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(54) **ROBOTIC CLEANER**

(71) Applicant: **SHARKNINJA OPERATING LLC**, Needham, MA (US)

(72) Inventor: **Derek LESSARD**, Dorchester, MA (US)

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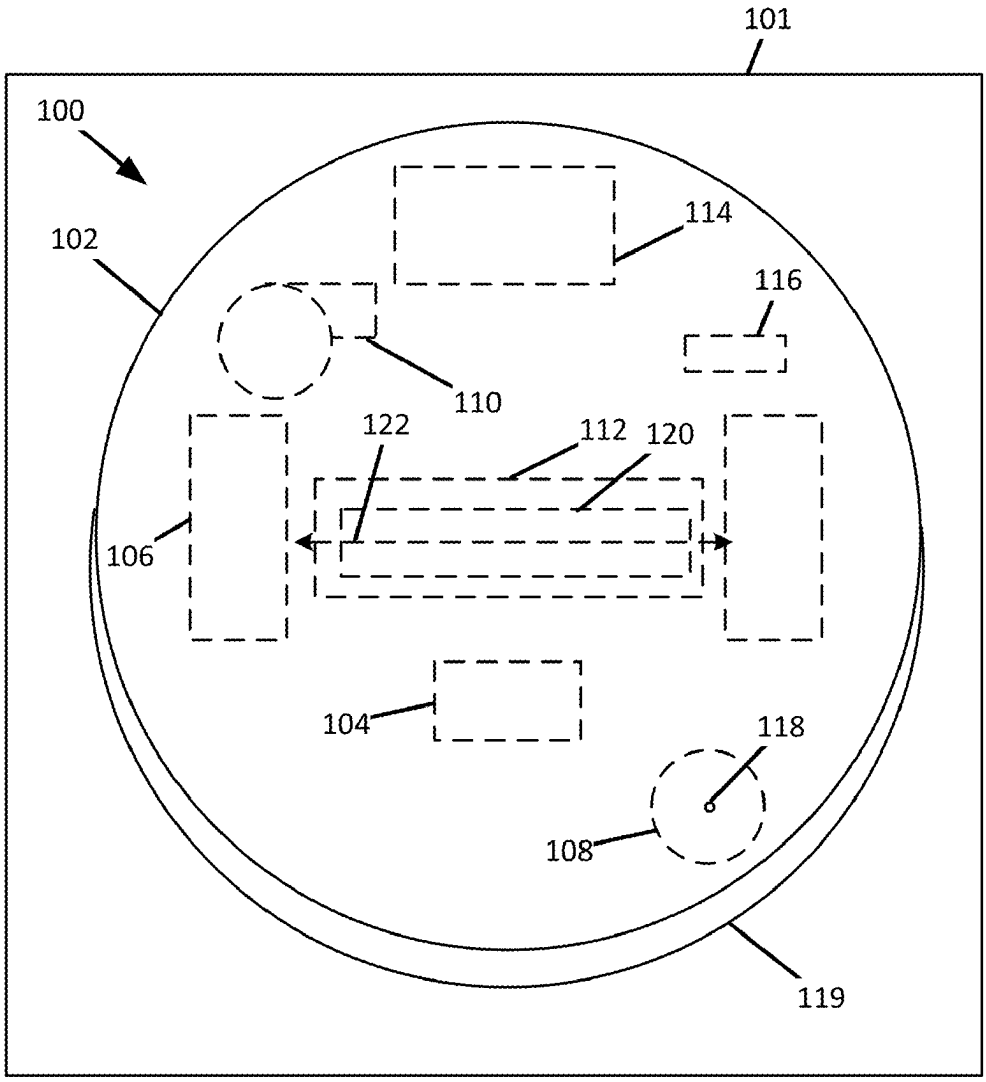
(52) **U.S. Cl.**

CPC ***A47L 9/2852*** (2013.01); ***A47L 9/009*** (2013.01); ***A47L 9/0488*** (2013.01); ***A47L 9/2805*** (2013.01); *A47L 2201/04* (2013.01)

(57) **ABSTRACT**

A robotic cleaner may include one or more driven wheels, one or more environmental sensors, at least one of the one or more environmental sensors configured to detect a first obstacle having a first vertically extending surface, one or more edge cleaning implements, and a controller communicatively coupled to the one or more driven wheels and the one or more environmental sensors. In response to detecting the first obstacle, the controller may be configured to cause the robotic cleaner to move through a rotation angle such that at least one of the one or more edge cleaning implements approaches the first vertically extending surface.



