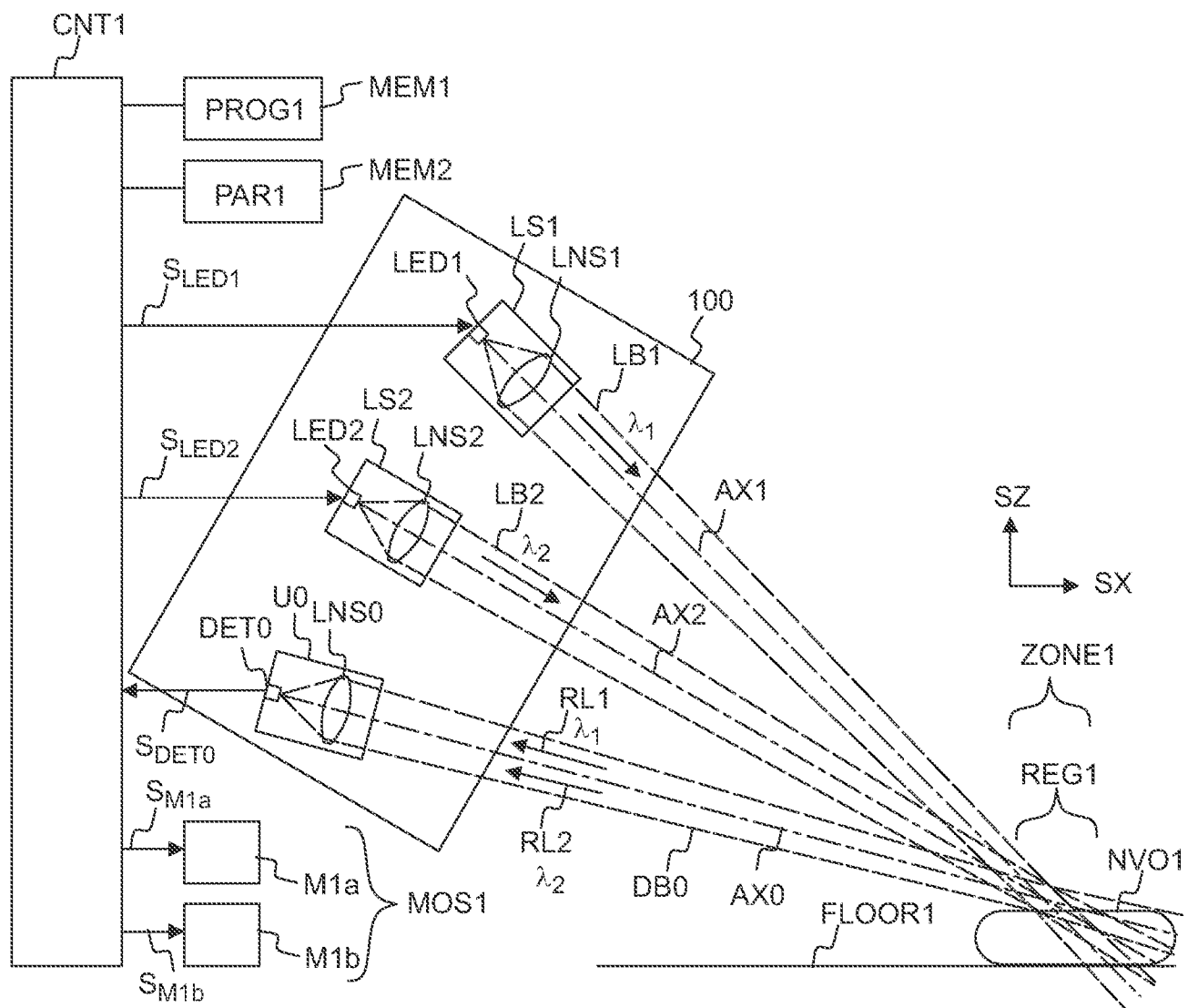
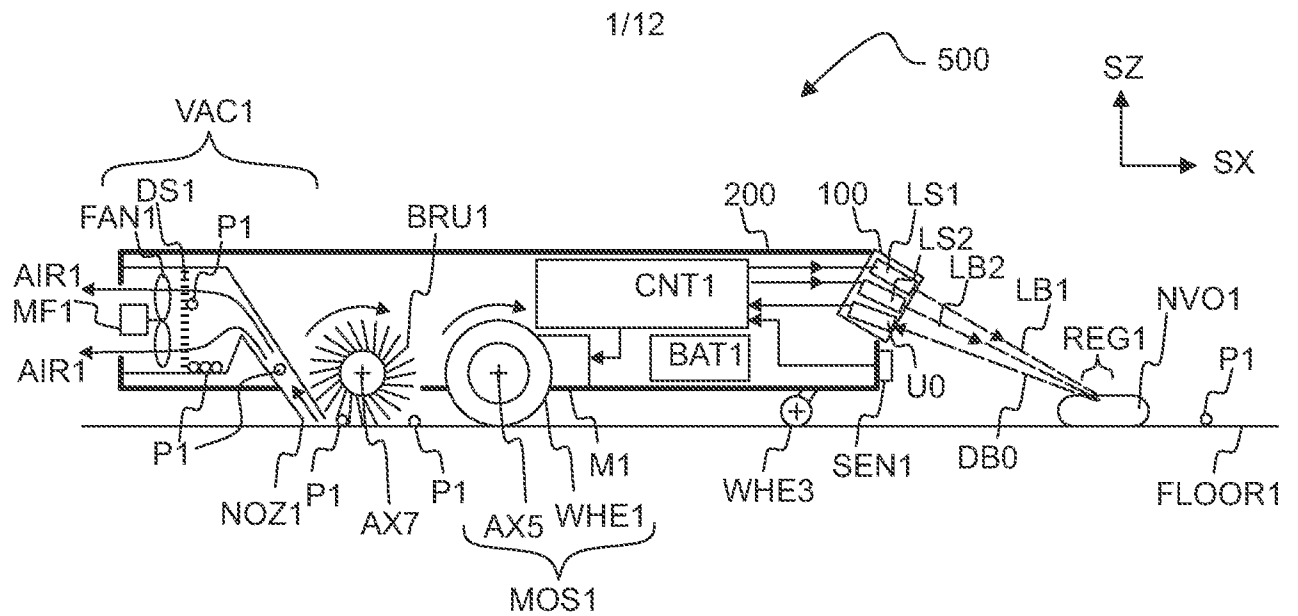
8. The device (500) according to any of the claims 1 to 7, comprising a first
30 detector unit (U0a) to form a first surveillance region (REG1a), and a second detector unit (U0b) to form a second surveillance region (REG1b), wherein the first light source (LS1) is arranged to illuminate the first surveillance region (REG1a) and the second surveillance region (REG1b) with the first illuminating light (LB1), which has the first wavelength (λ_1).

35

9. The device (500) according to any of the claims 1 to 8, comprising one or more detector units (U0a, U0b), wherein each detector unit (U0a, U0b) defines a surveillance region (REG1a, REG1b), wherein the combined width (w_{TOT}) of the surveillance regions (REG1a, REG1b) of the one or more detector units (U0a, U0b) is greater than the width (w_{CLEAN}) of a cleaning region (CREG1) of the cleaning device (500), the cleaning region (CREG1) being the floor area, which is cleaned by the cleaning device (500) during a single forward movement of the cleaning device (500).
10. The device (500) according to any of the claims 1 to 9, comprising one or more detector units (U0a, U0b), wherein each detector unit (U0a, U0b) defines a surveillance region (REG1a, REG1b), wherein the combined width (w_{TOT}) of the surveillance regions (REG1a, REG1b) of the one or more detector units (U0a, U0b) is greater than 80% of the width (w_{500}) of the cleaning device (500).
11. The device (500) according to any of the claims 1 to 10, wherein the light sources (LS1, LS2) are arranged to modulate the first illuminating light (LB1) and the second illuminating light (LB2), wherein the same detector unit (D0) is arranged to detect first reflected light (RL1) at the first wavelength (λ_1), and to detect second reflected light (RL2) at the second wavelength (λ_2), wherein the first detector signal value (S_{DET1}) and the second detector signal value (S_{DET2}) are formed by demodulation.
12. The device (500) according to any of the claims 1 to 11, wherein the presence sensor (100) is a non-imaging sensor, so as to ensure privacy of the operating environment of the cleaning device (500).
13. A method for cleaning a floor (FLOOR1) with an autonomous cleaning device (500), the cleaning device (500) comprising:
- a vacuum unit (VAC1) to remove dust particles (P1) from a floor (FLOOR1),
 - a motive system (MOS1) to move the cleaning device (500) on the floor (FLOOR1),
 - a control system (SYS1) to control movements of the cleaning device (500) based on signals obtained from one or more sensors (SEN1, 100),

wherein the cleaning device (500) comprises an optical presence sensor (100) for detecting the presence of a non-vacuumable object (NVO1), the optical presence sensor (100) comprising:

- a first light source (LS1) to illuminate a surveillance region (REG1) with first illuminating light (LB1), which has a first wavelength (λ_1), the first wavelength (λ_1) being within an optical absorption band of liquid water,
 - a second light source (LS2) to illuminate the surveillance region (REG1) with second illuminating light (LB2), which has a second wavelength (λ_2),
 - one or more detectors (DET0) to gather reflected light (RL1, RL2) from the surveillance region (REG1),
- the method comprising:
- moving the cleaning device (500),
 - forming a first detector signal value (S_{DET1}) indicative of spectral intensity of gathered reflected light (RL1) at the first wavelength (λ_1),
 - forming a second detector signal value (S_{DET2}) indicative of spectral intensity of gathered reflected light (RL2) at the second wavelength (λ_2),
 - determining based on the first detector signal value (S_{DET1}) and based on the second detector signal value (S_{DET2}) whether a non-vacuumable object (NVO1) is present in the surveillance region (REG1),
- wherein the first wavelength (λ_1) is within an optical absorption band of liquid water.



