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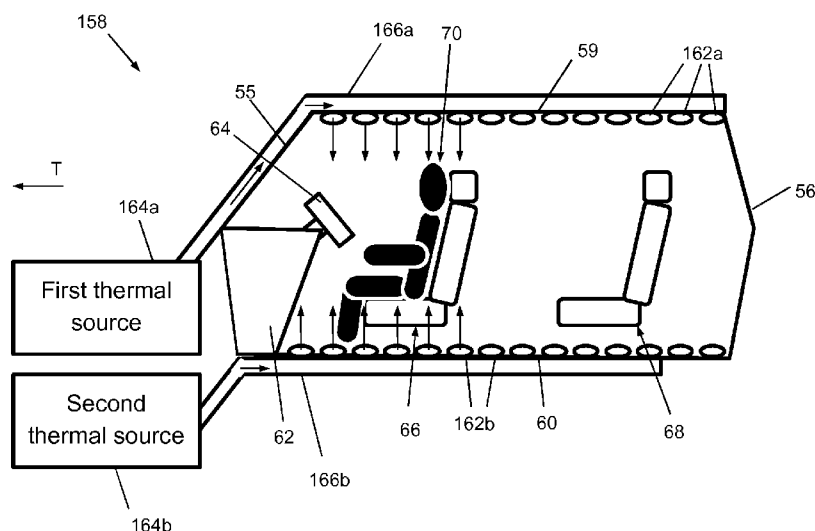


Fig. 4

(57) Abstract: A vehicle system for use in a vehicle, including an airflow system and a vehicle cabin defined, at least in part, by an upper cabin surface (59) and a lower cabin surface (60), the airflow system being configured to condition air in the vehicle cabin and comprising at least one upper air vent (162a) disposed in the upper cabin surface (59) and at least one lower air vent (162b) disposed in the lower cabin surface (60), an airflow apparatus (158) configured to direct an airflow through the at least one lower air vent (162b) and the at least one upper air vent (162a), and a control system comprising one or more controllers configured to control the airflow through the at least one lower air vent (162b) and the at least one upper air vent (162a).



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A VEHICLE SYSTEM

TECHNICAL FIELD

5 The present disclosure relates to vehicle airflow systems. Aspects of the invention relate to a vehicle system comprising an airflow system and a vehicle cabin, to a control system, to a method, to a vehicle, to computer software and to a computer readable medium.

10 BACKGROUND

In conventional vehicles, seating is arranged so that occupants face a vehicle dashboard. In conventional vehicle air conditioning systems, air outlets are disposed around the vehicle dashboard and, more recently, outlets are also disposed between
15 front and second row seats of the vehicle. This configuration is preferred because the range of movement of the occupants in relation to the outlets is limited.

However, these air conditioning systems dispense thermally conditioned air across the cabin space, thermally conditioning large areas of the vehicle. Such air conditioning
20 systems consume large quantities of energy, which is a particular issue in battery electric vehicles (BEV), because consuming large quantities of energy significantly impacts the range of a BEV.

Furthermore, for non-conventional seating arrangements arranging air outlets in the
25 dashboard is ineffective. For example, undesired temperature gradients may arise within a vehicle cabin as warm air rises under natural convection.

It is an aim of the present invention to address one or more of the disadvantages associated with the prior art.

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SUMMARY OF THE INVENTION

Aspects and embodiments of the invention provide a vehicle system including a vehicle cabin provided with an airflow system and at least one seat, a control system for such a
35 system, a vehicle comprising the vehicle system and/or the control system, a method,

computer software and a computer readable medium as claimed in the appended claims.

5 An aspect of the invention provides a vehicle system for use in a vehicle. The vehicle system includes a vehicle cabin defined, at least in part, by an upper cabin surface and a lower cabin surface. The vehicle system also includes an airflow system configured to condition air in the vehicle cabin, the airflow system comprising: at least one upper air vent disposed in the upper cabin surface and at least one lower air vent disposed in the lower cabin surface; an airflow apparatus configured to direct an airflow through the at least one lower air vent and the at least one upper air vent; and a control system
10 comprising one or more controllers configured to control the airflow through the at least one lower air vent and the at least one upper air vent, for example to control a temperature of the vehicle cabin.

