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(54) **Title:** ADAPTING A LINE-FOLLOWING AUTOMATED GUIDED VEHICLE

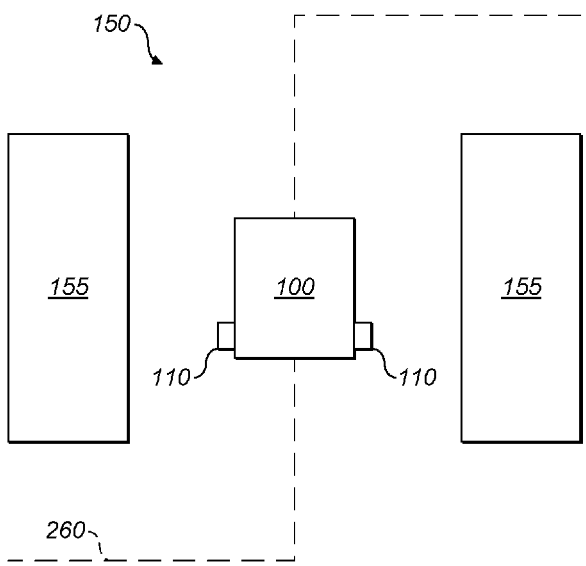

FIG. 4

(57) **Abstract:** A module to adapt an existing line-following automated guided vehicle into an automated guided vehicle that can navigate along a path without requiring a physical guide line to follow. The module has a communication interface which receives path information relating to a virtual path the line-following automated guided vehicle is to follow around an environment. An input to the module receives location information relating to the location of the line-following automated guided vehicle. A processor generates a control signal based on an off set between the location of the line-following automated guided vehicle and a location on the virtual path. The line-following automated guided vehicle has an existing steering controller that steers the line-following automated guided vehicle along a path by following a physical guide line. The control signal from the module is generated in a format to control the existing steering controller to steer the line-following automated guided vehicle navigate along the virtual path without needing to follow a physical guide line.

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Adapting a Line-Following Automated Guided Vehicle

Field of the Invention

The invention relates to a module and method to adapt an existing line-following automated guided vehicle into an automated guided vehicle that can navigate along a path without needing a physical guide line to follow. The invention also relates to a line-following automated guided vehicle which has had such a module retrofitted.

Background of the Invention

Many automated guided vehicles (AGVs) operating in an environment (such as a warehouse or factory) navigate by following a physical guide line pre-placed on the floor which marks out the path the automated guided vehicle should follow. The physical guide line is typically either a wire or magnetic tape which is buried under the floor, or a magnetic or coloured tape which is stuck to the surface of the floor.

Installing a physical guide line is time consuming and involves disruption, meaning that it is difficult and expensive to change the path of a line-following automated guided vehicle. Defining the physical guide line by installing a wire under the floor involves cutting a slot in the floor to receive the wire, which is disruptive and expensive. It is a little cheaper and easier to define the physical guide line with tape stuck to the surface of the floor, as this can be installed and removed more easily without needing to cut a slot in the floor. However, using tape has the disadvantage that it is susceptible to damage. If a line-following automated guided vehicle comes across a region of tape that has been damaged and partially destroyed, the line-following automated guided vehicle will not know the direction in which it is supposed to travel, and will usually come to a halt requiring operator intervention and time to repair the damaged tape.

There are a number of alternative navigation technologies available which remove the need for a physical guide line to be installed. In general, these navigation technologies rely on the automated guided vehicle being able to identify its location on a map of the environment. Such automated guided vehicles identify their location using laser-reflector navigation, vision systems or natural feature navigation, and are able to follow a virtual path draw on the map, rather than relying on a physical guide line.

Ideally, existing line-following automated guided vehicles would be replaced with automated guided vehicles which do not require a physical guide line. However, there is already a large inventory of existing line-following automated guided vehicles operating in warehouses and factories, so there is some resistance to change because of the cost involved with scrapping all of these existing automated guided vehicles. Hence, it would be desirable to find a way to adapt existing line-following automated guided vehicles.

Summary of the Invention

According to a first aspect of the invention, there is provided a module. The module may be retrofitted into a line-following automated guided vehicle comprising a steering controller configured to steer the line-following automated guided vehicle along a path by following a physical guide line (such as a tape or wire). The module is configured to adapt the line-following automated guided vehicle into an automated guided vehicle that can navigate along a path without needing a physical guide line to follow.