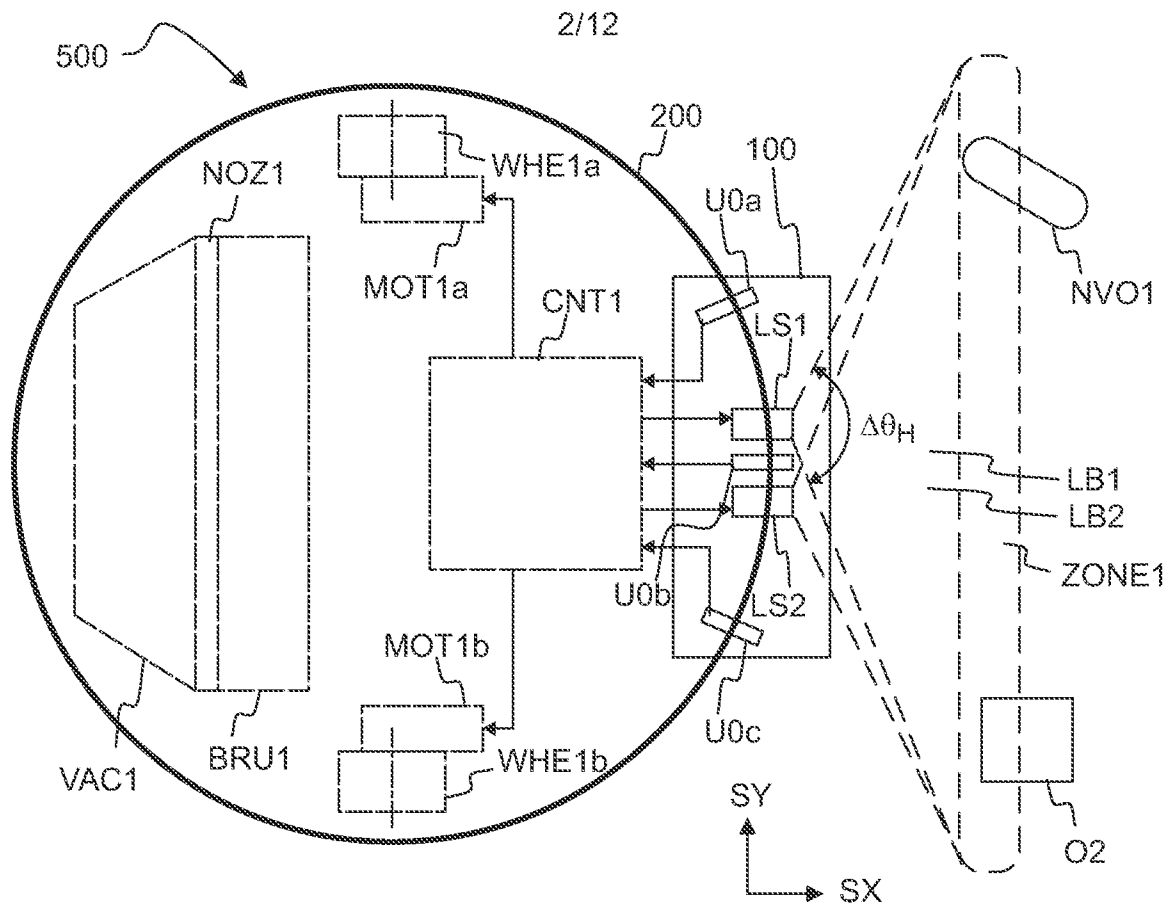


Fig. 3a

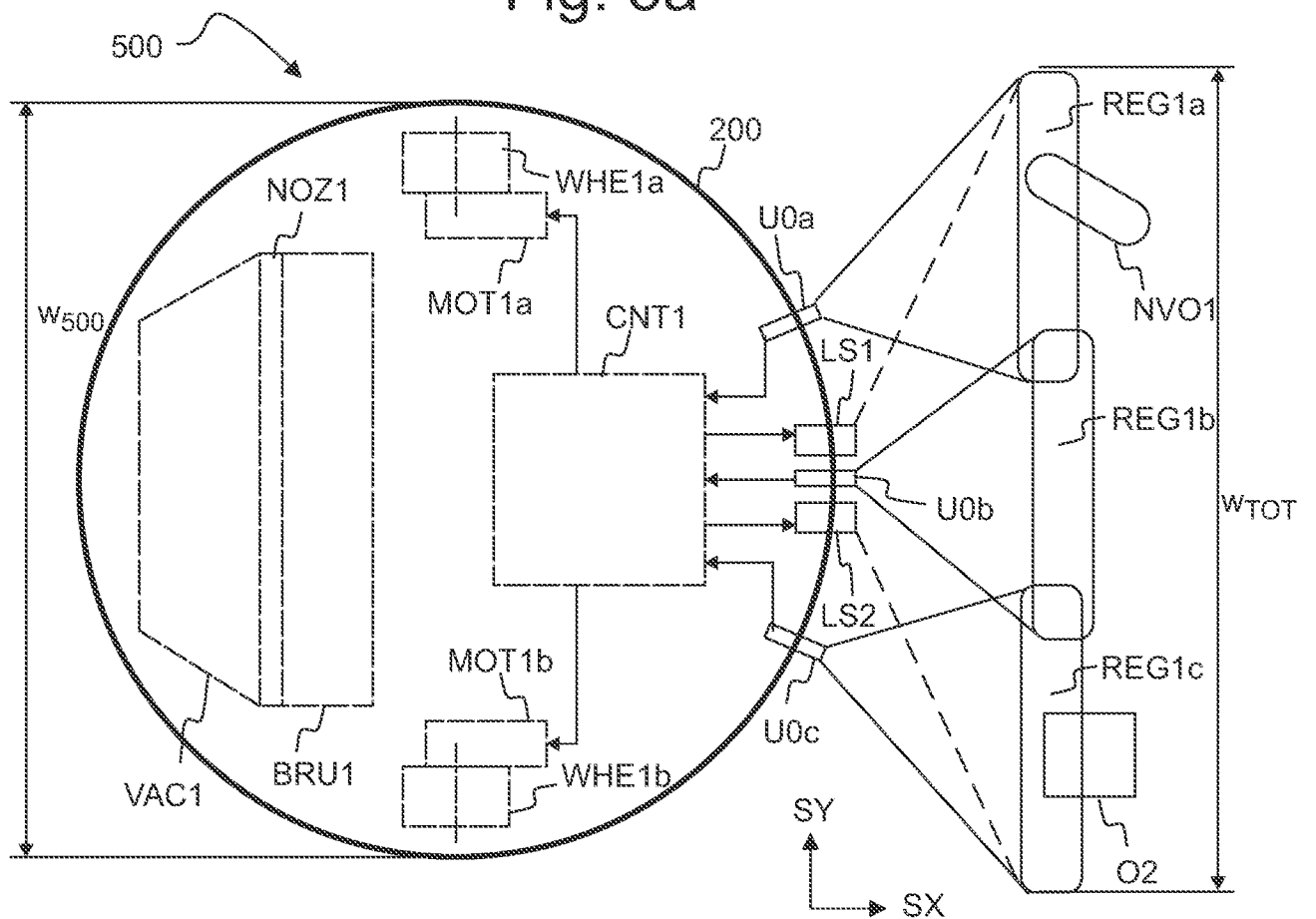


Fig. 3b

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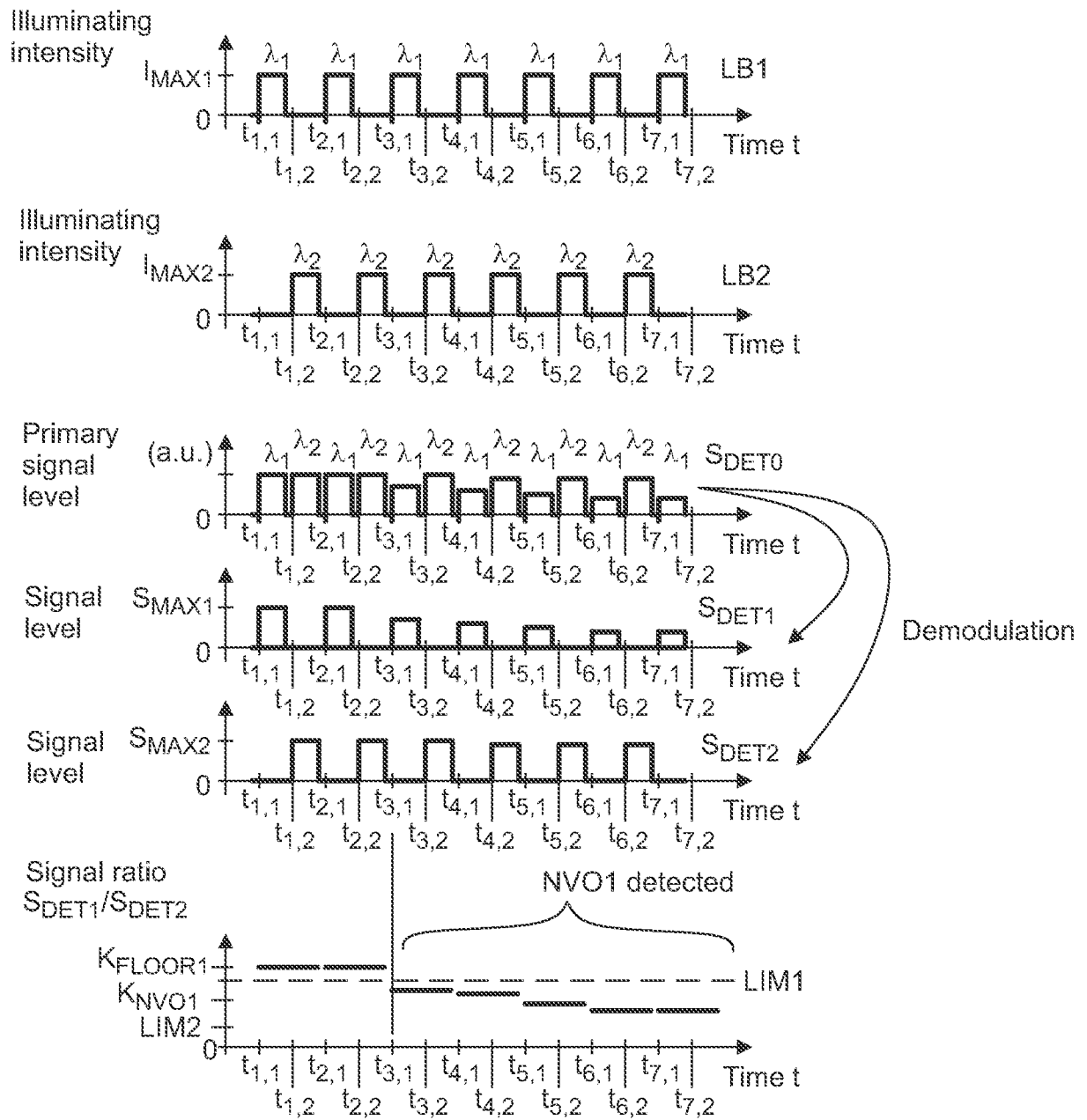


Fig. 4

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Spectral transmittance of liquid water
(Layer thickness = 1 mm)

