

Sensor Apparatus for Detecting an Object in a Vicinity

Field of the Invention

5 The present invention relates to a sensor apparatus for detecting an object in a vicinity, and particularly, relates to a sensor apparatus that is capable of being detachably attached to a movable device and programmable to detect an object in a desired zone around the movable device when being attached to the movable device.

Background

With the ascend of technology, robotic devices are widely used in the consumer market and industry. These robotic devices move around a place relying on sensors and navigation systems without any human intervention whilst it is on the move. Some
15 examples of such robotic devices are robotic vacuum cleaners, Autonomous Guided Vehicles (AGVs) that transport articles or objects around within a premises. Add-on autonomous kits that are attachable to ordinary movable devices and transform the ordinary movable devices into intelligent self-navigating devices are also well known.

20 One indispensable component of these robotic devices is the sensor system. The robotic devices are equipped with various types of sensors for sensing the environment in order to determine its location and the path to the destination. While it is important to sense the environment so that the robotic devices move according to planned paths, it is also important that the robotic devices are equipped with object detection sensors for detecting
25 obstacles in the planned paths to prevent collision, or even crashing into the obstacles. These object detection sensors are conventionally build-in sensors whose positions are configured according to the shape and size of robotic devices and which have to be optimized to provide better coverage and effective detection. As most autonomous robotic devices are designed from ground up, sensor layout is highly tailored and customized,
30 and at times even blending in with the surface.

In the case when the add-on autonomous kits are coupled to various movable devices to enable self-navigation, the movable devices also need to be provided with object detection sensors for safety. One approach may be to attach a combination of active and
35 passive sensors to the movable devices to cover the most critical areas and customize a sensor layout for each device. However, since a variety of movable devices may be used,

to configure sensor positions of the object detection sensors for each movable device is time-consuming, tedious, un-scalable and expensive.

Therefore, it is desirable to have “plug-and-run” object detection sensors which are capable of being detachably attached to the movable devices and which are also cheap, suitable for mass-production and computationally easy to set up.

Summary

In accordance with one aspect of the present invention, there is provided a sensor apparatus for detecting an object in a vicinity, the sensor apparatus comprising a plurality of sensing elements, each configured to transmit and receive detection signals, the sensing elements being arranged in a plurality of directions such that detection ranges of the sensing elements overlap to provide a coverage of at least 90 degrees; and an attachment member configured to detachably attach the sensor apparatus to a device.

The sensor apparatus may further include a controller configured to determine whether an object is present in the vicinity based on the detection signals received by the sensing elements.

The controller may determine a value indicating a distance of the object from the sensing apparatus for each of the sensing elements based on the detection signals received when the controller determines that the object is present in the vicinity.

The sensor apparatus may further include a storage unit configured to store a value indicating a safe distance for each of the sensing elements.

The controller may generate a signal when the value indicating the distance of the object determined by the controller for at least one of the sensing elements is less than the value indicating the safe distance stored in the storage unit for the corresponding at least one of the sensing elements.

The controller may generate a signal when the value indicating the distance of the object determined by the controller for at least one of the sensing elements is less than the value indicating the safe distance stored in the storage unit for the corresponding at least one of the sensing elements for a predefined period.

The sensor apparatus may further include a communication module configured to transmit the signal generated by the controller to a remote controller.

5 The controller may determine that an object is present in the vicinity when the detection signals received by at least one of the sensing elements indicate that an object is present in the vicinity.

10 The controller may control each of the sensing elements to generate a detection signal at a different timing or at a different frequency.

Each of the sensing elements may be oriented at an angle to an adjacent sensing element, the angle being smaller than an angle of coverage of the adjacent sensing element.

15 The sensing elements may be arranged on a hemispherical surface or a spherical surface.

The sensing elements may be arranged on surfaces of a convex uniform polyhedron.

20 The sensing elements may be arranged on surfaces of a truncated icosahedron, each surface being provided with one of the sensing elements.

The sensor apparatus may further include a housing configured to protect the sensing elements and allow the detection signals to pass through without any distortion.

25 The sensing elements may be sonar sensing elements and an opening is provided on the housing for each of the sensing elements.

30 The sensor apparatus may further include an indicator associated with each of the sensing elements and configured to indicate a status of the sensing elements.

The sensor apparatus may further include a displacement detector configured to detect a displacement of the sensor apparatus and generate a signal when the sensor apparatus is displaced from a desired orientation.

