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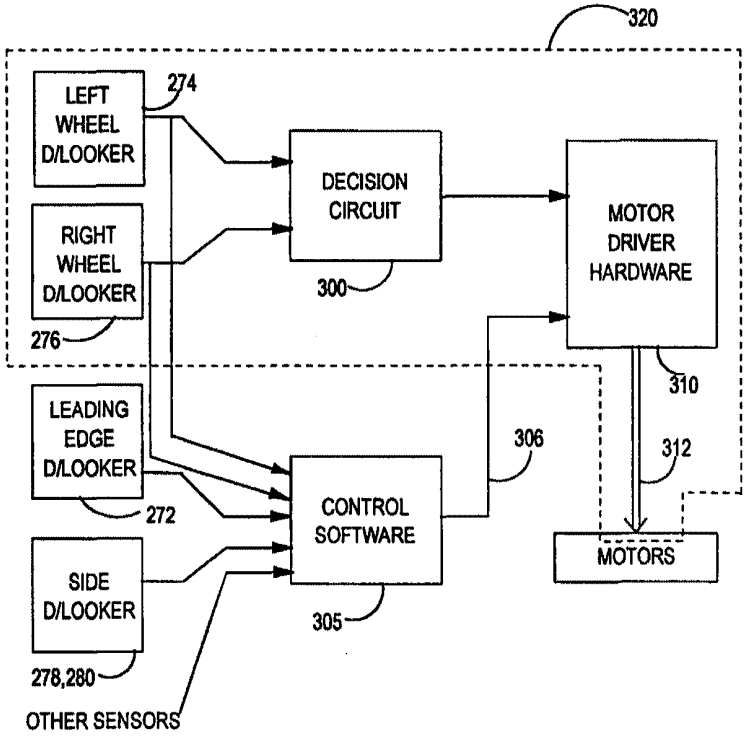
(54) Title: SENSORS ARRANGEMENT

(57) Abstract

An autonomous vehicle (100), such as a robotic cleaning device, comprises wheels (104) for supporting the vehicle and for allowing the vehicle to traverse a surface. Downward looking wheel sensors (274, 276) are provided for sensing the presence of a surface in front of the wheels and a further sensor (272) is provided at or near a leading edge of the vehicle for sensing the presence of a surface beneath the leading edge of the vehicle. The vehicle is arranged so that movement of the vehicle is possible if the leading edge sensor (272) detects the absence of a surface beneath the leading edge of the vehicle providing the wheel sensors (274, 276) indicate the presence of a surface adjacent the wheel. When the leading edge sensor (272) detects the absence of a surface beneath the leading edge of the vehicle, the vehicle performs an edge following routine.



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Sensors Arrangement

The invention relates to an arrangement of sensors for an autonomous vehicle, particularly but not exclusively for an autonomous vacuum cleaner.

An autonomous vehicle generally has a plurality of sensors for detecting obstacles in the path of the vehicle to prevent collision or accidents. While some autonomous vehicles can cope with undulating surfaces, they usually need to avoid any areas where there is a significant change in height, such as stairs where there is a danger that the machine can become stuck or fall, causing damage to the vehicle and to others. It is know to provide an autonomous vehicle with sensors that monitor the presence of a surface; these are often called "downlooking" or "drop-off" sensors.

A robotic cleaning device described in Patent Application WO 93/03399 has drop-off sensors at a forward edge of the cleaning device and is arranged to stop the drive motors when one of the drop-off sensors senses the absence of a surface beneath the cleaning device.

Safety regulations require that downlooking sensors should cause the vehicle to stop whenever the sensors detect the absence of a surface. This places severe constraints on flexibility of controlling the vehicle near to any places where there is a significant change in height. The present invention seeks to provide more flexibility in operating an autonomous vehicle under these conditions.

According to a first aspect of the invention, there is provided an autonomous vehicle comprising wheels for supporting the vehicle and for allowing the vehicle to traverse a surface, wherein downward looking wheel sensors are provided for sensing the presence of a surface in front of the wheels and a further sensor is provided at or near a leading edge of the vehicle for sensing the presence of a surface beneath the leading edge of the vehicle.

Preferably the vehicle is arranged so that movement of the vehicle is permitted when the leading edge sensor detects the absence of a surface beneath the leading edge of the vehicle providing the wheel sensors indicate the presence of a surface adjacent the wheel. This allows more flexibility in controlling movement of the cleaning device.

Preferably, the vehicle is arranged to operate so that when the leading edge sensor detects the absence of a surface beneath the leading edge of the vehicle, the vehicle performs an edge following routine. The edge following routine can be a zig-zag movement along the edge, or it can use a further downlooking sensor which senses the presence of a surface adjacent a side edge of the vehicle.

Further aspects of the invention provide a method of operating an autonomous vehicle, software for performing a method of controlling operation of an autonomous vehicle and a control apparatus for controlling operation of an autonomous vehicle.

An embodiment of the present invention will now be described, by way of example only, with reference to the accompanying drawings, wherein:

Figure 1 is a perspective view of an autonomous vehicle, specifically a vacuum cleaner, according to an embodiment of the invention;

Figure 2 is a front view of the autonomous vehicle of Figure 1;

Figure 3 is a rear view of the autonomous vehicle of Figure 1;

Figures 4a and 4b are side views, taken from the right and left sides respectively, of the autonomous vehicle of Figure 1;

Figures 5a and 5b are underneath and plan views respectively of the autonomous vehicle of Figure 1;

Figure 6 is a schematic view illustrating the positioning of infra-red sensors on the autonomous vehicle of Figure 1;

Figure 7 is a schematic view illustrating the grouping of infra-red sensors on the autonomous vehicle of Figure 1;

Figure 8 is a schematic view illustrating the positioning of ultra-sonic sensors on the autonomous vehicle of Figure 1; and

Figure 9 is a schematic view illustrating the positioning of further infra-red sensors on the autonomous vehicle of Figure 1;

Figure 10 shows the form of a downlooking sensor;

Figure 11 schematically shows how the downlooking sensors are used by the control system for the vehicle;

Figure 12 shows a control system for the cleaner;

Figure 13 shows one example of a sideways downlooking sensor;

Figures 14 and 15 show two ways in which the cleaner can operate when the cleaner reaches an edge of a surface that it is cleaning; and

Figure 16 is a flow diagram of a method for operating the cleaner.

The embodiment illustrated takes the form of an autonomous vacuum cleaner. The vacuum cleaner 100 shown in the said drawings has a supporting chassis 102 which is generally circular in shape and is supported on two driven wheels 104 and a castor wheel 106. The chassis 102 is preferably manufactured from high-strength moulded plastics material, such as ABS, but can equally be made from metal such as aluminium or steel. The chassis 102 provides support for the components of the cleaner 100 which will be described below. The driven wheels 104 are arranged at either end of a diameter of the chassis 102, the diameter lying perpendicular to the longitudinal axis of the cleaner 100. Each driven wheel 104 is moulded from a high-strength plastics material and carries a comparatively soft, ridged band around its circumference to enhance the grip of the wheel 104 when the cleaner 100 is traversing a smooth floor. The soft, ridged band also enhances the ability of the wheels 104 to mount and climb over small obstacles. The driven wheels 104 are mounted independently of one another via support bearings (not shown) and each driven wheel 104 is connected directly to a motor 105 which is capable of driving the respective wheel 104 in either a forward direction or a reverse direction. By driving both wheels 104 forward at the same speed, the cleaner 100 can be driven in a forward direction. By driving both wheels 104 in a reverse

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