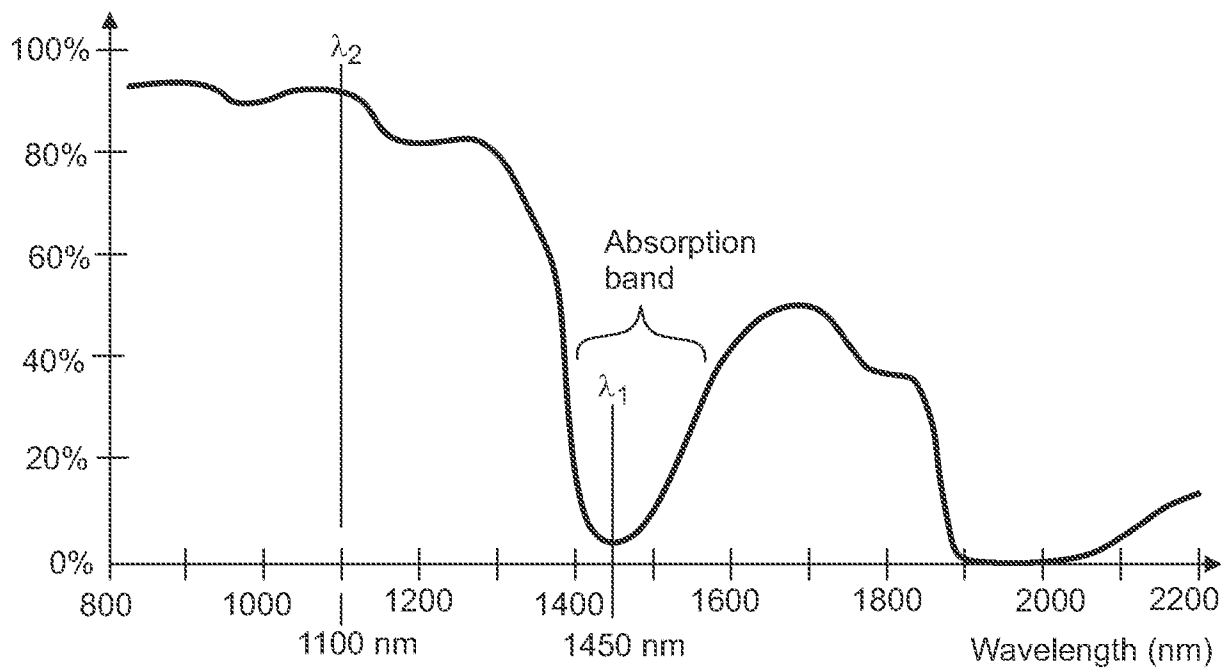


Fig. 5

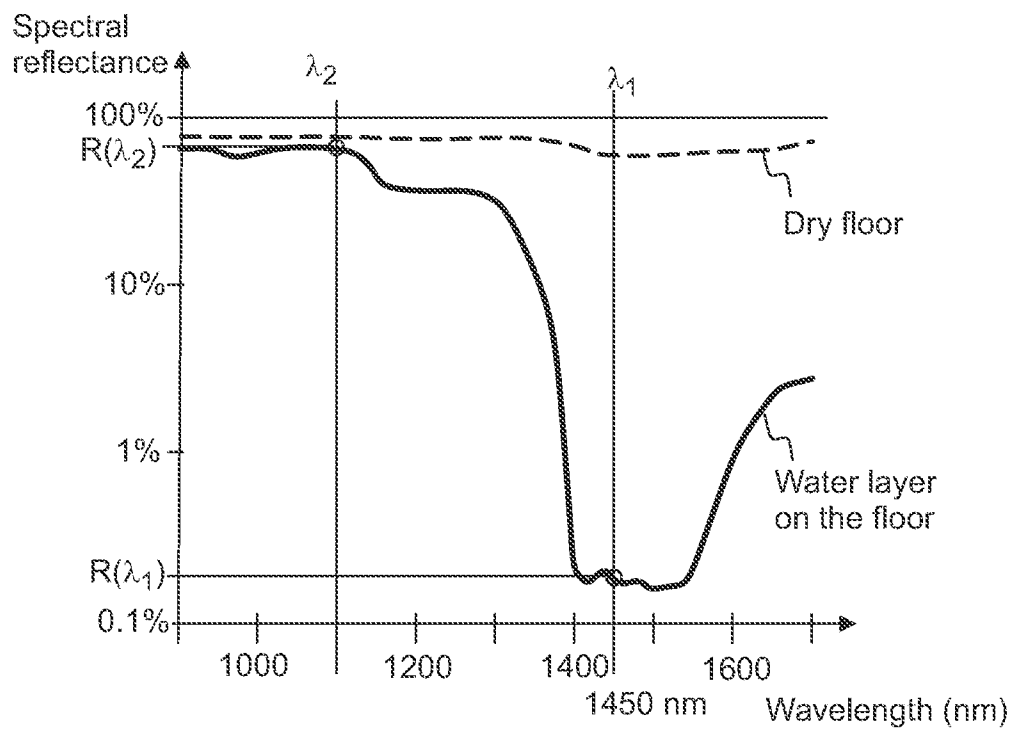


Fig. 6

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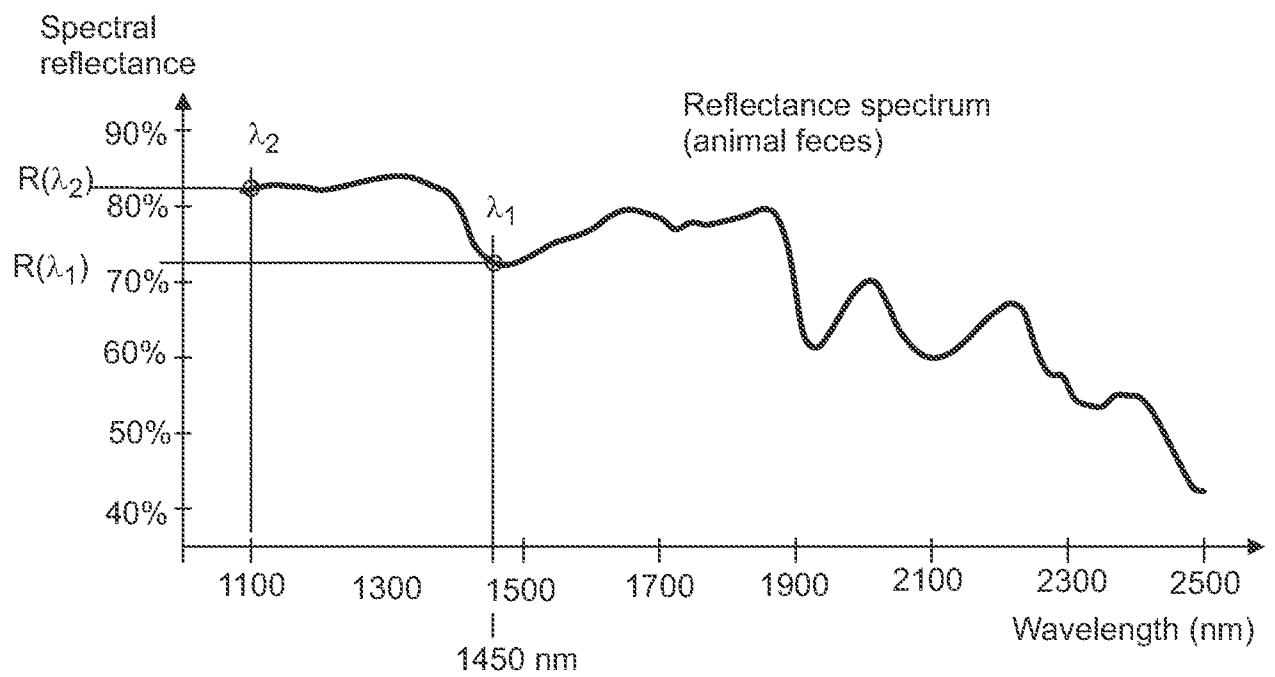