35 In accordance with another aspect of the present invention, there is provided a method for detecting an object in a vicinity, the method comprising: obtaining a value indicating a safe distance for each of a plurality of sensing elements, the sensing elements being arranged

in a plurality of directions such that detection ranges of the sensing elements overlap to provide a coverage of at least 90 degrees; transmitting and receiving detection signals by the sensing elements; determining whether an object is present in a vicinity based on the detection signals received by the sensing elements; determining a value indicating a distance of the object for each of the sensing elements based on the detection signals received when the object is determined to be present in the vicinity; and generating a signal when the value indicating the distance of the object determined for at least one of the sensing elements is less than the value indicating the safe distance obtained for the corresponding at least one of the sensing elements.

Brief Description of the Drawings

Embodiments of the sensor apparatus will now be described with reference to the accompanying figures in which:

Fig. 1 is a perspective view of an example of a sensor apparatus;

Fig. 2 is an exploded view of the sensor apparatus of Fig. 1;

Fig. 3 is a view showing an interior of the sensor apparatus of Fig. 1;

Figs. 4A and 4B are perspective views of another example of the sensor apparatus;

Fig. 5 shows other examples of the sensor apparatus;

Fig. 6 is a flowchart illustrating a set-up process of the sensor apparatus when the sensor apparatus is attached to a movable device;

Fig. 7 shows a top view and a side view of desired zones around the movable device within which an object needs to be detected;

Fig. 8 shows positions at which the sensor apparatuses are attached to the movable device;

Fig. 9 illustrates the set-up process by placing objects on the boundaries of the desired zones;

Fig. 10 is a table elaborating results of the set-up process;

Fig. 11 illustrates the scaling up and scaling down of the desired zones without re-learning;

- 5 Fig. 12 shows addition of the sensor apparatuses to cover new zones within which an object needs be detected;

Fig. 13 illustrates a case when a sensor apparatus is misplaced; and

- 10 Fig. 14 is a flowchart illustrating an object detection method performed by the sensor apparatus in operation.

Detailed Description

- 15 Figs. 1 to 3 illustrate an example of a sensor apparatus 100 for detecting an object in a vicinity. Fig. 1 is a perspective view of the exemplary sensor apparatus 100 when assembled; Fig. 2 is an exploded view of the sensor apparatus 100; and Fig. 3 is a view showing an interior of the sensor apparatus 100.

- 20 The exemplary sensor apparatus 100 includes a plurality of sensing elements 102 mounted on a housing 110 having a soccer ball shape. The sensing elements 102 are arranged in a plurality of directions such that detection ranges of the sensing elements 102 overlap to provide near 360 degrees of detection coverage. Each of the sensing elements 102 is capable of transmitting a detection signal and receiving the detection
25 signal reflected from objects in the vicinity. In the exemplary sensor apparatus 100, active sonar sensing elements that transmit sound waves and receive reflected sound waves are used as the sensing elements 102. Other types of sensors may also be employed as the sensing elements 102.

- 30 The housing 110 consists of 20 regular hexagonal panels and 12 regular pentagonal panels having sides of the same length, which form surfaces of a truncated icosahedron. Each of these panels except one panel is provided with an opening for accommodating one sonar sensing element 102 so that each of the sonar sensing elements 102 of the sensor apparatus 100 is arranged to face a different direction to transmit and receive
35 detection signals. To provide 360 degrees of detection coverage, each sonar sensing element 102 may be oriented at an angle smaller than a cone angle of adjacent sonar sensing element 102 with respect to the adjacent sonar sensing element 102. When a

pulse of sound is transmitted from a sonar sensing element 102, the width of the sound wave increases in a cone shaped pattern as the sound travels, and the cone angle of the sonar sensing element 102 refers to the area of coverage of that sonar sensing element 102.

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A light-emitting diode (LED) 112 is provided for each of the sonar sensing elements 102 as an indicator indicating a status of the sensing elements 102. For example, when a sonar sensing element 102 is transmitting or receiving the detection signals, the associated LED is switched on. The LEDs 112 may indicate the status of the sensor apparatus 100 as well. For example, when all the LEDs are blinking, it indicates that the sensor apparatus 100 is in a set-up process (i.e. in a learning mode); and all the LEDs may be switched on to indicate that the sensor apparatus 100 has a fault.