15 Disposing air vents in an upper and lower surface of the cabin enables the vehicle system to operate to counteract natural convection within the cabin. For example, to maintain a warm temperature throughout the cabin, the system can replenish warm air rising by convection by directing warm air into the cabin through the or each lower air vent. It may even be possible to create opposed airflows through the upper and lower
20 air vents if desired.

In this respect, 'warm air' may be defined with reference to a measured cabin temperature, namely as referring to air that is at a temperature above that measured in the cabin. Correspondingly, 'cool air' typically refers to air that is at a lower temperature
25 than air in the cabin.

The air vents may be bi-directional, such that the vents can operate as either inlets or outlets with respect to the airflow system, thereby increasing the modes of operation of which the system is capable. In this respect, for consistency with conventional
30 arrangements in which vents through which air is directed into a cabin are referred to as outlets, in the following description operating a vent as an 'outlet' entails directing air into the cabin through the vent, and operating a vent as an 'inlet' entails drawing air out of the cabin through the vent.

Also, placing vents in the upper or lower surfaces of the cabin greatly increases flexibility in terms of their positions relative to users compared with conventional arrangements having dashboard-mounted air outlets.

- 5 The vehicle system may comprise a first airflow apparatus configured to direct a first airflow through at least one upper air vent in the upper cabin surface, and a second airflow apparatus configured to direct an airflow through at least one lower air vent in the lower cabin surface. The first airflow apparatus may be configured to direct an airflow which is at a lower temperature than an airflow directed by the second airflow apparatus,
- 10 such that the first airflow apparatus is operable to cool the vehicle cabin while the second airflow apparatus is operable to warm the vehicle cabin. For example, the first airflow apparatus optionally comprises an air conditioning unit, and the second airflow apparatus may comprise a heater. Alternatively, the first airflow apparatus may be configured to direct an airflow which is at a higher temperature than an airflow directed
- 15 by the second airflow apparatus. The first and second airflow apparatuses may each include provisions for both heating and cooling an airflow.

- The air flow apparatus may comprise one or more of: a pump for generating air flow; a thermal source for thermally conditioning air; and a valve system for controlling air flow.
- 20 The valve system may comprise a valve positioned at each of the outlets. For example, in some embodiments the first airflow apparatus comprises a first pump configured to direct a first airflow to at least one upper air vent in the upper cabin surface, and the second airflow apparatus comprises a second pump configured to direct an airflow to at least one lower air vent in the lower cabin surface.

- 25 The first airflow apparatus may be operable to provide suction that draws air into at least one upper air vent. Correspondingly, the second airflow apparatus may be operable to provide suction that draws air into at least one lower air vent.

- 30 The at least one upper air vent and the at least one lower air vent are optionally in vertical alignment with one another.

- The vehicle system may comprise an array of upper air vents disposed in the upper cabin surface. Similarly, the vehicle system may comprise an array of lower air vents
- 35 disposed in the lower cabin surface. For example, the or each array may be two-

dimensional and substantially cover a seating area within the cabin. The vents may be selectively operable, so that only a subset of the vents of the or each array are open, enabling airflows to be targeted at users within the cabin whilst avoiding conditioning unoccupied areas of the cabin.

5

The vehicle cabin may have a seat that is moveable into a plurality of positions, in which case the one or more controllers may be configured to receive a seat signal relating to at least one of: whether or not the seat is occupied, and the position of the seat. In such embodiments, the one or more controllers may be configured to generate a control
10 signal to control the airflow apparatus in response to the seat signal. The seat may be moveable to each of the plurality of positions by any one or more of: longitudinal movement; lateral movement; rotational movement; reclining movement; and folding movement. The control signal may be configured to adjust automatically a status of one or more of the air vents in response to the seat signal.