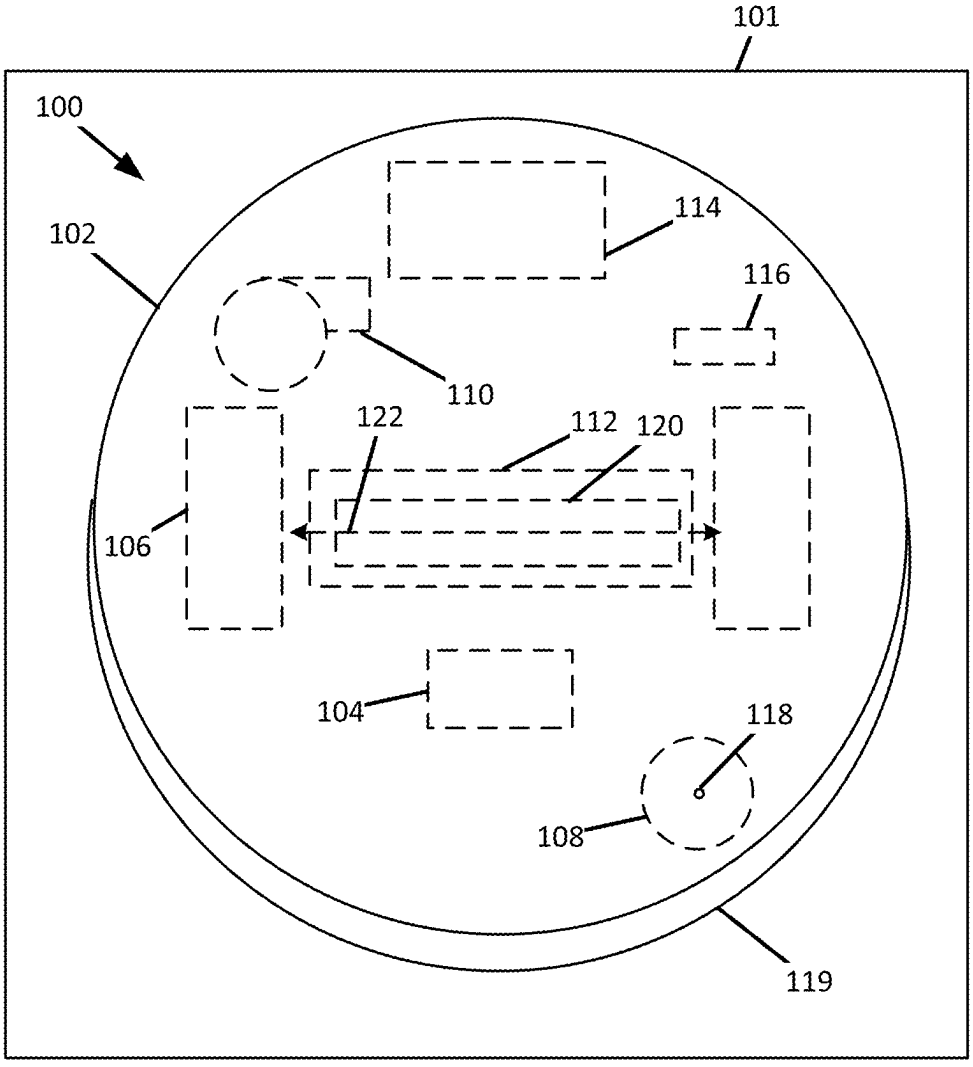

101
100
102
114
116
110
122
112
120
106
104
118
108
119

FIG. 1

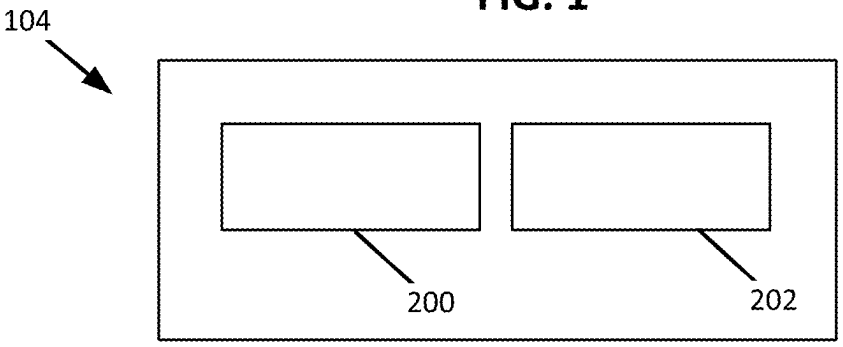

104
200
202

FIG. 2

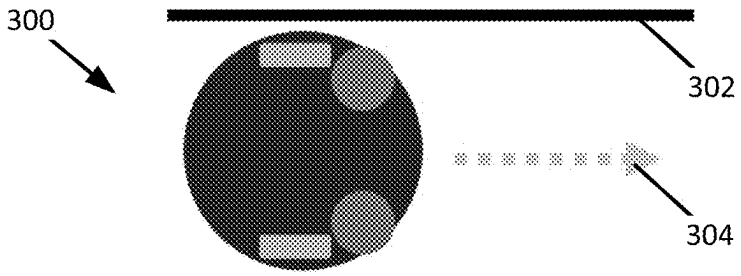


FIG. 3

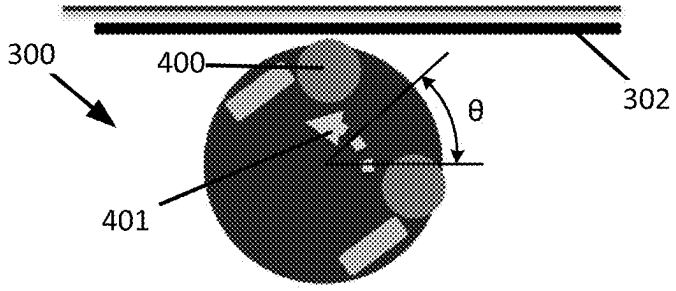


FIG. 4

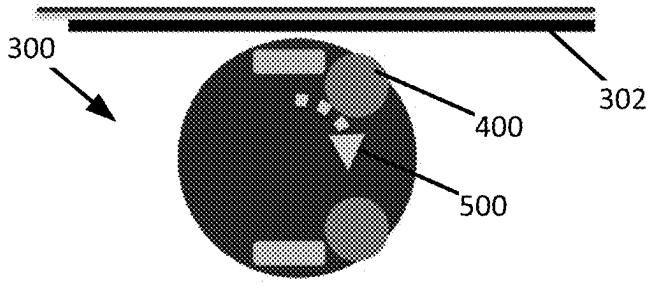


FIG. 5

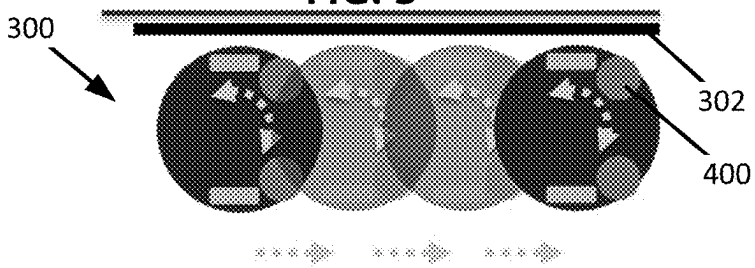


FIG. 6

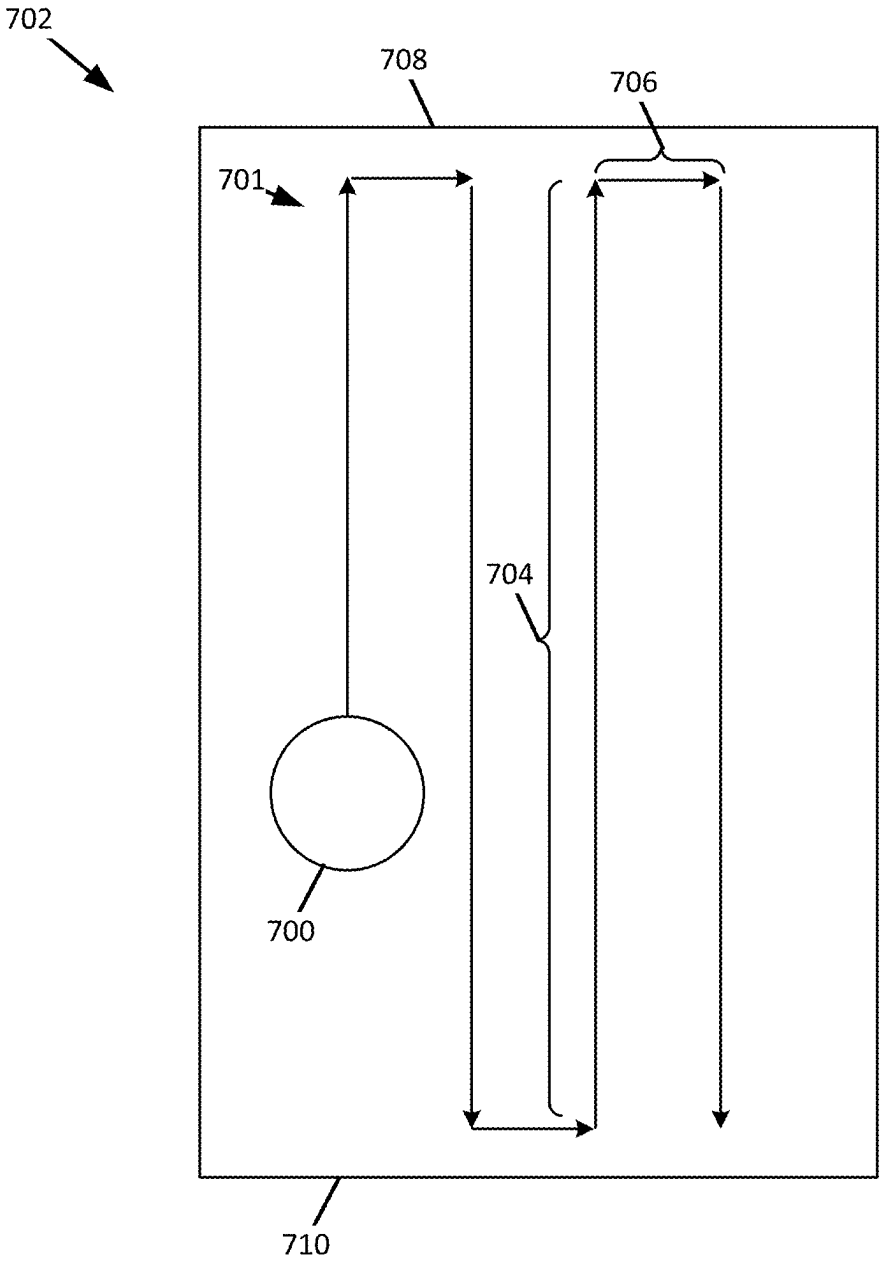


FIG. 7

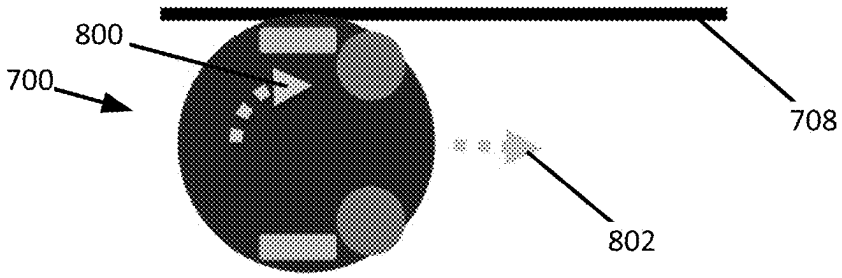


FIG. 8

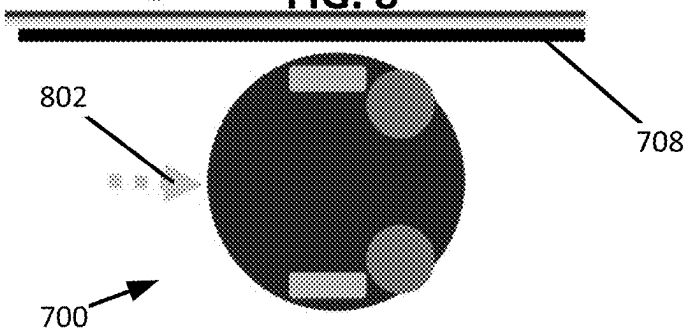


FIG. 9

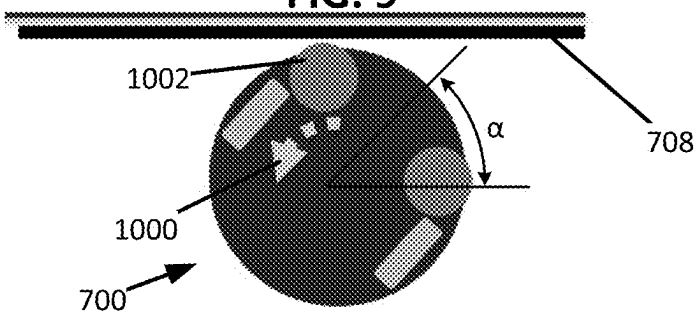


FIG. 10

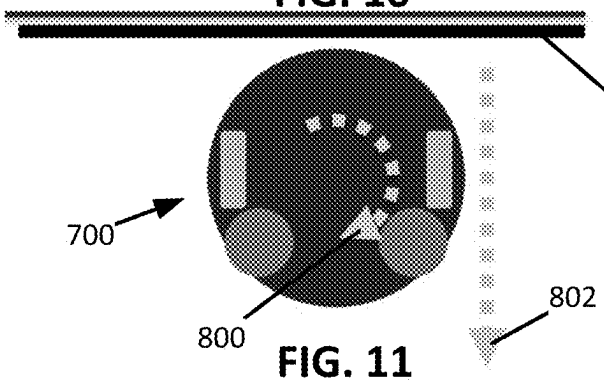


FIG. 11

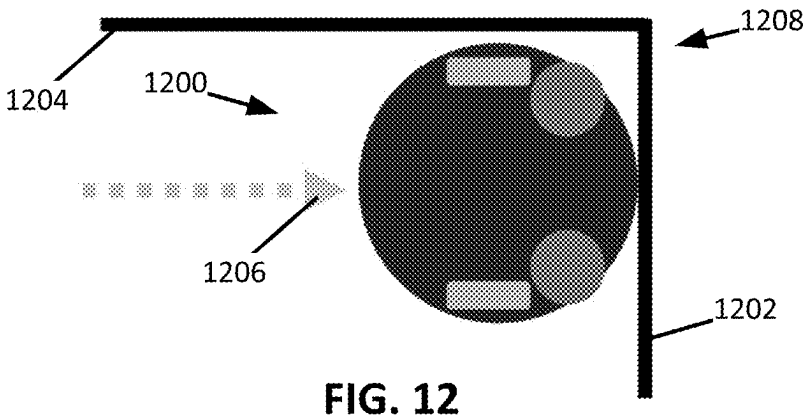


FIG. 12

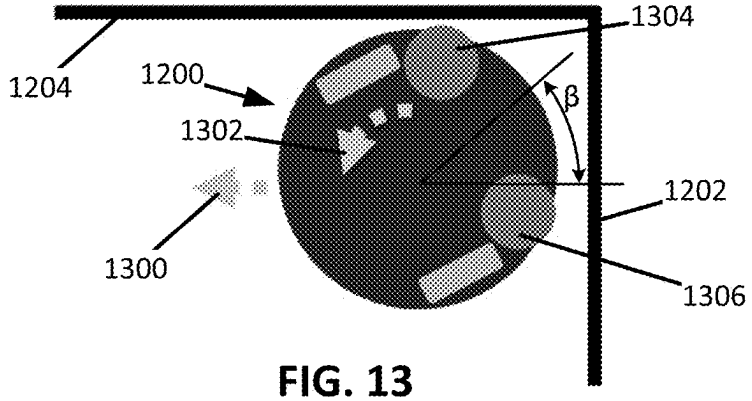


FIG. 13

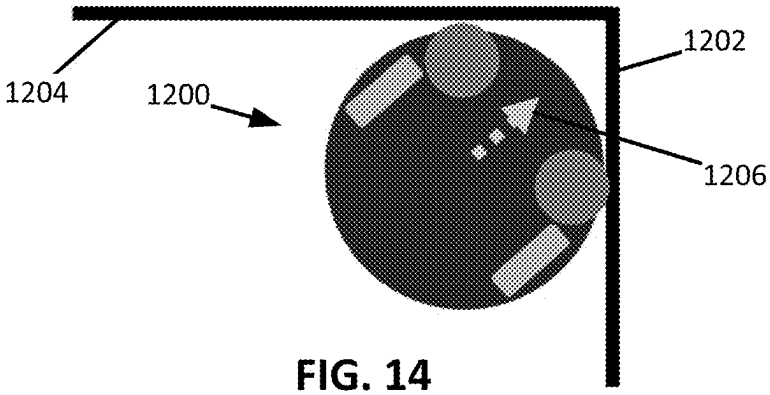


FIG. 14

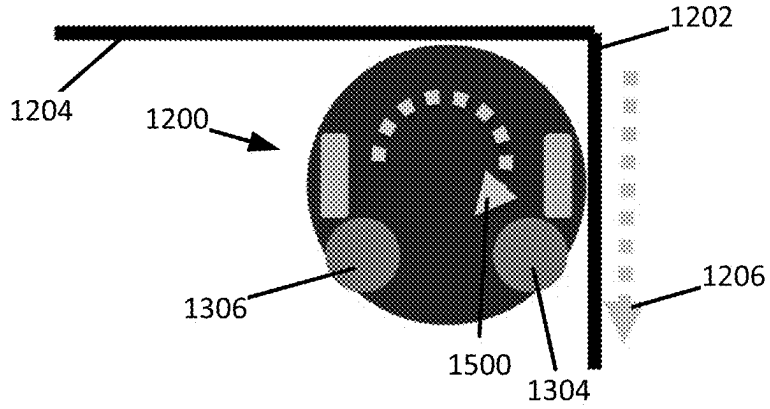


FIG. 15

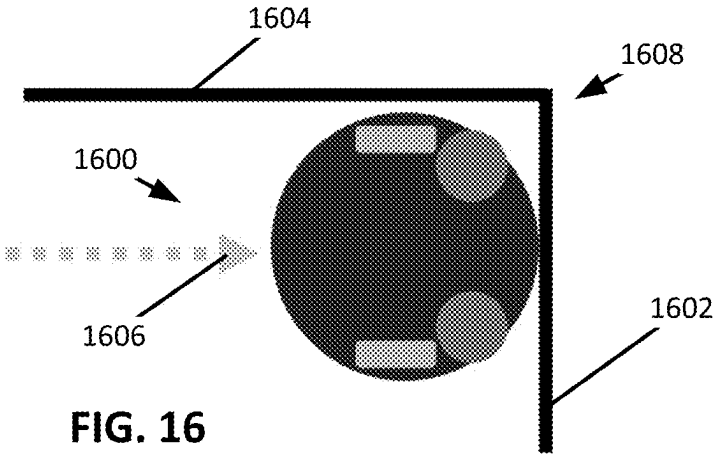


FIG. 16

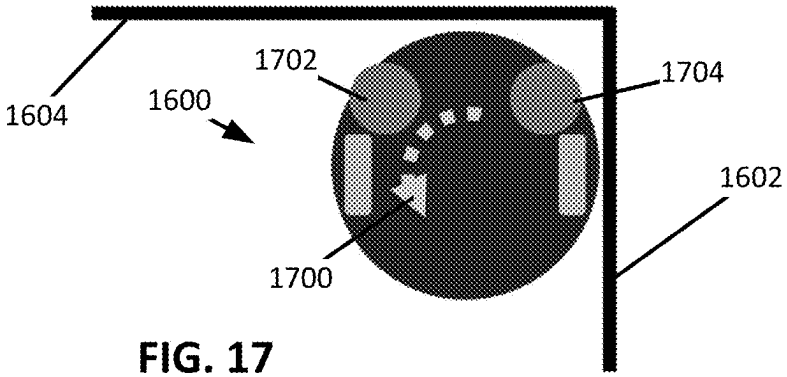


FIG. 17

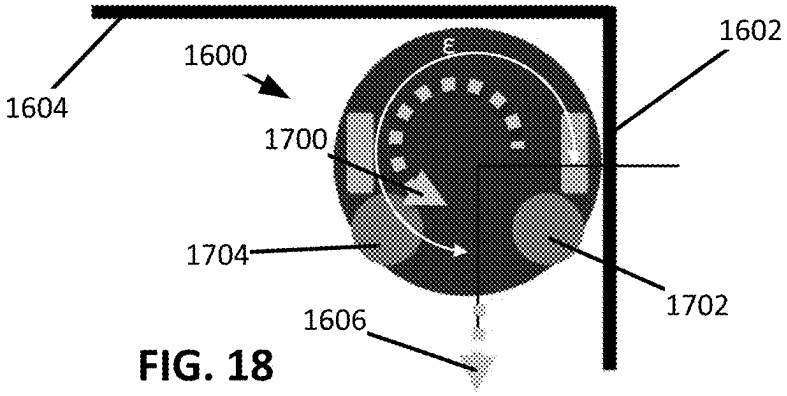


FIG. 18

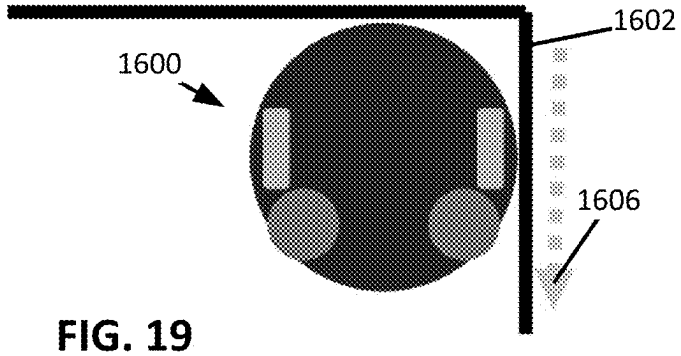


FIG. 19

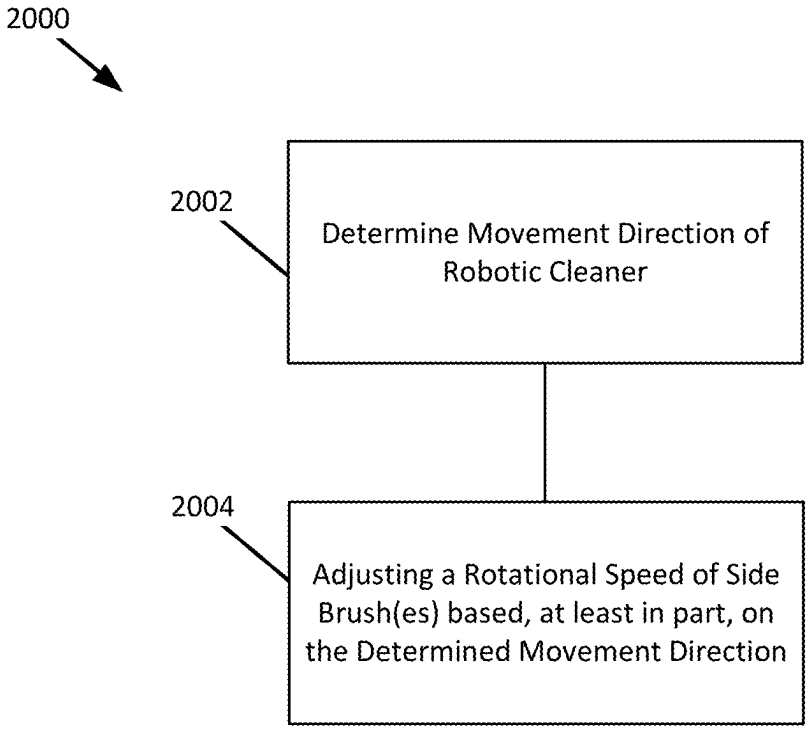

2000
2002
Determine Movement Direction of Robotic Cleaner
2004
Adjusting a Rotational Speed of Side Brush(es) based, at least in part, on the Determined Movement Direction

FIG. 20

ROBOTIC CLEANER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is a continuation application of U.S. application Ser. No. 17/718,901 filed on Apr. 12, 2022, which claims the benefit of U.S. Provisional Application Ser. No. 63/173,875 filed on Apr. 12, 2021, entitled Robotic Cleaner and U.S. Provisional Application Ser. No. 63/223,681 filed on Jul. 20, 2021, entitled Robotic Cleaner, each of which are fully incorporated herein by reference.

TECHNICAL FIELD

[0002] The present disclosure is generally directed to a robotic cleaner and more specifically to methods of edge cleaning using a robotic cleaner.

BACKGROUND INFORMATION

[0003] Autonomous cleaning devices (e.g., robotic cleaners) are configured to autonomously navigate a surface while at least partially cleaning the surface. One example of an autonomous cleaning device is a robotic vacuum cleaner. A robotic vacuum cleaner may include a suction motor, a dust cup fluidly coupled to the suction motor, and one or more driven wheels configured to urge the robotic vacuum cleaner across a surface to be cleaned. In operation, the robotic vacuum cleaner traverses the surface to be