The sensor apparatus 100 is provided with an attachment member 140 configured to detachably attach the sensor apparatus 100 to a movable device. The movable device may be push-carts, trolleys, wheelchairs and other platforms which are being pushed or pulled by human or add-on autonomous kits. The attachment member 140 includes a receptor having a mounting hole 142 for receiving a cylindrical insert. A variety of other mechanical means such as clamps may be used as the attachment member 140. The sensor apparatus 100 becomes a bolt-on component of the movable device when it is rigidly attached to the movable device via the attachment member 140 and is capable of detecting an object in the vicinity of the movable device.

A connection member 120 may be provided to connect the housing 110 with the attachment member 140. As shown in Fig. 2, the connection member 120 includes a hollow rectangular section 122 and a T-shaped inserting portion 124 on the end facing the attachment member 140. The attachment member 140 has a corresponding T-shaped receptor 144 on the side facing the connection member 120 for receiving the T-shaped inserting portion 124. On the end of the connection member 120 facing the housing 110, a rectangular opening 126 is formed for receiving a hollow rectangular inserting portion 154 of a support member 150 which is fixed to the housing 110. The connection member 120 and the support member 150 are rigidly connected using bolts through the holes 128 and 158 on the respective surfaces of the hollow rectangular section 122 and the hollow rectangular insertion portion 154, for example, the upper surfaces of the hollow rectangular section 122 and the hollow rectangular insertion portion 154 as shown in Fig. 2.

The support member 150 is fixed to the housing 110 with a fixing member 152, which is shown as a circular plate in between the hollow rectangular inserting portion 154 and a support plate 156. The fixing member 152 is fixed to one of the panels of the housing 110 by bolts such that the hollow rectangular inserting portion 154 protrudes from the housing 110 while the support plate 156 is contained in the housing 110. Thus, as mentioned above, in the sensor apparatus 100, one of the panels of the housing 110 is not provided with a sonar sensing element 102, and a total of 31 sonar sensing elements are used. Accordingly, the sensor apparatus 100 is able to provide near 360 degrees of detection coverage that only excludes the zone blocked by the attachment member 140. That is, a coverage of at least 330 degrees can be easily achieved, making the sensor apparatus 100 suitable for nearly all kinds of near-field object detection applications that require a wide coverage

The support plate 156 provides support to components inside the housing 110. The components contained in the housing 110 include a communication module 162, a controller 164 and a portable power supply 166. The components inside the housing 110 may be electrically connected to external devices through wiring that passes through an opening provided in the circular plate of the fixing member 152, the space inside the hollow rectangular inserting portion 154 and openings (not shown) provided on the lower surfaces of the hollow rectangular section 122 and the hollow rectangular insertion portion 154.

The portable power supply 166, such as batteries that may be rechargeable, supplies power to the communication module 162 and controller 164. Under certain circumstances, external power sources may be used to supply power to the communication module 162 and the controller 164.

The controller 164 controls the sonar sensing elements 102 and performs required processing of object detection. In order to prevent interferences among the detection signals transmitted by the sonar sensing elements 102, the controller 164 is capable of controlling each sonar sensing element 102 to generate a detection signal at a different timing or at a different frequency. When the sonar sensing elements 102 are controlled to generate and receive the detection signals sequentially, the controller 164 ensures that the interval between the generation of the two consecutive detection signals is sufficient for the sonar sensing element generating the former detection signal to receive the former detection signal reflected by objects in the vicinity.

The controller 164 processes the reflected detection signals received by the sonar sensing elements 102 and determine whether an object is present in the vicinity based on the reflected detection signals. For example, the controller 164 makes the decision that an object is present in the vicinity when the detection signals received by at least one of the sonar sensing elements 102 indicate that an object is present in the vicinity. When the controller 164 determines that there is an object present in the vicinity, the controller 164 determines a value indicating a distance of the object in the vicinity for each of the sonar sensing elements 102 based on the reflected detection signals received.

10 The controller 164 may be provided with a storage unit, such as a memory, configured to store a value indicating a safe distance for each of the sonar sensing elements 102 and may generate a signal, for example, an alarm, when the value indicating the distance of the object for at least one sonar sensing elements 102 is less than the value indicating the safe distance stored in the memory for the corresponding at least one sonar sensing elements 102, i.e. when an object is determined to be within an unsafe zone. The controller 164 may also be configured to generate an alarm signal only when the object is determined to be within the unsafe zone for a predefined period, for example, for a period of about 500ms.