Fig. 7a

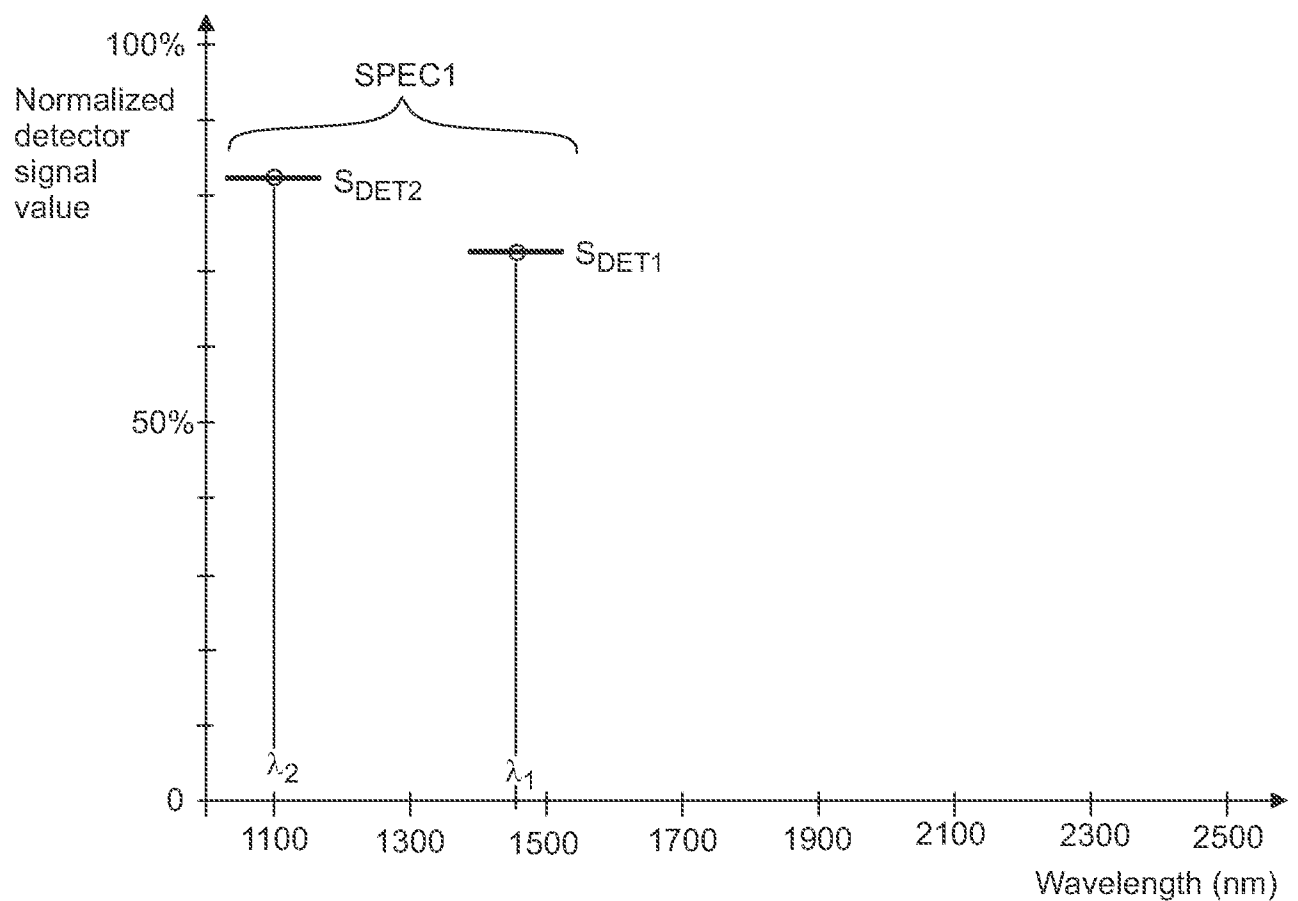


Fig. 7b

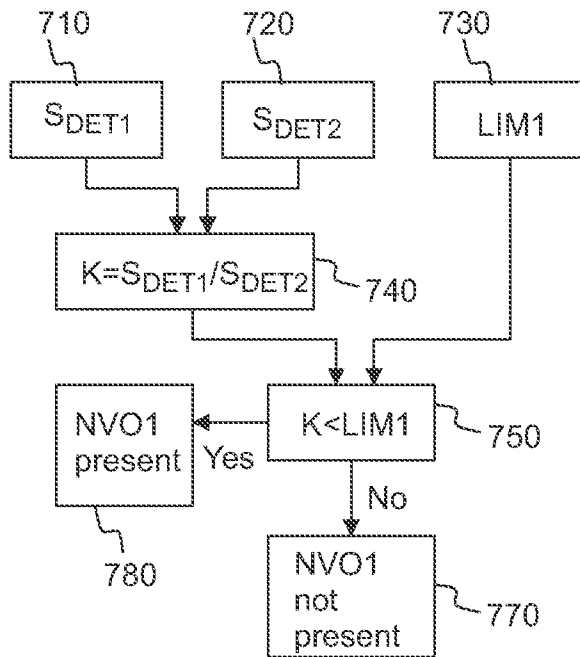


Fig. 7c

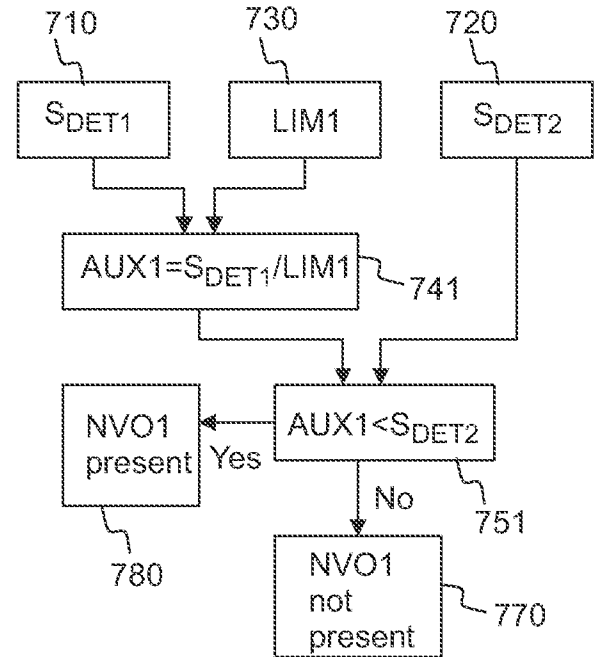


Fig. 7d

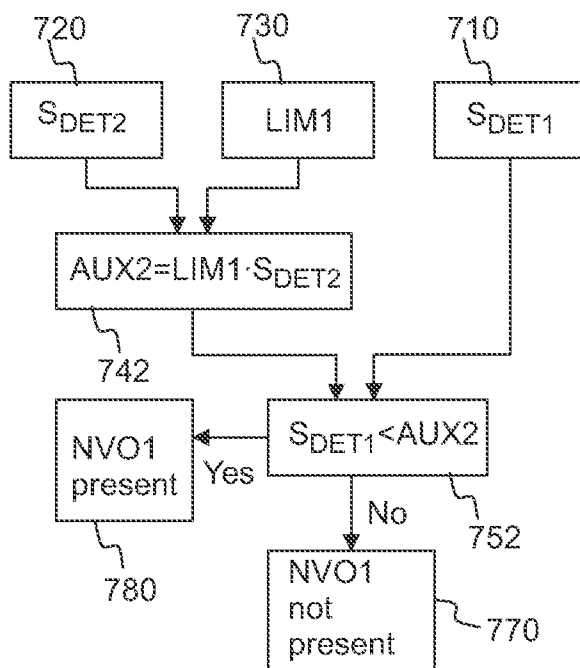


Fig. 7e