The module comprises a communications interface, an input, a processor and an output. The communication interface is configured to receive path information relating to a virtual path the line-following automated guided vehicle is to follow around an environment. The input is configured to receive location information relating to the location of the line-following automated guided vehicle. The processor is configured to generate a control signal based on an offset between the location of the line-following automated guided vehicle and a location on the virtual path. The control signal is generated in a format to control the steering controller of the line-following automated guided vehicle, in order to steer the line-following automated guided vehicle along the virtual path without needing to follow a physical guide line. The output is connectable to the steering controller of the automated guided vehicle, and the output provides the control signal to the steering controller.

By retrofitting existing line-following automated guided vehicles with such a module, existing line-following automated guided vehicles may be adapted to navigate without needing a physical guide line (such as a tape or wire) to follow, meaning that it is not necessary to purchase a new automated guided vehicle, which is a significant cost saving for the owner. This means that existing line-following automated guided vehicles can be retrofitted with new navigation technology, which means that existing line-following automated guided vehicles do not need to be scrapped, which reduces waste and is better for the environment.

The steering controller is the existing steering controller that was already fitted to the line-following automated guided vehicle prior to retrofitting the module and which is configured to steer the line-following automated guided vehicle along a path by following a physical guide line. The existing steering controller may be the steering controller which was fitted when the line-following automated guided vehicle was manufactured. As the module generates a control signal in a format which can control the existing steering controller that was already fitted into the line-following automated guided vehicle prior to retrofitting the module, it is not necessary to install a new steering controller, making it quicker, cheaper, easier and more desirable to adapt an existing line-following automated guided vehicle rather than buying a replacement.

The control signal may comprise a signal configured to steer one or more steering wheels of the line-following automated guided vehicle.

The control signal may comprise a signal configured to control the relative rate of rotation of two or more wheels of the line-following automated guided vehicle. The control signal may comprise a differential voltage which indicates the relative rate of rotation of the two or more wheels. Line-following automated guided vehicle typically have a pair of differentially driven wheels, which allows the direction of the line-following automated guided vehicle to be controlled by varying the relative rate of rotation of the wheels. The steering controller typically controls the relative rate of rotation of the wheels based on a differential voltage. By generating a control signal which is a differential voltage, the module may directly drive the existing steering controller in the line-following automated guided vehicle, so it is not necessary to install a new steering controller, making it easier and cheaper to adapt a line-following automated guided vehicle.

The communications interface may receive the path information from a central control system. This allows the automated guided vehicle to be easily controlled from a remote location, and changes to the path can be easily implemented by entering new path information into the central control system. The path information may be updated as the automated guided vehicle navigates around the environment. The path information can be updated based on changing operational parameters, for example, the path may be changed to respond to an urgent task request, or the automated guided vehicle may be stopped in response to an emergency.

The communications interface may receive the path information incrementally, for example, over a wireless communications links with the central control system. Alternatively, the communications interface may download the path information (over either a wired or wireless communications link) which is stored in memory of the module. The path information may be downloaded when the automated guided vehicle is installed, before the automated guided vehicle begins navigating the path, or while the automated guided vehicle is navigating the path.

The path information may comprise an instruction configured to instruct the automated guided vehicle to perform an action at a defined location on the path. The action may be stopping the automated guided vehicle, changing the speed of the automated guided vehicle, or selecting a path of the automated guided vehicle from a plurality of possible paths. Previously, such instructions had to be made by modifying the path in some way. For example, an RFID tag was placed next to the tape or wire defining the path; an RFID reader was placed on the automated guided vehicle which detected the RFID tag and carried out the action associated with the RFID tag. Providing instructions in the path information provides a much more flexible way to implement an action which does not require the path to be modified, or tags to be placed around the environment, and allows the actions to be changed in real time.

The module may be configured to generate, and output, an instruction to the automated guided vehicle to carry out the action at the defined location. The instruction may instruct the steering controller and/or drive controller of the automated guided vehicle to carry out the action. The module may comprise a transmitter configured to transmit the instruction to an RFID reader of the automated guided vehicle and the communication may mimic a communication from an RFID tag which causes the automated guided vehicle to carry out the action.