20 The communication module 162 is configured to communicate with a remote controller wirelessly, for example, via WiFi, Bluetooth, Zigbee, etc. The communication module 162 is configured to at least transmit the alarm signal generated by the controller to the remote controller. Other information, such as the reflected detection signals received by the sonar sensing elements 102, and the value indicating the distance of the object present in the vicinity for each of the sonar sensing elements 102, may also be transmitted to the remote controller by the communication module 162. An example of the remote controller may be a controller of an add-on autonomous kit, such as the add-on offboard navigation apparatus disclosed in the Singapore Patent Application No. 201307180-8. The communication module 162 may be configured to communicate with external devices via a wired means, for example, Ethernet.

A power button may be provided on any part of the sensor apparatus 100 to switch on or off the sensor apparatus 100. The paring between the sensor apparatus 100 and the controller of the add-on autonomous kit may be configured before attaching the sensor apparatus to the movable device so that when the sensor apparatus 100 is attached to the movable device and switched on, the connection between the sensor apparatus and the controller of the add-on autonomous kit is established automatically via the

communication module 162. The sensor apparatus 100 and the controller of the add-on autonomous kit may be coupled such that the controller of the add-on autonomous kit may force the movable device to stop moving when the connection between the sensor apparatus 100 and the add-on autonomous kit is not established or lost, for example, when the sensor apparatus 100 is switched off or the power from the portable power supply 166 runs out.

Figs. 4A and 4B are perspective views of another example of the sensor apparatus 200. The housing 210 of the sensor apparatus 200 includes a bowl-like structure 212 containing half of the panels of the truncated icosahedron (i.e. 10 regular hexagonal panels and 6 regular pentagonal panels), and a circular plate 214 that covers the bowl-like structure 212. Unlike the sensor apparatus 100, the connection member 220 of the sensor apparatus 200 is not provided with a hollow rectangular section. An opening 216 is provided below the connection member 220 for wiring if needed. In the sensor apparatus 200, 16 sonar sensing elements are used to provide 180 degrees of detection coverage. Other parts of the sensor apparatus 200 are similar to those of the sensor apparatus 100.

The sensing elements 102 of the sensor apparatus may be arranged in a variety of ways as long as they are arranged to face different directions to cover a detection range of at least 90 degrees, for example, 120 degrees, 160 degrees, etc. Fig. 5 shows other examples of the sensor apparatuses 300, 400 and 500. The sensor apparatus 300 has a housing in a shape of a convex uniform polyhedron on which the sensing elements 102 are provided; the sensor apparatus 400 has a spherical housing; and the sensing elements 102 of the sensor apparatus 500 are arranged on a hemispherical surface. The sensing elements 102 may be fixed to the arranged positions by means other than a housing.

The sensor apparatus described above is capable of being detachably attached to any object, such as a movable device, in an ad-hoc fashion without wiring and initial input of safe distances. After being mounted to the movable device, the sensor apparatus may be programmed by a simple set-up process to learn the safe distances based on a desired zone around the movable device. As soon as the safe distances are established, the sensor apparatus is able to function as an object detector for detecting an object in the desired zone around the movable device to safeguard the movable device during navigation.

Fig. 6 is a flowchart illustrating a set-up process 600 or a learning mode for the sensor apparatus when the sensor apparatus is attached to the movable device; and Figs. 7 to

10 illustrate the steps of the set-up process 600 with respect to an exemplary movable device 700.

5 In step 602, desired zones around the movable device within which an object should be detected for safety are determined based on the shape of the movable device, the environment in which the movable device operates, etc. The desired zones usually cover a few meters from the movable device. As illustrated in Fig. 7, two desired zones Z1, Z2 viewed from the top and the side of the movable device 700 are determined at two ends of the movable device 700.

10 In step 604, positions at which the sensor apparatuses are attached to the movable device are determined and the sensor apparatuses are then attached to the movable device via the attachment members. For example, to provide coverage over the two desired zones Z1, Z2, two sensor apparatuses 100a, 100b, such as two exemplary sensor
15 apparatuses 100 that are capable of providing 360 degrees of detection coverage, are positioned in the middle regions of the two ends of the movable device 700 as shown in Fig. 8.