cleaned while collecting at least a portion of any debris present on the surface to be cleaned. However, robotic vacuum cleaners may have difficulty cleaning adjacent one or more obstacles (e.g., walls) that extend from the surface to be cleaned as a result of a geometry of the robotic vacuum cleaner. The addition of one or more side brushes that are configured urge debris proximate a periphery of the robotic vacuum cleaner towards a suction inlet of the robotic vacuum cleaner may improve cleaning performance adjacent an obstacle such as a wall. However, the movement behavior of the robotic cleaner when adjacent the obstacle may impact the performance of the one or more side brushes.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] These and other features and advantages will be better understood by reading the following detailed description, taken together with the drawings, wherein:

[0005] FIG. **1** is a schematic example of a robotic cleaner, consistent with embodiments of the present disclosure.

[0006] FIG. **2** is a schematic example of a controller of the robotic cleaner of FIG. **1**, consistent with embodiments of the present disclosure.

[0007] FIG. **3** is a schematic example of a robotic cleaner executing one or more steps of a method of cleaning proximate a vertically extending surface, consistent with embodiments of the present disclosure.

[0008] FIG. **4** is a schematic example of the robotic cleaner of FIG. **3** carrying out one or more steps of the method of FIG. **3**, consistent with embodiments of the present disclosure.

[0009] FIG. **5** is a schematic example of the robotic cleaner of FIG. **3** carrying out one or more steps of the method of FIG. **3**, consistent with embodiments of the present disclosure.

[0010] FIG. **6** is a schematic example of the robotic cleaner of FIG. **3** carrying out one or more steps of the method of FIG. **3**, consistent with embodiments of the present disclosure.

[0011] FIG. **7** is a schematic example of a robotic cleaner traveling along a cleaning path having one or more row portions and one or more turn-around portions, consistent with embodiments of the present disclosure.

[0012] FIG. **8** is a schematic example of a robotic cleaner of FIG. **7** executing one or more steps of a method of cleaning proximate to a vertically extending surface at a respective one of the turn-around portions of FIG. **7**, consistent with embodiments of the present disclosure.