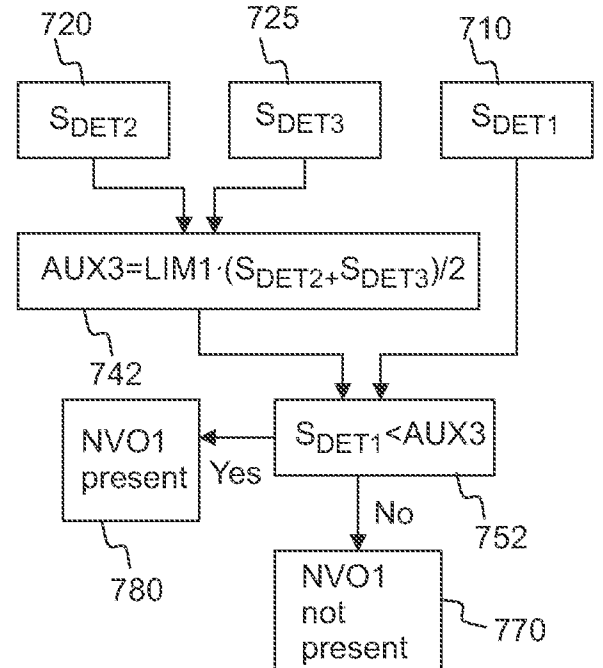


Fig. 7f

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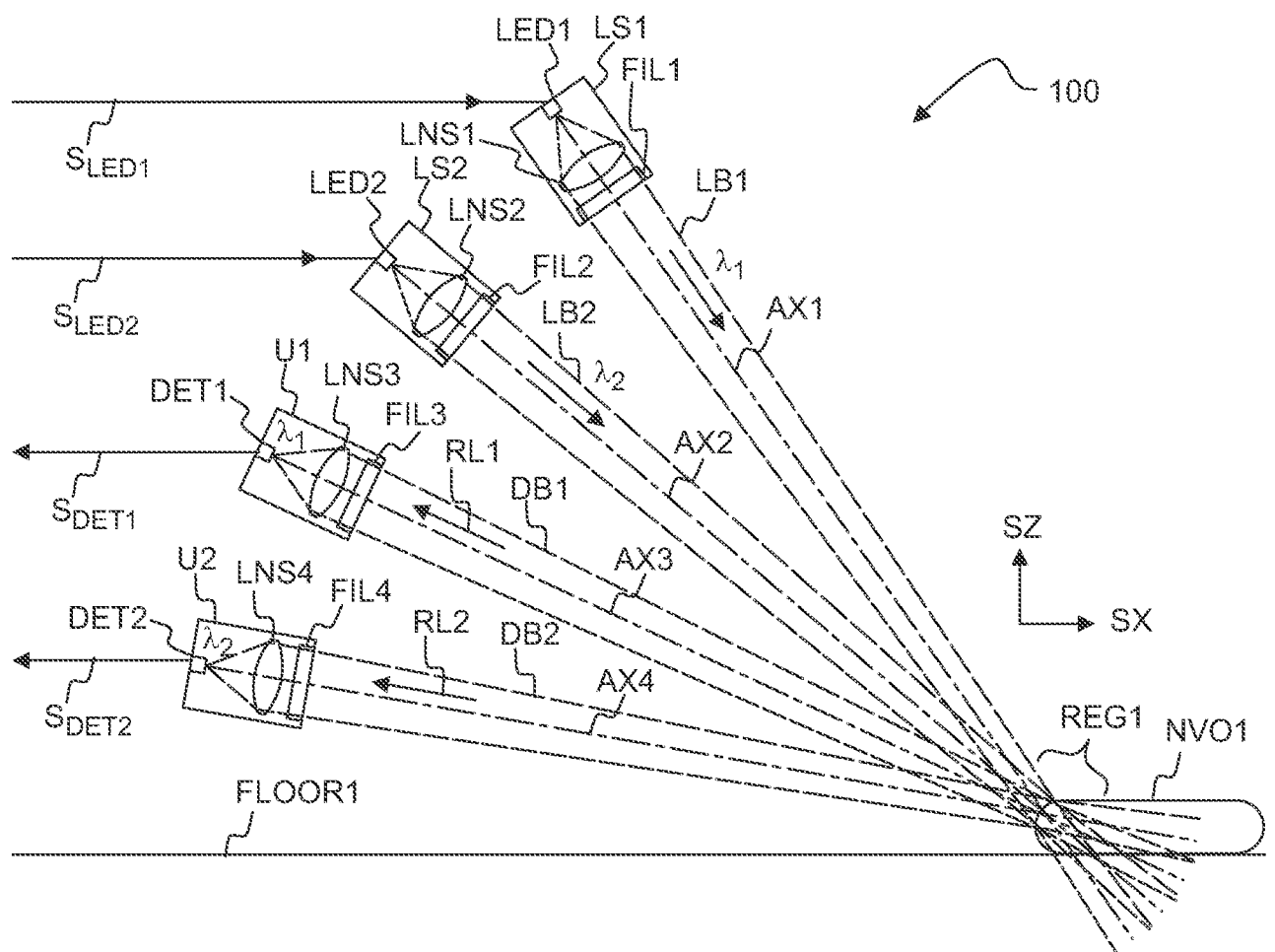


Fig. 8

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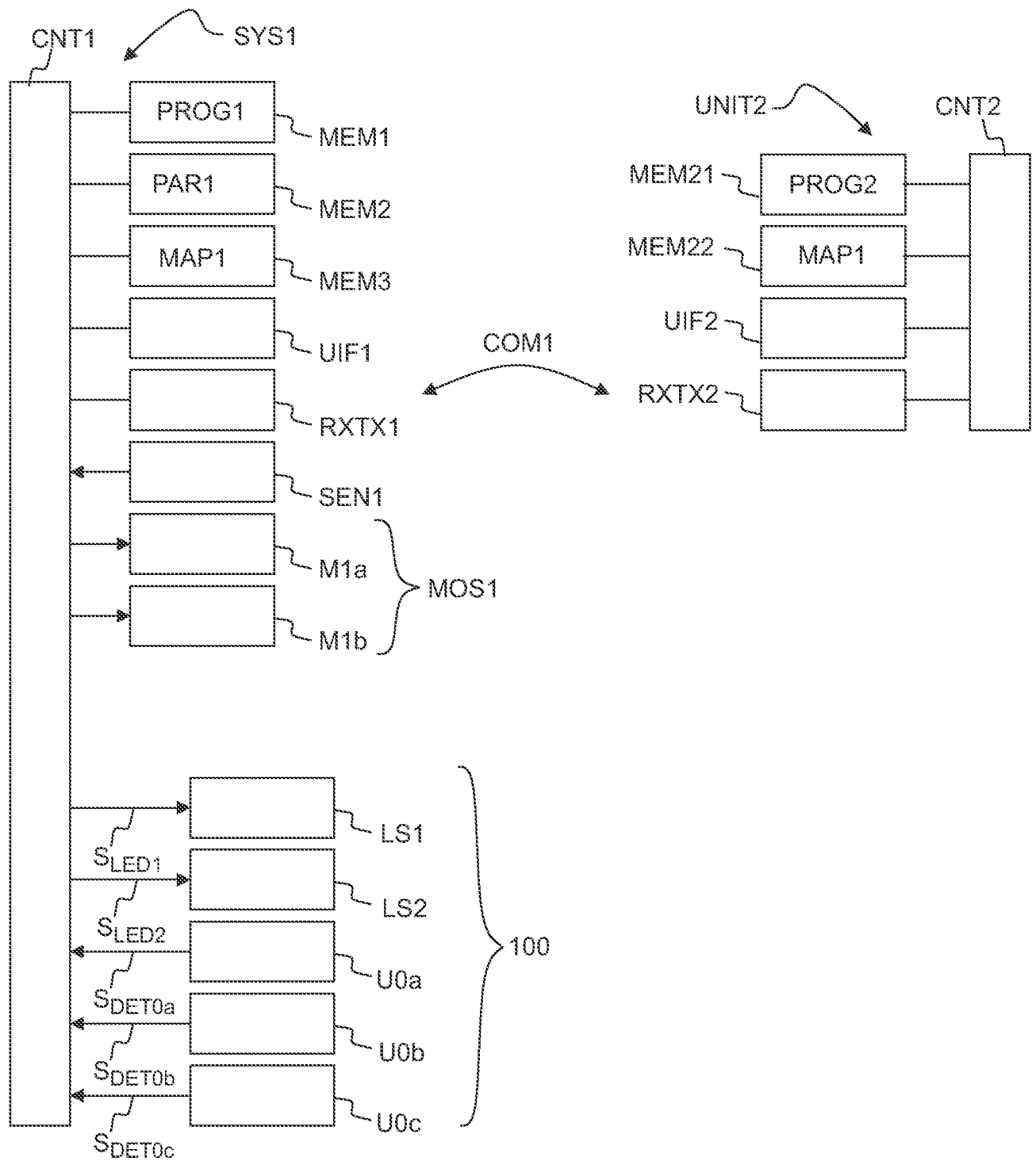