The location information may be received from a sensor. The sensor may be, for example, a laser scanner or a camera.

The location information may be received from a laser-target navigation device, a natural feature navigation device, or a vision guidance device.

According to a second aspect of the invention, there is provided a method of adapting a line-following automated guided vehicle into an automated guided vehicle that can navigate along a path without needing a physical guide line to follow. The line-following automated guided vehicle has an existing steering controller which steers the line-following automated guided vehicle along a path by following a physical guide line. The method retrofits a module which controls the existing steering controller to allow the line-following automated guided vehicle to navigate along a path without requiring a physical guide line to follow.

The method comprises installing a module according to the first aspect onto a line-following automated guided vehicle.

The method may comprise installing a sensor on the line-following automated guided vehicle, where the sensor is configured to generate location information relating to the location of the line-following automated guided vehicle. The module is retrofitted to the line-following automated guided vehicle. The module comprises a communication interface, an input, a processor and an output. The communications interface is configured to receive path information relating to a virtual path the line-following automated guided vehicle is to follow around an environment. The input is configured to receive the location information. The processor is configured to generate a control signal based on an offset between the location of the line-following automated guided vehicle and a location on the path. The control signal is generated in a format to control the steering controller on the line-following automated guided vehicle in order to steer the line-following automated guided vehicle navigate along the virtual path without requiring a physical guide line. The output is configured to provide the control signal. The input of the module is connected to the sensor. The output of the module is connected to the existing steering controller of the line-following automated guided vehicle.

According to a third aspect of the invention, there is provided a line-following automated guided vehicle having retrofitted thereon a module according to the first aspect.

According to a fourth aspect of the invention, there is provided a line-following automated guided vehicle adapted according to the method of the second aspect.

Brief Description of the Drawings

The invention shall now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 illustrates a typical line-following automated guided vehicle;

Figure 2 illustrates the line-following automated guided vehicle of Figure 1 navigating around a warehouse;

Figure 3 illustrates the line-following automated guided vehicle of Figure 1 adapted using a module into an automated guided vehicle that no longer needs a physical guide line to follow; and

Figure 4 illustrates the automated guided vehicle of Figure 3 navigating around a warehouse.

Detailed Description

Figure 1 illustrates a typical line-following automated guided vehicle 100. In this example, the line-following automated guided vehicle 100 is a tricycle with a single front wheel 115 and a pair of rear steering wheels 110. The line-following automated guided vehicle 100 is steered using a differential drive mechanism, that is, the steering controller 120 independently controls the rate of rotation of each of the steering wheels 110 in order to control the direction of travel of the line-following automated guided vehicle 100.

As shown in Figure 2, the line-following automated guided vehicle 100 navigates around obstacles 155 (such as shelves) in a warehouse 150 by following a path defined by a pre-placed physical guide line in the form of tape 160 which is stuck to the floor of the warehouse 150. The line-following automated guided vehicle 100 has a camera 130 which is pointed at the tape 160. The camera 130 sends images of the tape 160 to the navigation controller 140. The navigation controller 140 uses the images of the tape 160 to generate a signal to instruct the steering controller 120 to adjust the rotation rate of the steering wheels 110 in order to make the line-following automated guided vehicle track along the tape 160. For example, the navigation controller 140 may seek to keep the tape 160 in the centre of the image and if the navigation controller 140 senses that the tape 160 has moved to the right in the image, the navigation controller 140 generates a signal to indicate that the automated guided vehicle 100 should be steered to the right until the tape 160 again appears in the centre of the image.

As shown in Figure 3, a module 170 may be retrofitted into a line-following automated guided vehicle 100, in order to adapt the line-following automated guided vehicle 100 so that it can navigate without needing a physical guide line, such as tape 160, to define the path along which the line-following automated guided vehicle 100 should travel. Instead, a virtual path 260 may be defined on a map of the environment held at a central control system 190. This means that it is no longer necessary to install a physical guide line, such as tape 160 in the warehouse 150, which avoids disruption to the warehouse 150 and eliminates the cost of installing the tape 160. It also becomes much easier to change the path, for example, by redrawing the virtual path 260 on the map at the central control system 190, and the virtual path 260 could even be changed in real time in response to a changing operational need (such as an urgent task request).