[0013] FIG. **9** is a schematic example of the robotic cleaner of FIG. **7** carrying out one or more steps of the method of FIG. **8**, consistent with embodiments of the present disclosure.

[0014] FIG. **10** is a schematic example of the robotic cleaner of FIG. **7** carrying out one or more steps of the method of FIG. **8**, consistent with embodiments of the present disclosure.

[0015] FIG. **11** is a schematic example of the robotic cleaner of FIG. **7** carrying out one or more steps of the method of FIG. **8**, consistent with embodiments of the present disclosure.

[0016] FIG. **12** is a schematic example of a robotic cleaner executing one or more steps of a method of cleaning proximate to a vertically extending surface at a corner region, consistent with embodiments of the present disclosure.

[0017] FIG. **13** is a schematic example of the robotic cleaner of FIG. **12** carrying out one or more steps of the method of FIG. **12**, consistent with embodiments of the present disclosure.

[0018] FIG. **14** is a schematic example of the robotic cleaner of FIG. **12** carrying out one or more steps of the method of FIG. **12**, consistent with embodiments of the present disclosure.

[0019] FIG. **15** is a schematic example of the robotic cleaner of FIG. **12** carrying out one or more steps of the method of FIG. **12**, consistent with embodiments of the present disclosure.

[0020] FIG. **16** is a schematic example of a robotic cleaner executing one or more steps of a method of cleaning proximate to a vertically extending surface at a corner region, consistent with embodiments of the present disclosure.

[0021] FIG. **17** is a schematic example of the robotic cleaner of FIG. **16** carrying out one or more steps of the method of FIG. **16**, consistent with embodiments of the present disclosure.

[0022] FIG. **18** is a schematic example of the robotic cleaner of FIG. **16** carrying out one or more steps of the method of FIG. **16**, consistent with embodiments of the present disclosure.

[0023] FIG. **19** is a schematic example of the robotic cleaner of FIG. **16** carrying out one or more steps of the method of FIG. **16**, consistent with embodiments of the present disclosure.

[0024] FIG. **20** is a flow chart of an example of a side brush control method, consistent with embodiments of the present disclosure.