Fig. 9

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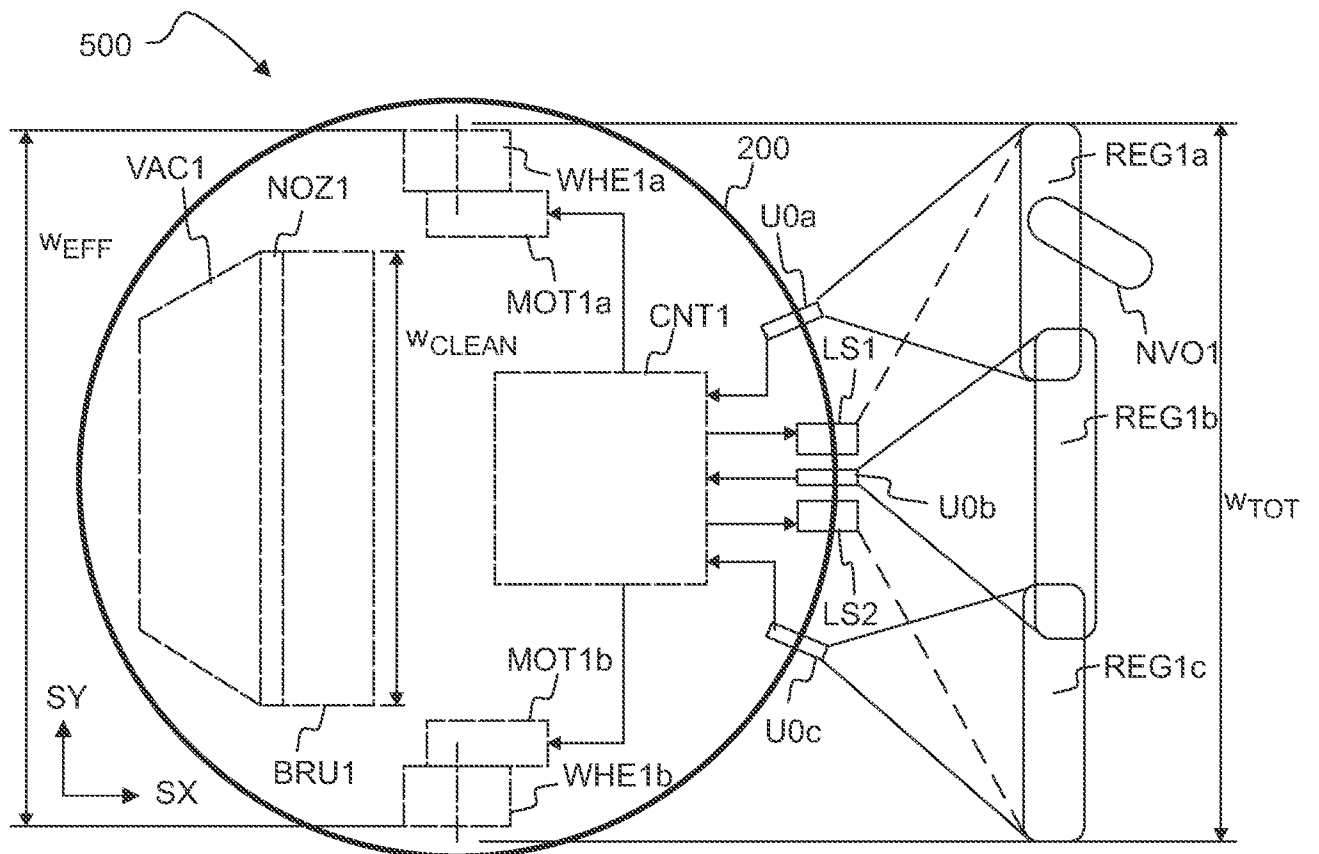