The central control system 190 sends path information wirelessly to the module 170. The module 170 has a wireless communication interface 176 which receives information about the virtual path 260.

A guidance system 180 is mounted to the roof of the line-following automated guided vehicle 100. The guidance system 180 includes a camera which generates images of the warehouse 150. These images are passed to a processor in the guidance system 180 which processes the images to ascertain the location of the automated guided vehicle 100 in the warehouse 150 using a natural feature navigation algorithm. The location of the automated guided vehicle 100 is passed to input 172 of the module 170 which is connected to processor 174.

The processor 174 determines an offset between the location of the automated guided vehicle 100 and a desired location on the virtual path 260. The processor 174 generate a control signal based on the offset - the control signal indicates the steering adjustment that is needed to ensure that automated guided vehicle 100 navigates along the virtual path 260.

The control signal is generated in a format to control the existing steering controller 170 that was already installed in the line-following automated guided vehicle 100 (for example, when the line-following automated guided vehicle 100 was manufactured). The output 176 is connected to the existing steering controller 120 and provides the control signal to the existing steering controller 170. As far as the existing steering controller 120 is concerned, the control signal appears identical to the control signal the existing steering controller 120 expected to receive when the automated guided vehicle was operating as a line-following automated guided vehicle. So, the existing steering controller 120 uses the control signal to control the relative rate of rotation of the steering wheels 110, just as it had previously. This is an advantage as it is not necessary to install a new steering controller or adapt the line-following automated guided vehicle 100 in any way other than installing the module 170, which reduces the cost of adapting the line-following automated guided vehicle 100.

Although the invention has been described in terms of particular embodiments, the skilled person will appreciate that various modifications could be made without departing from the scope of the appended claims.

Although the automated guided vehicle 100 has been described as navigating around a warehouse 150, the automated guided vehicle 100 could be used in any environment. The automated guided vehicle 100 could be used on an industrial site, like a factory, manufacturing plant or processing plant. For example, the automated guided vehicle may be used at an automotive manufacturing plant. The automated guided vehicle 100 may be used, for example, to supply raw materials, move products between manufacturing stages, or take away finished products for storage, packaging or despatch. The automated guided vehicle 100 may be used in logistics operations, for example, in a hospital, an airport, or a seaport. The automated guided vehicle 100 may be used to move items around a hazardous environment.

The automated guided vehicle 100 has been described as being a tricycle having a single front wheel 115. However, the automated guided vehicle 100 could instead have two front wheels 115.

Instead of being steered with a differential drive mechanism, the automated guided vehicle 100 could be driven by steering the front wheel 115 or front wheels 115 using the steering controller 120.

The path information may include an instruction which instructs the automated guided vehicle 100 to perform an action at a defined location on the path. For example, the action might be stopping at a particular location to collect an item, or slowing down at a particular location because of pedestrians.

Instead of a camera, the guidance system 180 could use a laser scanner. Instead of a natural feature algorithm, the guidance system 180 could use laser-target navigation (that is, a laser scanner in combination with a network of reflectors at known positions), or vision-based navigation.

Claims

1. A module configured to be retrofitted into a line-following automated guided vehicle, the line-following automated guided vehicle comprising a steering controller configured to steer the line-following automated guided vehicle along a path by following a physical guide line, the module configured to adapt the line-following automated guided vehicle into an automated guided vehicle that can navigate along a path without requiring a physical guide line to follow, the module comprising:

a communication interface configured to receive path information relating to a virtual path the line-following automated guided vehicle is to follow around an environment;

an input configured to receive location information relating to the location of the line-following automated guided vehicle;

a processor configured to generate a control signal based on an offset between the location of the line-following automated guided vehicle and a location on the virtual path, wherein the control signal is generated in a format to control the steering controller of the line-following automated guided vehicle in order to steer the line-following automated guided vehicle along the virtual path without needing to follow a physical guide line; and

an output connectable to the steering controller of the line-following automated guided vehicle, wherein the output provides the control signal to the steering controller.

2. The module of claim 1, wherein the control signal comprises a signal configured to steer one or more steering wheels of the automated guided vehicle.