DETAILED DESCRIPTION

[0025] The present disclosure is generally directed to a robotic cleaner. The robotic cleaner includes a controller, a suction motor, one or more driven wheels, one or more edge cleaning implements, and one or more environmental sensors. The controller is communicatively coupled to the suction motor, the one or more driven wheels, the one or more edge cleaning implements, and the one or more environmental sensors. The controller is configured to control the operation of one or more of the one or more driven wheels, the one or more edge cleaning implements, and/or the suction motor in response to one or more signals output by the one or more environmental sensors. The controller is further configured to store one or more instructions that cause the robotic cleaner to carry out a method of cleaning proximate to a vertically extending surface (e.g., a wall) in response to at least one of the one or more environmental sensors detecting one or more vertical surfaces proximate the robotic cleaner. The method is configured to cause the robotic cleaner to maneuver such that at least one of the one or more edge cleaning implements approaches at least one vertically extending surface proximate the robotic cleaner.

[0026] FIG. **1** shows a schematic example of a robotic cleaner **100** (e.g., a robotic vacuum cleaner). As shown, the robotic cleaner **100** includes a body **102**, a controller **104**, one or more driven wheels **106**, one or more edge cleaning implements **108**, a suction motor **110**, a suction inlet **112** fluidly coupled to the suction motor **110**, a dust cup **114** fluidly coupled to the suction inlet **112** such that the suction motor **110** urges debris into the dust cup **114** through the suction inlet **112**, and one or more environmental sensors **116**. Examples of the one or more edge cleaning implements **108** may include a side brush (e.g., having one or more bristles that extend within and/or beyond a perimeter of the robotic cleaner **100**), an air jet assembly (e.g., configured to generate a directed stream of air that extends outwardly from the body **102** of the robotic cleaner **100** in a manner that is configured to disturb debris adjacent the robotic cleaner **100**), and/or any other edge cleaning implement. For the purposes of clarity herein, the one or more edge cleaning implements **108** will be generally discussed in the context of one or more side brushes. The controller **104** is communicatively coupled to one or more of the one or more driven wheels **106**, the one or more side brushes **108**, the suction motor **110**, and/or the one or more environmental sensors **116**.

[0027] The one or more environmental sensors **116** may be configured to detect one or more obstacles in a movement path of the robotic cleaner **100**. An obstacle may include a non-traversable drop-off (e.g., a cliff) in a surface to be cleaned (e.g., a floor) **101** and/or a vertically extending (e.g., a vertical) surface (e.g., a wall or piece of furniture) extending from the surface to be cleaned **101**. For example, the controller **104** can be configured to receive at least one input from at least one of the one or more environmental sensors **116** and, based, at least in part, on the input, control the rotational speed of the one or more driven wheels **106** (e.g., to avoid a collision with an obstacle in the path of the robotic cleaner **100**). By way of further example, the controller **104** can be configured to receive at least one input from at least one of the one or more environmental sensors **116** indicative of a vertically extending surface of an obstacle (e.g., a wall or furniture) in a movement path of the robotic cleaner **100** and, in response to receiving the signal, cause the robotic cleaner **100** to carry out a method of cleaning proximate to the vertically extending surface. The method of cleaning proximate to the vertically extending surface may include causing the robotic cleaner **100** to move through a rotation angle such that at least one of the one or more side brushes **108** approaches the vertically extending surface.

[0028] The one or more environmental sensors **116** may include, for example, one or more of an infrared (IR) sensor, an ultrasonic sensor, a stereo or monocular camera, a tactile switch (e.g., actuated in response to displacement of a displaceable bumper), a magnetic field sensor, and/or any other type of environmental sensor.

[0029] The one or more side brushes **108** may be configured to extend within or beyond a periphery of the robotic cleaner **100**. For example, each of the one or more side brushes **108** may not extend beyond a periphery of the body **102** of the robotic cleaner **100**. In some instances, a rotational speed of the one or more side brushes **108** may be varied. For example, the rotational speed of the one or more side brushes **108** may be varied in response to at least one of the one or more environmental sensors **116** detecting an obstacle. By way of further example, in some instances, the rotational speed of the one or more side brushes **108** may be varied based on a direction of movement (e.g., forward movement, reverse movement, or turning movement).

[0030] As shown, the one or more side brushes **108** are configured to rotate about a respective side brush rotational axis **118** that extends transverse to (e.g., perpendicular to) a bottom surface of the body **102** of the robotic cleaner **100**. In other words, each side brush rotational axis **118** of the one or more side brushes **108** extends transverse to (e.g., perpendicular to) the surface to be cleaned **101**. In some instances, the one or more side brushes **108** may extend substantially (e.g., within 1°, 2°, 5°, or 10° of) perpendicular to the surface to be cleaned **101**. The one or more side brushes **108** are configured to rotate about each side brush rotational axis **118** such that the one or more side brushes **108** urge debris on the surface to be cleaned **101** in a direction of a movement path of the suction inlet **112**.

[0031] As shown, the one or more side brushes **108** may be positioned forward of the suction inlet **112**, relative to a forward movement direction of the robotic cleaner **100**. In other words, the one or more side brushes **108** may be positioned between a forward most portion of the robotic cleaner **100** (e.g., a displaceable bumper **119**) and the suction inlet **112**.

[0032] The suction inlet **112** may also include an agitator **120** (e.g., a brush roll) configured to rotate about an agitator rotational axis **122**. The agitator **120** is configured to agitate the surface to be cleaned **101**, dislodging at least a portion of any debris on the surface to be cleaned **101**. The agitator rotational axis **122** may extend parallel to or substantially (e.g., within 1°, 2°, 5°, or 10° of) parallel to the surface to be cleaned **101**.

[0033] FIG. **2** shows a schematic example of the controller **104**. As shown, the controller **104** includes one or more processors **200** and one or more memories **202** (e.g., non-transitory memories) communicatively coupled to the one or more processors **200**. The one or more memories **202** are configured to store one or more instructions that are configured to be executed by the one or more processors **200**. Execution of the one or more instructions by the one or more processors **200** causes the robotic cleaner **100** to carry out

one or more behaviors (e.g., obstacle avoidance, cleaning patterns, movement speed, and/or any other behavior).

[0034] FIGS. **3-6** show a schematic example of a robotic cleaner **300**, which may be an example of the robotic cleaner **100** of FIG. **1**, executing a method of cleaning proximate to a vertically extending surface of an obstacle **302** (e.g., a wall) while following a perimeter of the vertically extending surface. One or more steps of the method shown in FIGS. **3-6** may be embodied as one or more instructions stored in one or more memories (e.g., the one or more memories **202** of FIG. **2**), wherein the one or more instructions are configured to be executed on one or more processors (e.g., the one or more processors **200** of FIG. **2**). For example, the controller **104** may be configured to cause one or more steps of the method to be carried out. Additionally, or alternatively, one or more steps of the method may be carried out in any combination of software, firmware, or circuitry (e.g., an application-specific integrated circuit).

[0035] As shown in FIG. **3**, the robotic cleaner **300** is travelling along (or following) the obstacle **302** according to a forward movement direction **304**. After traveling for a predetermined distance and/or for a predetermined time along the obstacle **302**, the robotic cleaner **300** stops forward movement. The predetermined distance may be in a range of, for example, 4 centimeters (cm) to 12 cm. By way of further example, the predetermined distance may be 1 cm, 2 cm, 5 cm, 8 cm, 12 cm, 16 cm, and/or any other predetermined distance. The predetermined time may be in a range of, for example, 0.5 seconds to 3 seconds. By way of further example, the predetermined time may be in a range of 1 second to 2 seconds. By way of still further example, the predetermined time may be 1.5 seconds.

[0036] As shown in FIG. **4**, after travelling the predetermined distance and/or for the predetermined time, the robotic cleaner **300** is caused to rotate in a first rotation direction **401** (e.g., counter-clockwise) such that at least one side brush **400** of the robotic cleaner **300** first (or initially) approaches the obstacle **302**. The robotic cleaner **300** rotates in the first rotation direction **401** through a rotation angle θ and/or for a predetermined time. Rotation of the robotic cleaner **300** through the rotation angle θ causes the at least one side brush **400** to approach the obstacle **302** and, in some instances, come into engagement (e.g., contact) with the obstacle **302**. As such, the side brush **400** urges at least a portion of debris adjacent the obstacle away from the obstacle and towards a movement path of the robotic cleaner **300**. When rotating the side brush **400** towards the obstacle **302**, the robotic cleaner **300** may be spaced apart from the obstacle **302** by a sufficient distance such that only the side brush **400** contacts the obstacle **302** (e.g., such that a displaceable bumper of the robotic cleaner **300** does not contact the obstacle **302**). The rotation angle θ may measure, for example, between 15° and 45°. By way of further example, the rotation angle θ may measure 30°.