15

Beneficially, the ability of the vehicle system to adapt its operation based on position as well as occupation leads to improvements in how effective the air flow system is at directing air over users, while reducing energy wastage by avoiding conditioning air in unoccupied areas of the cabin.

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The vehicle system may comprise a user preference module for providing user preference data to the one or more controllers, the one or more controllers being configured to provide a control signal to the airflow apparatus to selectively control which of the plurality of air outlets to direct the airflow through in dependence on the occupancy
25 signal, on the seat signal, and on the user preference data. The user preference data may include at least one of a temperature of the airflow and a speed of the airflow.

The or each airflow produced by the upper and lower vents may be substantially orthogonal to the upper and lower cabin surfaces. In practice, this will generally entail a
30 substantially vertical airflow. Directing the or each airflow in this way may enable it to be used to create a thermal curtain, namely a substantially laminar flow that resists convection across it and therefore advantageously limits heat transfer by convection between different regions of the vehicle. In particular, the thermal curtain may substantially inhibit heat transfer by convection between regions of the cabin that are

inboard and outboard of the thermal curtain. For example, the thermal curtain may provide a substantially laminar air flow between the vehicle seat and a sidewall. In this manner, the cabin air inboard of the thermal curtain, for example in the region of the user, may be isolated from the cabin air outboard of the thermal curtain. The air flow
5 through the vents effectively operates as a barrier between regions so that different conditions can be implemented in the different regions of the vehicle without contamination or mixing. In simple terms, therefore, thermal curtains may be used to create different temperature zones within the cabin, the temperature in each zone being controllable substantially independently of the other zones.

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In some examples, a single air flow apparatus may create a thermal curtain. Air vents in one surface may also be used to create a thermal curtain. The thermal curtain effect may also be enhanced by directing an airflow into the cabin through one air vent, and generating suction to draw air out of the cabin through an opposing air vent.

15

The one or more controllers are optionally configured to receive a temperature demand signal and to generate a control signal to control the airflow apparatus in response to the temperature demand signal. For example the one or more controllers may be configured to: receive a temperature demand signal and a temperature signal; compare
20 the temperature demand signal and the temperature signal; and generate a control signal to control the airflow apparatus based on the comparison between the temperature demand signal and the temperature signal.

25

For example, if the temperature demand signal exceeds the temperature signal, the one or more controllers may operate the airflow apparatus to direct warm air into the cabin through the or each lower vent. The one or more controllers may also operate the airflow apparatus to draw air out of the cabin through the or each upper vent in this situation.

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Conversely, if the temperature signal exceeds the temperature demand signal, the one or more controllers may operate the airflow apparatus to direct cool air into the cabin through the or each upper vent, whilst optionally also drawing air out of the cabin through the or each lower vent.

Another aspect of the invention provides a control system for a vehicle airflow apparatus, the apparatus being configured to control airflow through at least one lower air vent in a lower surface of a vehicle cabin and at least one upper air vent in an upper surface of the vehicle cabin. The control system comprises one or more controllers configured to:

5 receive a temperature demand signal indicative of a temperature demand; receive a temperature signal indicative of a temperature in the cabin; compare the temperature demand signal with the temperature signal; determine a control signal in dependence on the comparison between the demand signal and the temperature signal; and output the control signal to the airflow apparatus to control airflow to the lower air vent and the

10 upper air vent.

Optionally, the one or more controllers may collectively comprise: at least one electronic processor having one or more electrical inputs for receiving the temperature demand signal and the temperature signal; and at least one electronic memory device operatively

15 coupled to the at least one electronic processor and having instructions stored therein; wherein the at least one electronic processor is configured to access the at least one memory device and execute the instructions stored therein so as to determine the control signal.