3. The module of either of claims 1 or 2, wherein the control signal comprises a signal configured to control the relative rate of rotation of two or more wheels of the automated guided vehicle.

4. The module of claim 3, wherein the control signal comprises a differential voltage which indicates the relative rate of rotation of the two or more wheels.

5. The module of any preceding claim, wherein the communication interface receives the path information from a central control system.

6. The module of any preceding claim, wherein the path information comprises an instruction configured to instruct the automated guided vehicle to perform an action at a defined location on the path.

7. The module of claim 6, wherein the action is one of: stopping the automated guided vehicle; changing the speed of the automated guided vehicle; or selecting a path of the automated guided vehicle from a plurality of possible paths.

8. The module of any preceding claim, wherein the path information is updated as the automated guided vehicle navigates around the environment.

9. The module of any preceding claim, wherein the location information is received from a sensor, for example, a laser scanner or a camera.

10 The module of any preceding claim, wherein the location information is received from a laser-target navigation device, a natural feature navigation device, or a vision guidance device.

11. A method of adapting a line-following automated guided vehicle comprising a steering controller configured to steer the line-following automated guided vehicle along a path by following a physical guideline into an automated guided vehicle that can navigate along a path without requiring a physical guide line to follow, the method comprising:

installing a sensor on the line-following automated guided vehicle, wherein the sensor is configured to generate location information relating to the location of the line-following automated guided vehicle;

retrofitting a module on the line-following automated guided vehicle, the module configured to adapt the line-following automated guided vehicle to navigate along a path without requiring a physical guide line to follow, the module comprising:

a communication interface configured to receive path information relating to a virtual path the line-following automated guided vehicle is to follow around an environment;

an input configured to receive the location information;

a processor configured to generate a control signal based on an offset between the location of the line-following automated guided vehicle and a location on the virtual path, wherein the control signal is generated in a format to control the steering controller of the line-following automated guided vehicle in order to steer the line-following automated guided vehicle along the virtual path without needing to follow a physical guide line; and

an output configured to provide the control signal;

connecting the input of the module to the sensor; and

connecting the output of the module to the steering controller of the line-following automated guided vehicle.