[0037] As shown in FIG. **5**, after rotating through the rotation angle θ in the first rotation direction **401**, the robotic cleaner **300** rotates through the rotation angle θ and/or for a predetermined time in a second rotation direction **500** (e.g., clockwise), the second rotation direction **500** being opposite the first rotation direction **401**. The robotic cleaner **300** rotates back to a position in which the forward movement direction **304** is substantially (e.g., within 1°, 2°, 5°, or 10° of) parallel with at least a portion of the obstacle **302**.

[0038] As shown in FIG. **6**, after rotating through the rotation angle θ and/or for the predetermined time in the second rotation direction **500**, the robotic cleaner **300** begins to follow the obstacle **302** while moving according to the forward movement direction **304** for a predetermined distance and/or a predetermined time. The robotic cleaner **300** can repeat the steps described in relation to FIGS. **3-6** until, for example, the robotic cleaner **300** reaches the reaches the end of the obstacle **302**.

[0039] FIG. **7** shows an example of a robotic cleaner **700**, which may be an example of the robotic cleaner **100** of FIG. **1**, carrying out a cleaning operation within an area **702** (e.g., a room of a house). As shown, the robotic cleaner **700** is caused to travel along a cleaning path **701**. The cleaning path **701** of the robotic cleaner **700** includes one or more row portions **704** and one or more turn-around portions **706**. Each row portion **704** extends transverse to (e.g., perpendicular to) an obstacle **708** (e.g., a wall) such that, while traveling according to a forward movement direction, the robotic cleaner **700** approaches the obstacle **708**. Each turn-around portion **706** corresponds to a location where the robotic cleaner **700** changes direction. For example, while traveling according to a forward movement direction after traversing a turn-around portion **706** that is proximate to the obstacle **708**, the robotic cleaner **700** moves away from the obstacle **708** and towards an opposing obstacle **710**.

[0040] FIGS. **8-11** show a schematic example of the robotic cleaner **700** of FIG. **7** executing a method of cleaning proximate to a vertically extending surface at the turn-around portions **706** of FIG. **7**. One or more steps of the method shown in FIGS. **8-11** may be embodied as one or more instructions stored in one or more memories (e.g., the one or more memories **202** of FIG. **2**), wherein the one or more instructions are configured to be executed on one or more processors (e.g., the one or more processors **200** of FIG. **2**). For example, the controller **104** may be configured to cause one or more steps of the method to be carried out. Additionally, or alternatively, one or more steps of the method may be carried out in any combination of software, firmware, or circuitry (e.g., an application-specific integrated circuit).

[0041] As shown in FIG. **8** when the robotic cleaner **700** reaches a respective turn-around portion **706** the robotic cleaner **700** is caused to rotate in a first rotation direction **800** (e.g., clockwise) such that a forward movement direction **802** extends substantially (e.g., within 1°, 2°, 5°, or 10° of) parallel to at least a portion of the obstacle **708**. As shown in FIG. **9**, after rotating such that the forward movement direction **802** extends substantially parallel to at least a portion of the obstacle **708**, the robotic cleaner **700** moves along (or follows) the obstacle **708** in the forward movement direction **802** for a predetermined distance and/or a predetermined time. The predetermined distance may correspond to, for example, half the cleaning width of the robotic cleaner **700** (or less than half the cleaning width of the robotic cleaner **700**).

[0042] As shown in FIG. **10**, after traveling the predetermined distance and/or for the predetermined time in the forward movement direction **802**, the robotic cleaner **700** is caused to stop and rotate in a second rotation direction **1000** (e.g., counter-clockwise) through a rotation angle α and/or for a predetermined time, the second rotation direction **1000** being opposite the first rotation direction **800**. Rotation of the robotic cleaner **700** through the rotation angle α causes

the at least one side brush **1002** of the robotic cleaner **700** to first (or initially) approach the obstacle **708** and, in some instances, brings the at least one side brush **1002** into engagement (e.g., contact) with the obstacle **708**. As such, the side brush **1002** urges at least a portion of debris adjacent the obstacle away from the obstacle and towards a movement path of the robotic cleaner **700**. When rotating the side brush **1002** towards the obstacle **708**, the robotic cleaner **700** may be spaced apart from the obstacle **708** by a sufficient distance such that only the side brush **1002** contacts the obstacle **302** (e.g., such that a displaceable bumper of the robotic cleaner **700** does not contact the obstacle **708**). The rotation angle α may measure, for example, between 30° and 60°. By way of further example, the rotation angle α may measure 45°.

[0043] As shown in FIG. **11**, after rotating through the rotation angle α and/or for the predetermined time in the second rotation direction **1000**, the robotic cleaner **700** rotates in the first rotation direction **800** until the forward movement direction **802** extends substantially parallel to at least one of the one or more row portions **704**. For example, the robotic cleaner **700** may rotate through the rotation angle α plus an additional 90° in the first rotation direction **800**. After completing rotation, the robotic cleaner **700** may travel along a respective row portion **704** in a direction away from the obstacle **708** until the robotic cleaner **700** reaches another turn-around portion **706** adjacent the opposing obstacle **710**. Upon reaching the later turn-around portion **706**, the robotic cleaner **700** may carry out the steps described in relation to FIGS. **8-11**. The method shown in FIGS. **8-11** may be carried out until, for example, the robotic cleaner **300** completes cleaning within the area **702**.

[0044] FIGS. **12-15** show a schematic example of a robotic cleaner **1200**, which may be an example of the robotic cleaner **100** of FIG. **1**, executing a method of cleaning proximate to a vertically extending surface at a corner region **1208** (e.g., a region where a first and second obstacle **1202** and **1204** intersect). One example of the corner region **1208** may include a region defined at the intersection of a first wall with a second wall (e.g., a region where the first and second walls intersect at a substantially perpendicular angle). One or more steps of the method shown in FIGS. **12-15** may be embodied as one or more instructions stored in one or more memories (e.g., the one or more memories **202** of FIG. **2**), wherein the one or more instructions are configured to be executed on one or more processors (e.g., the one or more processors **200** of FIG. **2**). For example, the controller **104** may be configured to cause one or more steps of the method to be carried out. Additionally, or alternatively, one or more steps of the method may be carried out in any combination of software, firmware, or circuitry (e.g., an application-specific integrated circuit).

[0045] As shown in FIG. **12**, the robotic cleaner **1200** is traveling according to a forward movement direction **1206** in a direction of the corner region **1208** (e.g., in a direction substantially parallel to the second obstacle **1204**). The corner region **1208** is defined by the first obstacle **1202** and the second obstacle **1204** (e.g., at an intersection of the first and second obstacle **1202** and **1204**). The robotic cleaner **1200** can be configured to detect the first obstacle **1202** using at least one environmental sensor as the robotic cleaner **1200** approaches the first obstacle **1202**. As shown, the robotic cleaner **1200** is brought into engagement (e.g., contact) with the first obstacle **1202** while following the second obstacle **1204**. For example, the robotic cleaner **1200** may engage the first obstacle **1202** such that a displaceable bumper of the robotic cleaner **1200** is displaced, actuating one or more tactile switches.

[0046] As shown in FIG. **13**, in response engaging the first obstacle **1202** (e.g., in response to the displaceable bumper actuating one or more tactile switches), the robotic cleaner **1200** is caused to move in a rearward movement direction **1300** for a predetermined distance and/or for a predetermined time, the rearward movement direction **1300** being opposite the forward movement direction **1206**. Movement in the rearward movement direction **1300** for the predetermined distance and/or for the predetermined time may be, for example, sufficient to allow the robotic cleaner **1200** to rotate relative to the first and second obstacles **1202** and **1204** (e.g., without contacting the obstacles **1202** and **1204**). After moving in the rearward movement direction **1300** for the predetermined distance and/or for the predetermined time, the robotic cleaner **1200** is caused to rotate according to a first rotation direction **1302** (e.g., counter-clockwise) through a rotation angle β and/or for a predetermined time. The rotation angle β may measure, for example, in a range of 15° to 45°. By way of further example, the rotation angle β may measure 30°.

[0047] As shown, when rotating through the rotation angle β in the first rotation direction **1302** and/or for the predetermined time, a first side brush **1304** of the robotic cleaner **1200** is caused to first (or initially) approach the second obstacle **1204** and a second side brush **1306** of the robotic cleaner **1200** is caused to first (or initially) approach the first obstacle **1202**. In some instances, one or more of the first and/or second side brushes **1304** and **1306** may come into engagement (e.g., contact) with the first and second obstacles **1202** and **1204**.