20 In step 606, objects resembling obstacles are placed on the boundaries of the desired zones to obtain values indicting safe distances for each of the sensing elements of each sensor apparatus. For example, in Fig. 9, objects may be placed at obstacle points A to H which are mainly on the vertices of the desired zones Z1, Z2. The number of the obstacle points used varies depending on the size and shape of the desired zones, the size and shape of the movable device, etc. To obtain values indicating safe distances for the
25 sensor apparatus 100a positioned on one end of the movable device 700, an object may be sequentially placed at the obstacle points. When an object is placed at the obstacle point A, the sensor apparatus 100a is controlled, for example, by the remote controller, to transmit and receive the detection signals in presence of the object at A so that a value indicating a distance of the object at A to the sensor apparatus 100a (i.e. the distance of
30 the object at A to the movable device 700) for each sensing element 102 is determined by the controller 164 of the sensor apparatus 100a base on the received detection signals. The process of determining the values indicating distances of the object to the sensor apparatus 100a is repeated for each obstacle point on the boundaries of the desired zone Z1. After the values indicating distances of objects at all the obstacle points for each
35 sensing element 102 are obtained, the minimum value among the values for one sensing element 102 is determined as a value indicating a safe distance for that sensing element 102 within which an object will trigger the controller 164 of the sensor apparatus 100a to

produce an alarm signal (step 608). In Fig. 10, the values indicating distances resulted from an example of a set-up process are illustrated in a table in which a desired zone for a sensing apparatus having 31 sensing elements are defined by 6 obstacle points. The last row of the table shows the value indicating a safe distance for each sensing element determined from the values obtained in the exemplary set-up process.

The coverage of the sensing apparatus 100a is then confirmed and the value indicating a safe distance for each sensing element 102 is stored in the memory of the controller 164 of the sensor apparatus 100a and is referred to in the operation of the sensing apparatus 100a. A similar process is carried out for the sensing apparatus 100b to obtain a value indicating a safe distance for each sensing element 102 of the sensing apparatus 100b and confirm the coverage.

The set-up process 600 is generally simple and can be quickly completed. For example, it takes about less than a minute to set up one sensor apparatus 100 with a spherical coverage (i.e. an all-round unsafe zone) for any type of movable devices.

After the coverage of the sensing apparatus is confirmed as a result of a set-up process, the coverage may be increased or decreased in a particular direction by applying a simple formula to increase or decrease the selected minimum values of the sensing elements proportionally. The minimum values of the sensing elements are changed on a selective basis depending on the direction of scaling. Fig. 11 illustrates the scaling up and scaling down of the coverage (i.e. the desired zones Z1, Z2) without re-learning. As shown in Fig. 11, the scaling up or scaling down of the coverage of the sensor apparatuses 100a, 100b may not be required in the downward or upward direction. In such cases, the minimum values of the sensing elements that are associated with the lower boundaries of the coverage are not changed proportionally.

Fig. 12 shows addition of the sensor apparatuses 100c, 100d to cover new desired zones Z3, Z4 within which an object needs be detected. For example, when detection of objects present near the sides of the movable device 700 is required, two sensor apparatuses 100c, 100d may be added to cover the desired zones Z3, Z4 by repeating the set-up process 600.

Since the sensor apparatus is detachably attached to the movable device by the attachment member, it is possible that the sensor apparatus may be displaced by external forces. In such cases, the sensor apparatus (e.g. the sensor apparatus 100d) is not able

to cover the desired zone (e.g. Z4) as illustrated in Fig. 13. In view of the problem, the sensor apparatus may include a displacement detector such as an inertia measurement unit (IMU) configured to detect a displacement of the sensor apparatus and produce an alarm when the displacement detector detects that the orientation of the sensor apparatus is changed. Hence, if the movable device is coupled to the add-on autonomous kit, the movable device may be stopped from self-navigation when such alarm is produced and transmitted to the controller of the add-on autonomous kit.

Fig. 14 is a flowchart illustrating an object detection method 1400 performed by the sensor apparatus in operation. After obtaining a value indicating a safe distance for each of the sensing elements of the sensor apparatus (step 1402), the sensing elements of the sensor apparatus transmit and receive detection signals (step 1404). The controller of the sensor apparatus determines whether an object is present in the coverage of the sensor apparatus based on the detection signals received (step 1406) and determines a value indicating a distance of the object from the sensing apparatus for each of the sensing elements based on the detection signals received when there is an object in the coverage (step 1408). The controller then compares the value indicating the distance of the object determined for each of the sensing elements to the value indicating the safe distance obtained for the corresponding the sensing element (step 1410) to make a decision (step 1412). If the value indicating the distance of the object determined for at least one of the sensing elements is less than the value indicating the safe distance obtained for the corresponding at least one of the sensing elements, i.e. if an object is determined to be within the coverage, the controller generates an alarm signal (step 1414), and the process is repeated from step 1404.

In step 1414, the sensor apparatus produces the alarm signal as soon as it detects an object in the coverage. However, an object may happen to be present in the desired zone for a very short period. For example, a man walks across in front of the movable device. In such circumstances, the object present does not raise any safety concerns. Thus, the sensor apparatus may be programmed to produce an alarm when the object is detected to be present in the coverage for some time greater than a certain period, such as a period of 500ms or a period of 1000ms.