12. A line-following automated guided vehicle having retrofitted thereon a module according to any of claims 1 to 10.

13. A line-following automated guided vehicle adapted according to the method of claim 11.

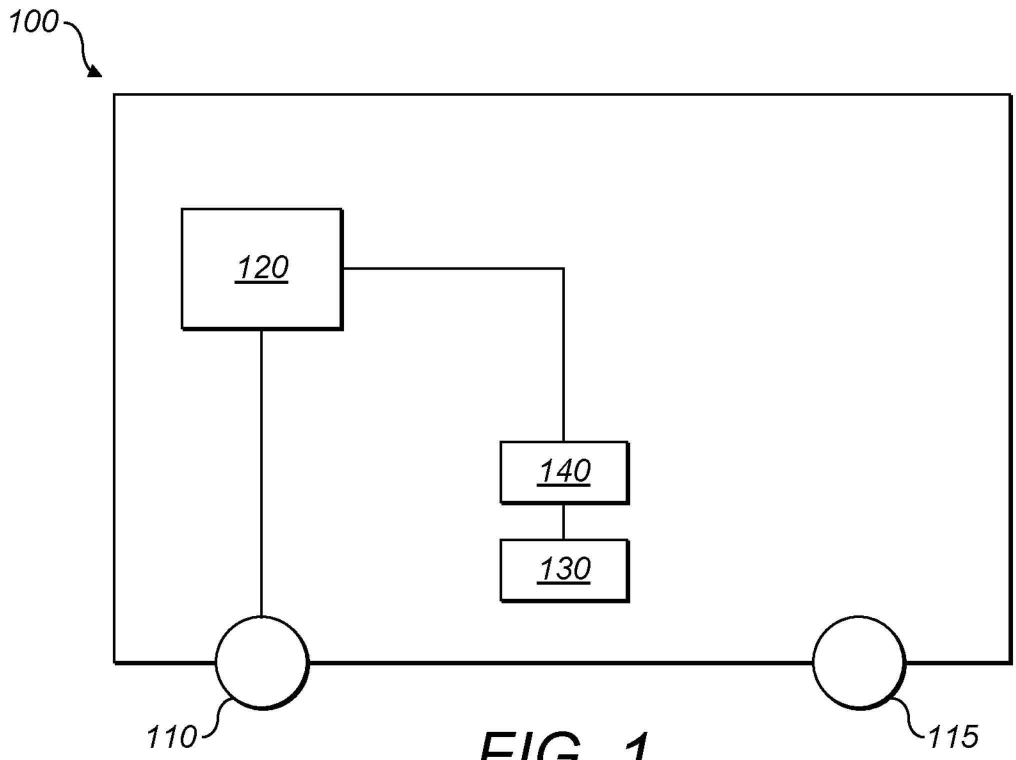

FIG. 1

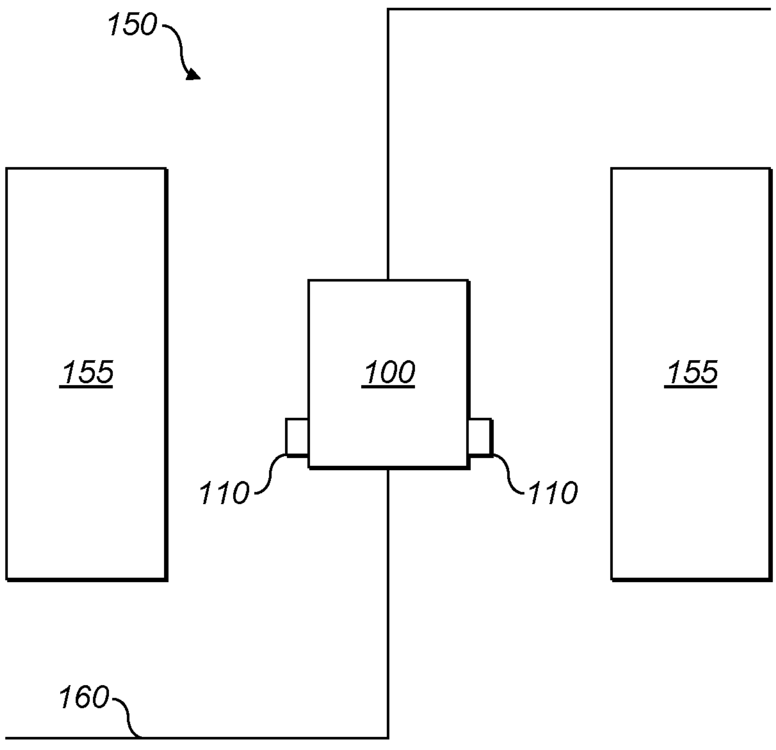

FIG. 2

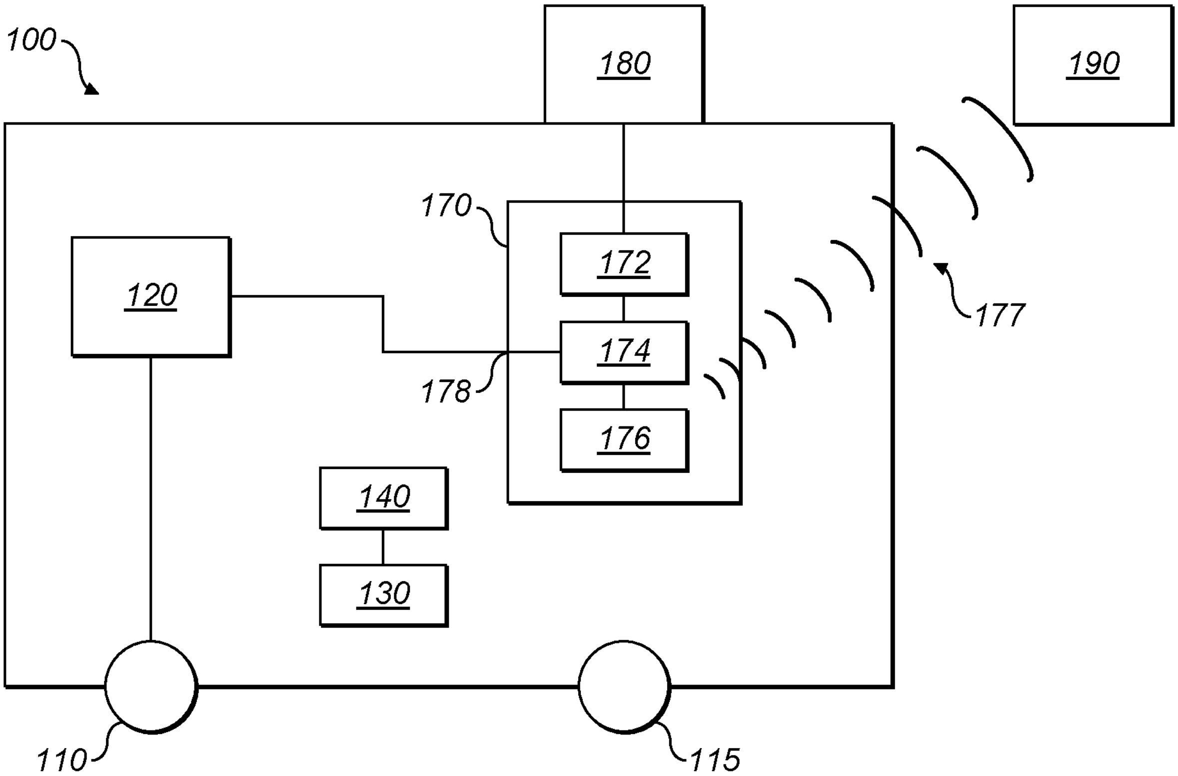
100
180
190
170
172
120
174
177
178
176
140
130
110
115