[0048] As shown in FIG. **14**, after rotating through the rotation angle β and/or for the predetermined time in the first rotation direction **1302**, the robotic cleaner **1200** is caused to move according to the forward movement direction **1206** until the robotic cleaner **1200** comes into engagement (e.g., contact) with the first and second obstacles **1202** and **1204**. For example, the robotic cleaner **1200** may continue to move in the forward movement direction **1206** until a displaceable bumper of the robotic cleaner **1200** is displaced, actuating one or more tactile switches. In some instances, after contacting the first and second obstacles **1202** and **1204**, the robotic cleaner **1200** may move in a reverse movement direction until the robotic cleaner **1200** comes out of engagement with the first and second obstacles **1202** and **1204**.

[0049] As shown in FIG. **15**, after the robotic cleaner **1200** has moved into engagement with the first and second obstacles **1202** and **1204**, the robotic cleaner **1200** is caused to rotate in a second rotation direction **1500** (e.g., clockwise), the second rotation direction **1500** being opposite the first rotation direction **1302**. As the robotic cleaner **1200** rotates according to the second rotation direction **1500**, the first and second side brushes **1304** and **1306** are configured to urge debris adjacent the first and second obstacles **1202** and **1204** towards a movement path of a suction inlet of the robotic cleaner **1200**. As shown, the robotic cleaner **1200** continues to rotate according the second rotation direction **1500** until the forward movement direction **1206** of the robotic cleaner **1200** is substantially parallel to at least a

portion of the first obstacle **1202**, allowing the robotic cleaner **1200** to move along (or follow) a perimeter of the first obstacle **1202**.

[0050] FIGS. **16-19** show a schematic example of a robotic cleaner **1600**, which may be an example of the robotic cleaner **100** of FIG. **1**, executing a method of cleaning proximate to a vertically extending surface at a corner region **1608** (e.g., a location where a first and second obstacle **1602** and **1604** intersect). One or more steps of the method shown in FIGS. **16-19** may be embodied as one or more instructions stored in one or more memories (e.g., the one or more memories **202** of FIG. **2**), wherein the one or more instructions are configured to be executed on one or more processors (e.g., the one or more processors **200** of FIG. **2**). For example, the controller **104** may be configured to cause one or more steps of the method to be carried out. Additionally, or alternatively, one or more steps of the method may be carried out in any combination of software, firmware, or circuitry (e.g., an application-specific integrated circuit).

[0051] As shown in FIG. **16**, the robotic cleaner **1600** is traveling according to a forward movement direction **1606** in a direction of the corner region **1608** (e.g., in a direction substantially parallel to the second obstacle **1604**). The corner region **1608** is defined by the first obstacle **1602** and the second obstacle **1604** (e.g., at an intersection of the first and second obstacle **1602** and **1604**). As shown, the robotic cleaner **1600** is brought into engagement (e.g., contact) with the first obstacle **1602**. For example, the robotic cleaner **1600** may engage the first obstacle **1602** such that a displaceable bumper of the robotic cleaner **1600** is displaced, actuating one or more tactile switches. In some instances, in response to the displaceable bumper being displaced, the robotic cleaner **1600** may move in a reverse movement direction such that the displaceable bumper comes out of engagement with the first obstacle **1602**, the reverse movement direction being opposite the forward movement direction **1606**.

[0052] As shown in FIGS. **17** and **18**, after engaging the first obstacle **1602** (e.g., after the displaceable bumper actuates one or more tactile switches), the robotic cleaner **1600** is caused to rotate according to a first rotation direction **1700** (e.g., counter-clockwise) through a rotation angle ε and/or for a predetermined time. As shown, when rotating through the rotation angle ε and/or for the predetermined time in the first rotation direction **1700**, a first side brush **1702** of the robotic cleaner **1600** is caused to first (or initially) approach the second obstacle **1604** and a second side brush **1704** of the robotic cleaner **1600** is caused to first (or initially) approach the first obstacle **1602** and the second obstacle **1604**. In some instances one or more of the first and second side brushes **1702** and **1704** may come into engagement (e.g., contact) with one or more of the first and/or second obstacles **1602** and **1604**.

[0053] As shown, the robotic cleaner **1600** rotates in the first rotation direction **1700** until the forward movement direction **1606** is substantially parallel to at least a portion of the first obstacle **1602**. The rotation angle ε may measure in a range of, for example, 255° and 285°. By way of further example, the rotation angle ε may measure 270°. By way of still further example, the rotation angle ε may measure greater than 90°, 95°, or 100°.

[0054] As shown in FIG. **19**, after rotation through the rotation angle ε is complete and the forward movement direction **1606** is substantially parallel to at least a portion of the first obstacle **1602**, the robotic cleaner **1600** is caused to move in the forward movement direction **1606** and follow the perimeter of the first obstacle **1602**.

[0055] FIG. **20** shows a flow chart of an example of a side brush control method **2000**. The method **2000** may be embodied as one or more instructions stored in one or more memories (e.g., non-transitory computer readable memories), wherein the one or more instructions are configured to be executed on one or more processors. For example, a controller (e.g., the controller **104** of FIG. **1**) may be configured to cause one or more steps of the method **2000** to be carried out. Additionally, or alternatively, one or more steps of the method **2000** may be carried out in any combination of software, firmware, or circuitry (e.g., an application-specific integrated circuit).

[0056] As shown, the method **2000** includes a step **2002**. The step **2002** may include determining a movement direction of a robotic cleaner (e.g., the robotic cleaner **100** of FIG. **1**). The movement direction may include forward movement, reverse movement, or turning movement (e.g., left or right turning movement). When a turning movement is determined, the step **2002** may further include determining a direction of turning (e.g., left/right or clockwise/counter-clockwise).

[0057] The method **2000** includes a step **2004**. The step **2004** may include adjusting a rotational speed of one or more side brushes based, at least in part, on the determined movement direction. Adjusting the rotational speed of one or more side brushes based, at least in part, on the determined movement direction may mitigate or prevent damage to the side brush, damage to a surface being cleaned, and/or side brush entanglement (e.g., resulting in an unintended stoppage of the side brush).

[0058] When moving in the forward direction, the one or more side brushes may operate at a cleaning speed. The cleaning speed may be, for example, in a range of 40% to 94% of a maximum rotation speed of the one or more side brushes. By way of further example, the cleaning speed may be 67% of the maximum rotation speed of the one or more side brushes. When moving in the reverse direction, the one or more side brushes may operate at a reversing speed, the reversing speed being less than the cleaning speed. The reversing speed may be, for example, in a range of 20% to 40% of the maximum rotation speed of the one or more side brushes. By way of further example, the reversing speed may be 30% of the maximum rotation speed of the one or more side brushes. When turning, the one or more side brushes may operate at a turning speed, the turning speed being less than the cleaning speed. The turning speed may be, for example, in a range of 20% to 40% of the maximum rotation speed of the one or more side brushes. By way of further example, the turning speed may be 30% of the maximum rotation speed of the one or more side brushes. In some instances, the turning speed and the reversing speed may be the same.

[0059] When the robotic cleaner includes two or more side brushes (e.g., a left side brush and a right side brush), at least one side brush may be operated at the turning speed and at least one other side brush may be operated at the cleaning speed based, at least in part, on the determined turning direction. For example, when turning, an inside side brush (e.g., the side brush closest to the center of the rotational arc of the turn) may be operated at the turning speed and an

outside side brush (e.g., the side brush furthest from the center of the rotational arc of the turn) may be operated at the cleaning speed. By way of further example, when the robotic cleaner is turning left, a side brush corresponding to a left side of the robotic cleaner may be operated at the turning speed and a side brush corresponding to a right side of the robotic cleaner may be operated at the cleaning speed. By way of still further example, when the robotic cleaner is turning right, a side brush corresponding to a right side of the robotic cleaner may be operated at the turning speed and a side brush corresponding to a left side of the robotic cleaner may be operated at the cleaning speed.

[0060] While the cleaning speed, reversing speed, and turning speed of the one or more side brushes is described in the context of percent of maximum rotation speed, the cleaning speed, reversing speed, and turning speed may be expressed in a manner independent of maximum rotation speed. For example, the cleaning speed, reversing speed, and turning speed may be expressed in terms of rotations per minute (RPM), voltage supplied to the one or more side brushes, and/or any other metric.