Fig. 10a

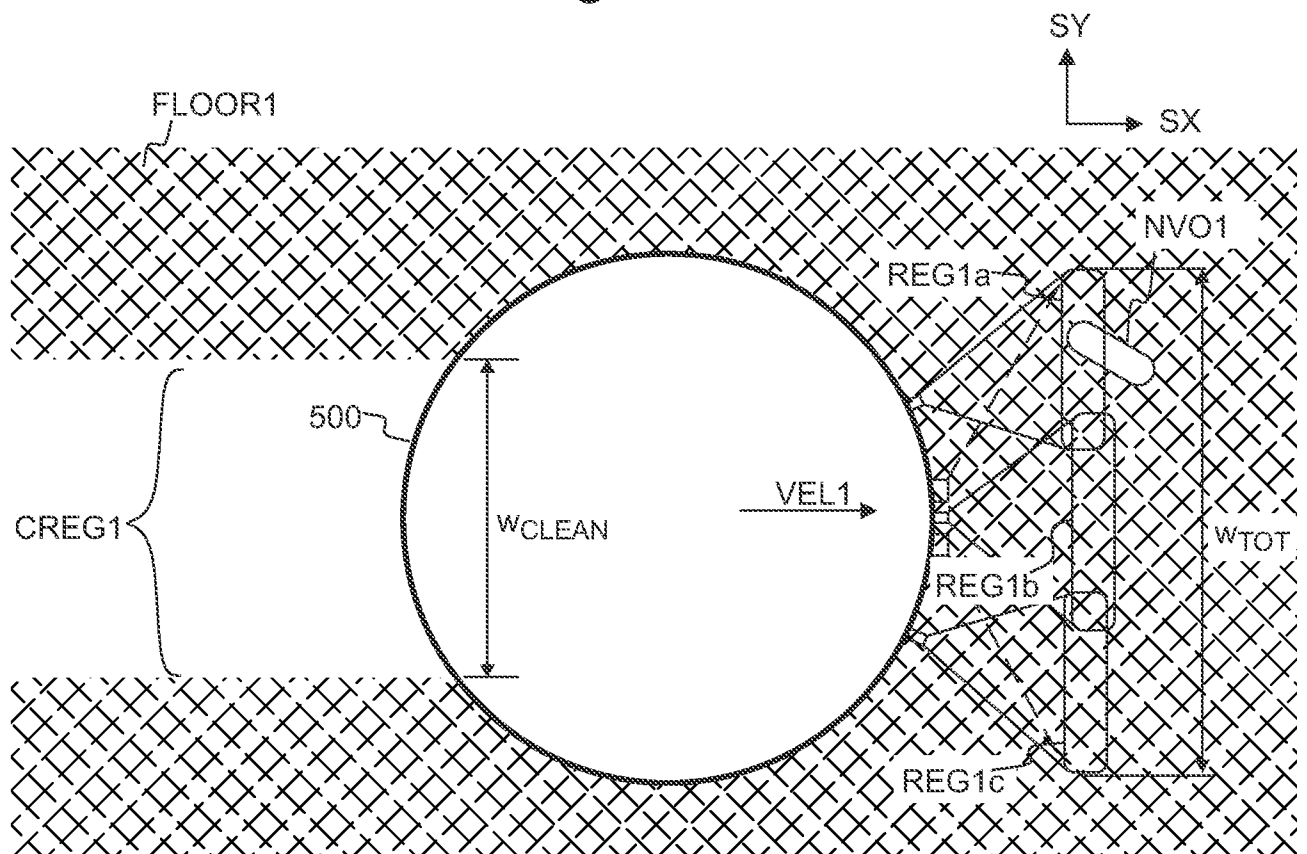


Fig. 10b

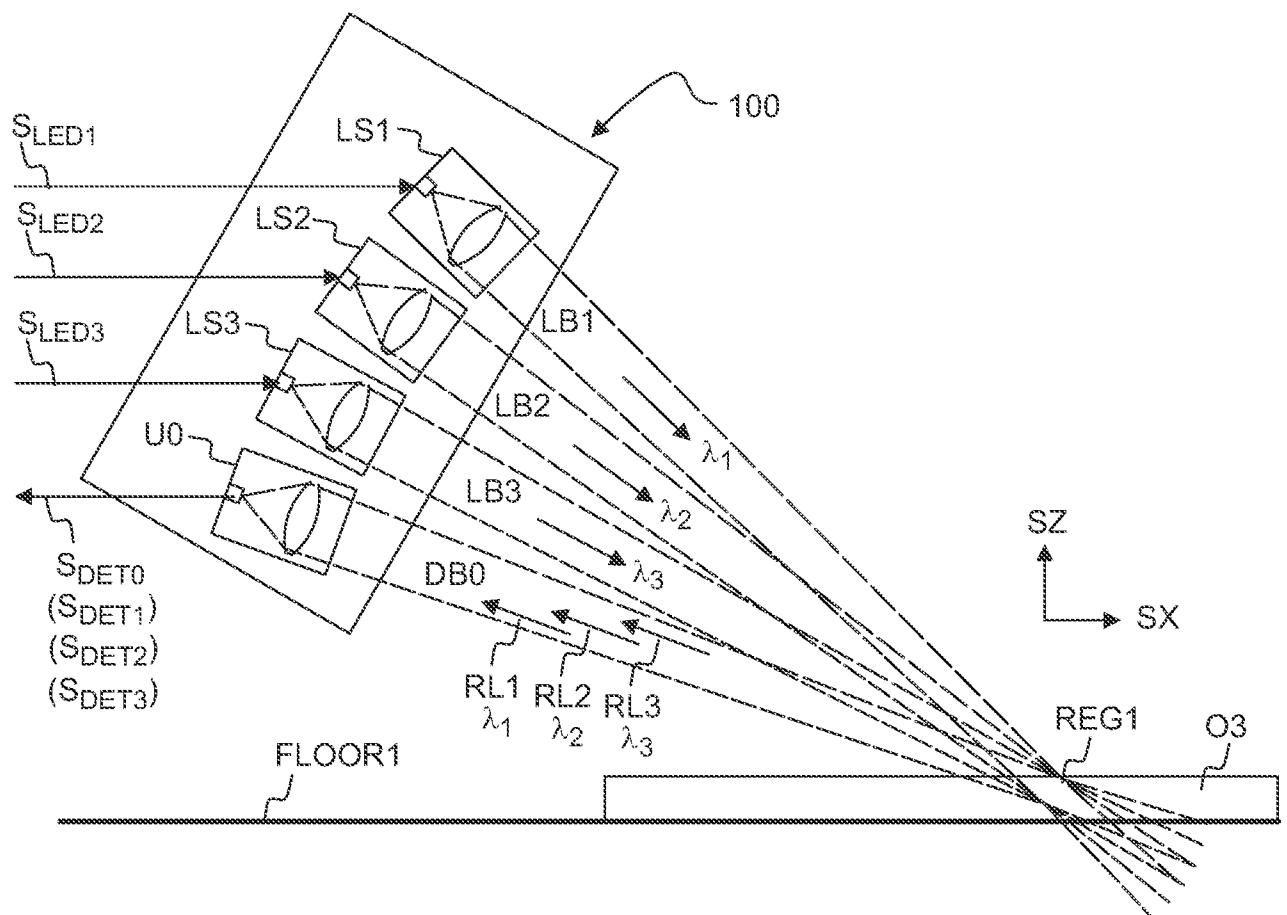


Fig. 11

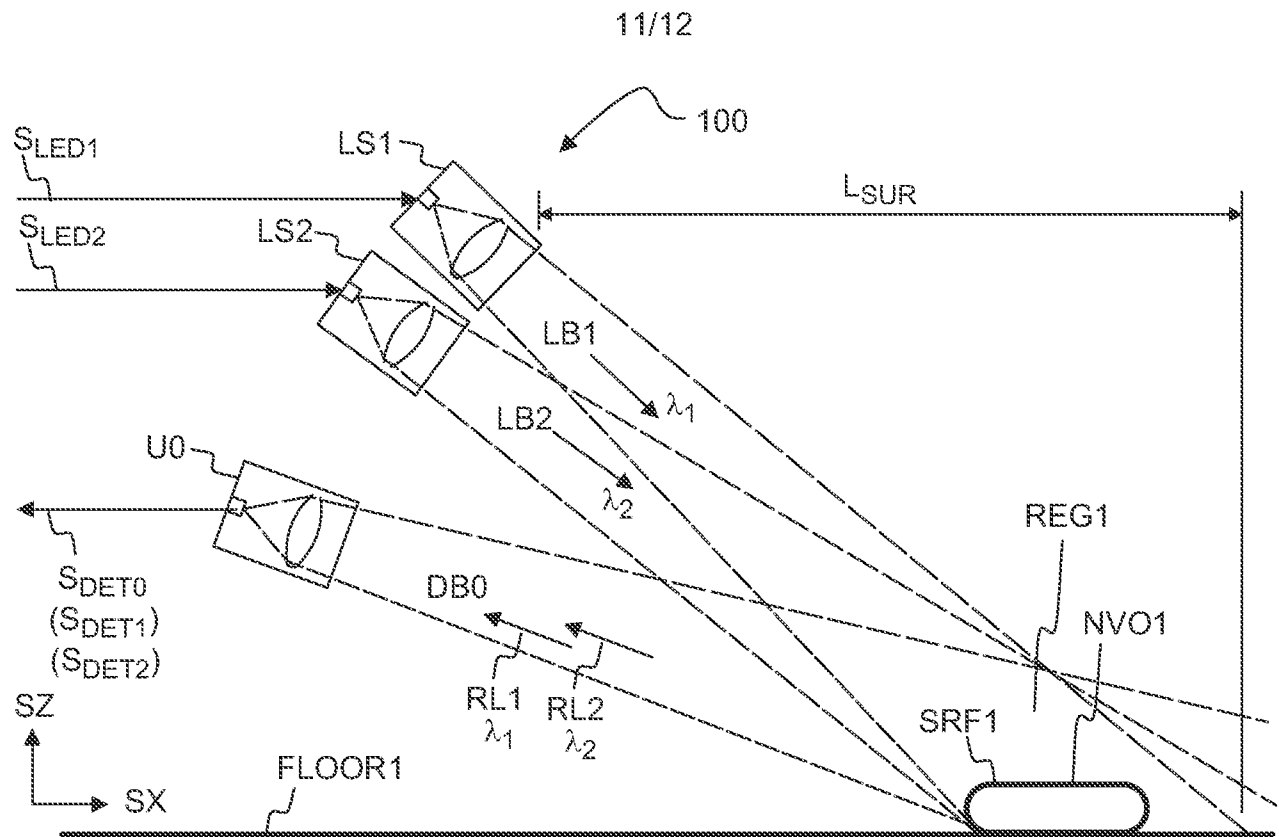


Fig. 12a

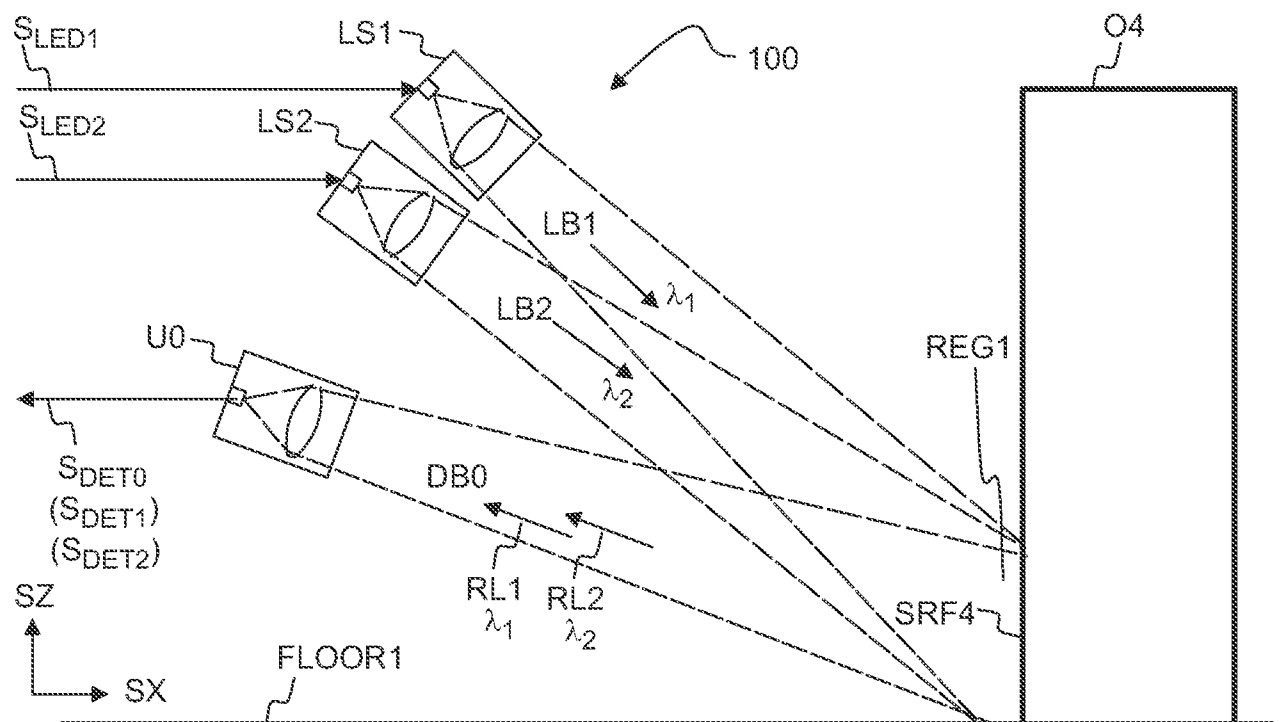


Fig. 12b

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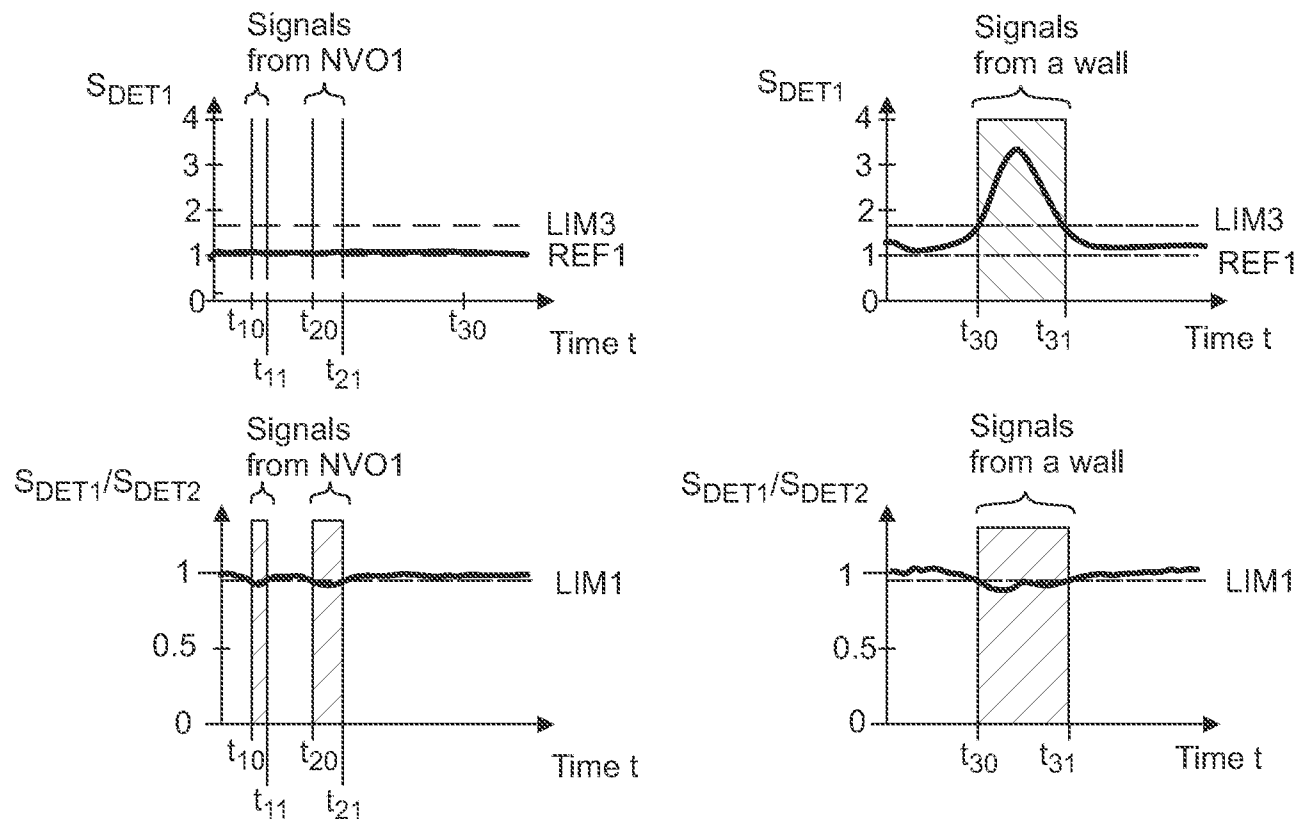


Fig. 13a

Fig. 13b

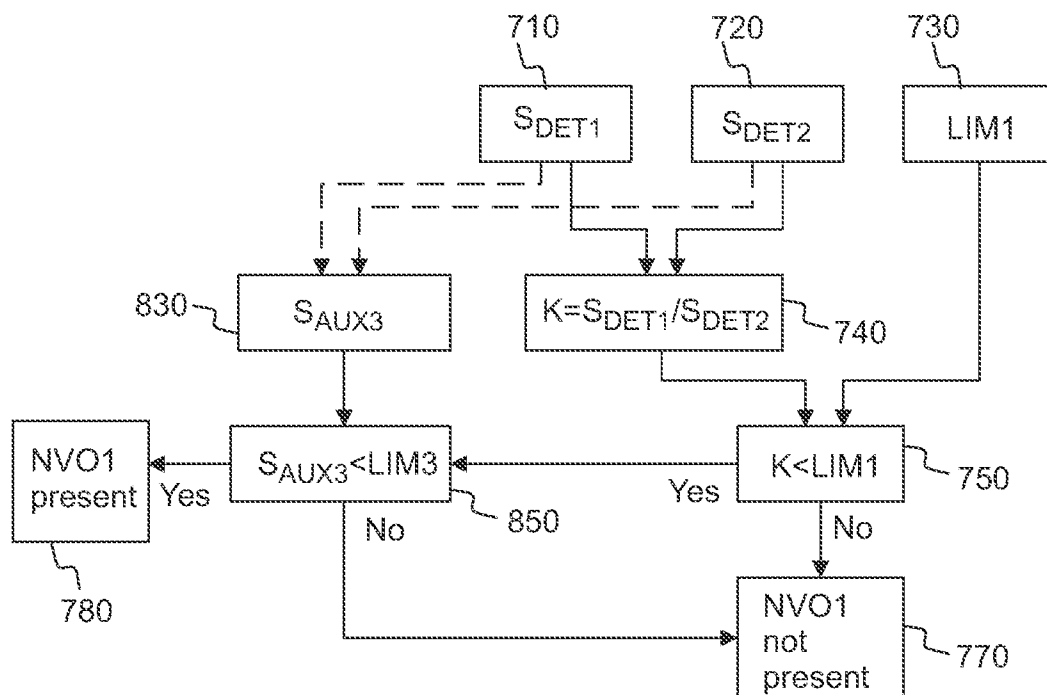


Fig. 14

INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2022/050160

A. CLASSIFICATION OF SUBJECT MATTER

INV. A47L9/00 G01N21/3554 G01N21/31
ADD. G01N21/359

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A47L G01N

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	DE 10 2018 200719 A1 (BSH HAUSGERAETE GMBH [DE]) 18 July 2019 (2019-07-18) paragraphs [0001], [0002], [0012], [0020] - [0028] figure 1 -----	1-6, 12, 13
X	US 2015/192466 A1 (KUSUKAME KOICHI [JP] ET AL) 9 July 2015 (2015-07-09) paragraph [0173] - paragraph [0178] paragraph [0219] paragraphs [0136], [0164] - [0175], [0203] - [0219] figures 3, 5 -----	1, 2, 4-7, 11-13
X	DE 10 2012 108008 A1 (MIELE & CIE [DE]) 6 March 2014 (2014-03-06) paragraphs [0001], [0006], [0019] figure 1 ----- -/-	1-5, 8, 12, 13

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

☒ See patent family annex.

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Date of the actual completion of the international search

3 June 2022

Date of mailing of the international search report

14/06/2022

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INTERNATIONAL SEARCH REPORT

International application No

PCT/FI2022/050160