FIG. 3

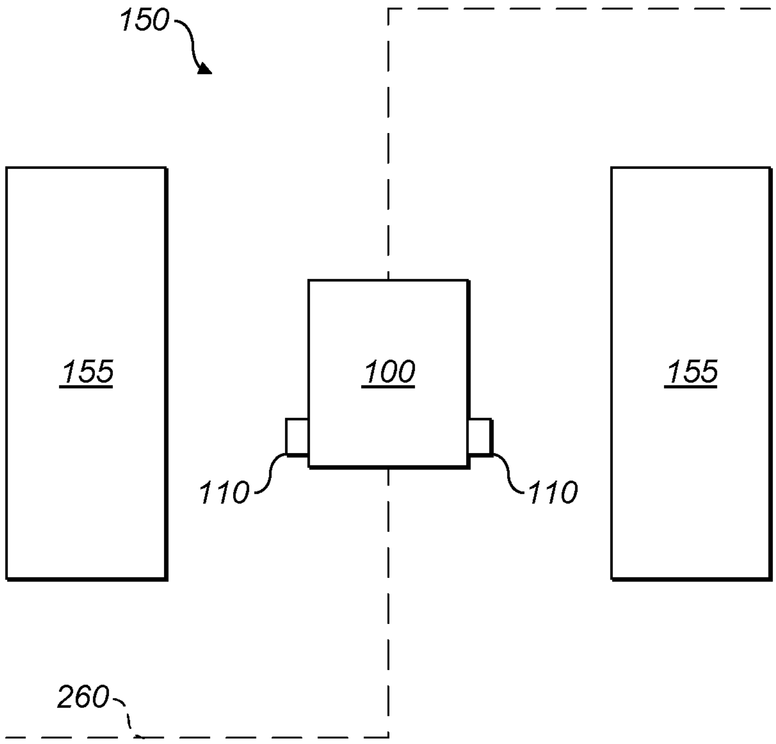
150
155
100
155
110
110
260

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2017/052695

A. CLASSIFICATION OF SUBJECT MATTER
INV. G05D1/00 G05D1/02
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G05D G01C

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 2009/118890 A1 (LIN YEN-CHUN [TW] ET AL) 7 May 2009 (2009-05-07) abstract; claim 1; figures 1-6 paragraphs [0016] - [0018], [0027] - [0033] -----	1,11
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 December 2017	11/12/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	De Syllas, Dimitri

1

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 530 056 A (MACKINNON ALLAN S [US] ET AL) 16 July 1985 (1985-07-16) abstract; claim 19; figures 1-2 column 13, lines 18-26 - column 15, line 13 column 25, line 50 - column 27, line 23 -----	1,11

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2017/052695

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