[0061] An example of a robotic cleaner, consistent with the present disclosure, may include one or more driven wheels, one or more environmental sensors, at least one of the one or more environmental sensors configured to detect a first obstacle having a first vertically extending surface, one or more edge cleaning implements, and a controller communicatively coupled to the one or more driven wheels and the one or more environmental sensors. In response to detecting the first obstacle, the controller is configured to cause the robotic cleaner to move through a rotation angle such that at least one of the one or more edge cleaning implements approaches the first vertically extending surface.

[0062] In some instances, the controller may be configured cause the robotic cleaner to follow the first vertically extending surface of the first obstacle. In some instances, the controller may be configured to cause the robotic cleaner to follow the first vertically extending surface of the first obstacle for a predetermined distance. In some instances, the predetermined distance may be in a range of 4 cm to 12 cm. In some instances, controller may be configured to cause the robotic cleaner to rotate through the rotation angle in a first rotation direction after traveling the predetermined distance. In some instances, the controller may be configured to cause the robotic cleaner to rotate through the rotation angle in a second rotation direction after rotating through the rotation angle in the first rotation direction, the second rotation direction being opposite the first rotation direction. In some instances, the controller may be configured to cause the robotic cleaner to travel along a cleaning path having one or more row portions and one or more turn-around portions, at least one turn-around portion being proximate the first vertically extending surface of the first obstacle. In some instances, the controller may be configured to cause the robotic cleaner to follow the first obstacle for a predetermined distance. In some instances, the predetermined distance may be less than or equal to half a cleaning width of the robotic cleaner. In some instances, the controller may be configured to cause the robotic cleaner to rotate through the rotation angle in a first rotation direction after traveling the predetermined distance. In some instances, the controller may be configured to cause the robotic cleaner to rotate in a second rotation direction after rotating through the rotation angle in the first rotation direction, the second rotation direction being opposite the first rotation direction. In some instances, the controller may be configured to cause the robotic cleaner to travel along a respective row portion after rotating through the rotation angle in the second rotation direction. In some instances, at least one of the environmental sensors may be configured to detect a second obstacle having a second vertically extending surface, the first and second vertically extending surfaces intersecting to form a corner region. In some instances, the controller may be configured to cause the robotic cleaner to contact the second obstacle while following the first vertically extending surface of the first obstacle. In some instances, the controller may be configured to cause the robotic cleaner to rotate through the rotation angle in a first rotation direction after contacting the second obstacle. In some instances, the controller may be configured to cause the robotic cleaner to rotate in a second rotation direction after rotating through the rotation angle in the first rotation direction, the second rotation direction being opposite the first rotation direction. In some instances, the controller may be configured to cause the robotic cleaner to rotate in the second rotation direction until a forward movement direction of the robotic cleaner is substantially parallel with at least a portion of the second obstacle. In some instances, the controller may be configured to cause the robotic cleaner to rotate in the first rotation direction until a forward movement direction of the robotic cleaner is substantially parallel with at least a portion of the second obstacle. In some instances, the rotation angle may be in a range of 255° to 285°. In some instances, the one or more edge cleaning implements may include a side brush.

[0063] While the principles of the invention have been described herein, it is to be understood by those skilled in the art that this description is made only by way of example and not as a limitation as to the scope of the invention. Other embodiments are contemplated within the scope of the present invention in addition to the exemplary embodiments shown and described herein. Modifications and substitutions by one of ordinary skill in the art are considered to be within the scope of the present invention, which is not to be limited except by the following claims.

What is claimed is:

1. A robotic cleaner comprising:

one or more driven wheels;

one or more environmental sensors configured to detect an obstacle having a vertically extending surface;

one or more edge cleaning implements; and

a controller communicatively coupled to the one or more driven wheels and the one or more environmental sensors, the controller is configured to cause the robotic cleaner to:

travel according to a forward direction of movement along a first row towards the vertically extending surface;

after reaching the vertically extending surface, rotate in a first rotation direction such that the forward direction of movement extends substantially parallel to the vertically extending surface;

after rotating such that the forward direction of movement is substantially parallel to the vertically extending surface, move according to the forward direction of movement for a predetermined distance; and

after moving according to the forward direction of movement for the predetermined distance, rotate in a

second rotation direction, the second rotation direction being opposite the first rotation direction.

2. The robotic cleaner of claim **1**, wherein, after rotating in the second rotation direction, the robotic cleaner is caused to rotate in the first rotation direction until the forward direction of movement extends away from the vertically extending surface.

3. The robotic cleaner of claim **2**, wherein, after rotating until the forward direction of movement extends away from the vertically extending surface, the robotic cleaner is caused to travel according to the forward direction of movement along a second row.

4. The robotic cleaner of claim **3**, wherein the second row is substantially parallel to the first row.

5. The robotic cleaner of claim **1**, wherein, after rotating in the second rotation direction, the robotic cleaner is caused to rotate until the forward direction of movement extends away from the vertically extending surface.

6. The robotic cleaner of claim **5**, wherein, after rotating until the forward direction of movement extends away from the vertically extending surface, the robotic cleaner is caused to travel according to the forward direction of movement along a second row, the second row extending substantially parallel to the first row.

7. The robotic cleaner of claim **1**, wherein the one or more edge cleaning implements include a side brush.

8. A robotic cleaner comprising:

one or more driven wheels;

one or more environmental sensors configured to detect an obstacle having a vertically extending surface;

one or more edge cleaning implements; and

a controller communicatively coupled to the one or more driven wheels and the one or more environmental sensors, the controller is configured to cause the robotic cleaner to:

rotate in a first rotation direction such that a forward direction of movement of the robotic cleaner extends substantially parallel to the vertically extending surface;

after rotating such that the forward direction of movement is substantially parallel to the vertically extending surface, the robotic cleaner is caused to move according to the forward direction of movement for a predetermined distance; and

after moving according to the forward direction of movement for the predetermined distance, rotate in a second rotation direction, the second rotation direction being opposite the first rotation direction, wherein rotation in the second rotation direction is configured to cause at least one of the one or more edge cleaning implements to approach the vertically extending surface to disturb debris adjacent the vertically extending surface.

9. The robotic cleaner of claim **8**, wherein, before rotating in the first rotation direction such that a forward direction of movement of the robotic cleaner extends substantially parallel to the vertically extending surface, the robotic cleaner is caused to travel according to the forward direction of movement along a first row towards the vertically extending surface.

10. The robotic cleaner of claim **9**, wherein, after rotating until the forward direction of movement extends away from the vertically extending surface, the robotic cleaner is caused to travel according to the forward direction of movement along a second row.

11. The robotic cleaner of claim **10**, wherein the second row is substantially parallel to the first row.

12. The robotic cleaner of claim **8**, wherein, after rotating in the second rotation direction, the robotic cleaner is caused to rotate in the first rotation direction until the forward direction of movement extends away from the vertically extending surface.

13. The robotic cleaner of claim **8**, wherein, after rotating in the second rotation direction, the robotic cleaner is caused to rotate until the forward direction of movement extends away from the vertically extending surface.

14. The robotic cleaner of claim **13**, wherein, after rotating until the forward direction of movement extends away from the vertically extending surface, the robotic cleaner is caused to travel according to the forward direction of movement.

15. The robotic cleaner of claim **8**, wherein the predetermined distance is in a range of 4 centimeters (cm) to 12 cm.

16. The robotic cleaner of claim **8**, wherein the one or more edge cleaning implements include a side brush.

17. A robotic cleaner comprising:

one or more environmental sensors configured to detect an obstacle having a vertically extending surface;

one or more edge cleaning implements; and

a controller communicatively coupled to the one or more environmental sensors, the controller is configured to cause the robotic cleaner to:

rotate in a first rotation direction such that a forward direction of movement of the robotic cleaner extends substantially parallel to the vertically extending surface;

after rotating such that the forward direction of movement is substantially parallel to the vertically extending surface, the robotic cleaner is caused to move according to the forward direction of movement for a predetermined distance; and

after moving according to the forward direction of movement for the predetermined distance, rotate in a second rotation direction through a first rotation angle, the second rotation direction being opposite the first rotation direction, wherein rotation in the second rotation direction is configured to cause at least one of the one or more edge cleaning implements to approach the vertically extending surface to disturb debris adjacent the vertically extending surface.

18. The robotic cleaner of claim **17**, wherein, after rotating in the second rotation direction, the robotic cleaner is caused to rotate in the first rotation direction through a second rotation angle until the forward direction of movement extends away from the vertically extending surface.

19. The robotic cleaner of claim **18**, wherein the second rotation angle is 90° greater than the first rotation angle.

20. The robotic cleaner of claim **17**, wherein the one or more edge cleaning implements include a side brush.

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