The examples of the sensor apparatus described above are able to function as “plug-and-run” object detection sensors capable of being detachably attached to any movable devices and being set up quickly. They are also cheap and suitable for mass-production so that they can be widely used in many different applications.

Whilst there has been described in the foregoing description embodiments of the present invention, it will be understood by those skilled in the technology concerned that many variations or modifications in details of design or construction may be made without
5 departing from the present invention.

Claims

1. A sensor apparatus for detecting an object in a vicinity, the sensor apparatus comprising:

5 a plurality of sensing elements, each configured to transmit and receive detection signals, the sensing elements being arranged in a plurality of directions such that detection ranges of the sensing elements overlap to provide a coverage of at least 90 degrees; and

10 an attachment member configured to detachably attach the sensor apparatus to a device.

2. The sensor apparatus according to claim 1, further comprising a controller configured to determine whether an object is present in the vicinity based on the detection signals received by the sensing elements.

15 3. The sensor apparatus according to claim 2, wherein the controller determines a value indicating a distance of the object from the sensing apparatus for each of the sensing elements based on the detection signals received when the controller determines that the object is present in the vicinity.

20 4. The sensor apparatus according to claim 3, further comprising a storage unit configured to store a value indicating a safe distance for each of the sensing elements.

25 5. The sensor apparatus according to claim 4, wherein the controller generates a signal when the value indicating the distance of the object determined by the controller for at least one of the sensing elements is less than the value indicating the safe distance stored in the storage unit for the corresponding at least one of the sensing elements.

30 6. The sensor apparatus according to claim 4, wherein the controller generates a signal when the value indicating the distance of the object determined by the controller for at least one of the sensing elements is less than the value indicating the safe distance stored in the storage unit for the corresponding at least one of the sensing elements for a predefined period.

35 7. The sensor apparatus according to claim 5 or 6, further comprising a communication module configured to transmit the signal generated by the controller to a remote controller.

8. The sensor apparatus according to any one of claims 2 to 7, wherein the controller determines that an object is present in the vicinity when the detection signals received by at least one of the sensing elements indicate that an object is present in the vicinity.
- 5 9. The sensor apparatus according to any one of claims 2 to 8, wherein the controller controls each of the sensing elements to generate a detection signal at a different timing or at a different frequency.
- 10 10. The sensor apparatus according to any one of claims 1 to 9, wherein each of the sensing elements is oriented at an angle to an adjacent sensing element, the angle being smaller than an angle of coverage of the adjacent sensing element.
11. The sensor apparatus according to any one of claims 1 to 10, wherein the sensing elements are arranged on a hemispherical surface or a spherical surface.
- 15 12. The sensor apparatus according to any one of claims 1 to 10, wherein the sensing elements are arranged on surfaces of a convex uniform polyhedron.
13. The sensor apparatus according to any one of claims 1 to 10, wherein the sensing elements are arranged on surfaces of a truncated icosahedron, each surface being provided with one of the sensing elements.
- 20 14. The sensor apparatus according to any one of claims 1 to 13, further comprising a housing configured to protect the sensing elements and allow the detection signals to pass through without any distortion.
- 25 15. The sensor apparatus according to claim 14, wherein the sensing elements are sonar sensing elements and an opening is provided on the housing for each of the sensing elements.
- 30 16. The sensor apparatus according to any one of claims 1 to 15, further comprising an indicator associated with each of the sensing elements and configured to indicate a status of the sensing elements.
- 35 17. The sensor apparatus according to any one of claims 1 to 16, further comprising a displacement detector configured to detect a displacement of the sensor apparatus and generate a signal when the sensor apparatus is displaced from a desired orientation.

18. A method for detecting an object in a vicinity, the method comprising:

obtaining a value indicating a safe distance for each of a plurality of sensing elements, the sensing elements being arranged in a plurality of directions such that detection ranges of the sensing elements overlap to provide a coverage of at least 90 degrees;

transmitting and receiving detection signals by the sensing elements;

determining whether an object is present in a vicinity based on the detection signals received by the sensing elements;

determining a value indicating a distance of the object for each of the sensing elements based on the detection signals received when the object is determined to be present in the vicinity; and

generating a signal when the value indicating the distance of the object determined for at least one of the sensing elements is less than the value indicating the safe distance obtained for the corresponding at least one of the sensing elements.