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 3 317 792 A1 (IROBOT CORP [US]) 9 May 2018 (2018-05-09) paragraphs [0060], [0072] figures 4C, 7 -----	9, 10
Y	EP 2 672 287 A1 (SAMSUNG ELECTRONICS CO LTD [KR]) 11 December 2013 (2013-12-11) paragraph [0076] -----	9, 10
A	US 2018/353042 A1 (GIL HWAN-HEE [KR] ET AL) 13 December 2018 (2018-12-13) paragraphs [0010], [0089], [0090], [0213] -----	1-13
A	US 2010/168694 A1 (GAKHAR SUDHANSHU [US] ET AL) 1 July 2010 (2010-07-01) paragraph [0073] -----	1-13

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/FI2022/050160

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102018200719 A1	18-07-2019	NONE	
US 2015192466 A1	09-07-2015	JP 6549842 B2	24-07-2019
		JP 6735395 B2	05-08-2020
		JP 2015148600 A	20-08-2015
		JP 2019194615 A	07-11-2019
		US 2015192466 A1	09-07-2015
DE 102012108008 A1	06-03-2014	NONE	
EP 3317792 A1	09-05-2018	CN 107847098 A	27-03-2018
		CN 110269546 A	24-09-2019
		EP 3317792 A1	09-05-2018
		US 2017001311 A1	05-01-2017
		US 2018169863 A1	21-06-2018
		WO 2017004524 A1	05-01-2017
EP 2672287 A1	11-12-2013	CN 103479307 A	01-01-2014
		EP 2672287 A1	11-12-2013
		JP 6336716 B2	06-06-2018
		JP 2013252431 A	19-12-2013
		US 2013331990 A1	12-12-2013
		US 2015112538 A1	23-04-2015
		WO 2013183955 A1	12-12-2013
US 2018353042 A1	13-12-2018	KR 20180134230 A	18-12-2018
		US 2018353042 A1	13-12-2018
		WO 2018226048 A1	13-12-2018
US 2010168694 A1	01-07-2010	AR 079176 A1	28-12-2011
		AU 2010332429 A1	31-05-2012
		BR 112012013127 A2	21-03-2017
		CN 102630156 A	08-08-2012
		EP 2512392 A2	24-10-2012
		KR 20120104240 A	20-09-2012
		RU 2012129670 A	27-01-2014
		US 2010168694 A1	01-07-2010
		WO 2011073825 A2	23-06-2011