20 The invention also extends to a vehicle comprising the vehicle system and/or the control system of the above aspects.

Another aspect of the invention provides a method of controlling airflow through at least one lower air vent in a lower surface of a vehicle cabin and at least one upper air vent

25 in an upper surface of the vehicle cabin. The method comprises: receiving a temperature demand signal indicative of a desired temperature for the vehicle cabin; receiving a temperature signal indicative of a measured temperature in the vehicle cabin; comparing the temperature signal with the temperature demand signal; and generating a control signal arranged to operate airflow apparatus to direct an airflow through at least one of

30 the at least one upper air vent and the at least one lower air vent in dependence on the comparison between the temperature signal with the temperature demand signal.

The method may comprise directing an airflow through the at least one upper air vent into the cabin if the temperature signal exceeds the temperature demand signal, and

directing an airflow through the at least one lower air vent into the cabin if the temperature demand signal exceeds the temperature signal. Such methods may also comprise directing an airflow out of the cabin through the at least one upper air vent if the temperature demand signal exceeds the temperature signal, and directing an airflow
5 out of the cabin through the at least one lower air vent if the temperature signal exceeds the temperature demand signal.

According to an aspect of the invention there is provided computer software which, when executed by one or more processors, causes performance of a method according to a
10 preceding aspect of the invention.

According to an aspect of the invention there is provided a computer readable medium having instructions stored therein which, when executed by one or more processors, causes performance of a method according to a preceding aspect of the invention.
15 Optionally, the computer readable medium comprises a non-transitory computer readable medium.

Any controller or controllers described herein may suitably comprise a control unit or computational device having one or more electronic processors. Thus the system may
20 comprise a single control unit or electronic controller or alternatively different functions of the controller may be embodied in, or hosted in, different control units or controllers.

As used herein the term 'controller' or 'control unit' will be understood to include both a single control unit or controller and a plurality of control units or controllers collectively
25 operating to provide any stated control functionality. To configure a controller, a suitable set of instructions may be provided which, when executed, cause said control unit or computational device to implement the control techniques specified herein. The set of instructions may suitably be embedded in said one or more electronic processors. Alternatively, the set of instructions may be provided as software saved on one or more
30 memory associated with said controller to be executed on said computational device. A first controller may be implemented in software run on one or more processors. One or more other controllers may be implemented in software run on one or more processors, optionally the same one or more processors as the first controller. Other suitable arrangements may also be used.

Within the scope of this application it is expressly intended that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual
5 features thereof, may be taken independently or in any combination. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination, unless such features are incompatible.

BRIEF DESCRIPTION OF THE DRAWINGS

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One or more embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

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Figure 1 shows a side view of a vehicle in accordance with an embodiment of the invention;

Figure 2 shows a schematic plan view of a seating arrangement of a vehicle cabin of the vehicle of Figure 1;

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Figure 3 shows a schematic plan view of air vents within a vehicle cabin in relation to the seating arrangement of Figure 2;

Figure 4 shows a schematic side view of a vehicle cabin of the vehicle of Figure 1;

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Figure 5 shows a schematic diagram of an airflow system for use in controlling air vents within the vehicle cabin in Figures 3 and 4;

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Figure 6 shows a schematic plan view of an alternative seating arrangement of a vehicle cabin of the vehicle of Figure 1; and

Figure 7 shows a method of operation of the airflow system of Figure 5.

DETAILED DESCRIPTION

In general terms, the present disclosure relates to a vehicle airflow system having one or more vents in each of the upper and lower surfaces of a vehicle cabin. As explained below, such a system finds particular application in an autonomous vehicle having seating that is more reconfigurable than for a conventional vehicle. However, such airflow systems offer benefits in any type of vehicle.

For example, by positioning vents in both the upper and lower surfaces of the vehicle cabin, the system can operate to combat natural convection within the cabin and therefore refine temperature control. In this respect, in a conventional arrangement a vertical temperature gradient may arise within the vehicle cabin due to the natural tendency for relatively dense cool air to displace relatively light warm air, so that cool air accumulates at the bottom of the cabin while warm air is pushed to the top. A conventional system having front-mounted, horizontally-oriented outlets has a limited ability to counteract this effect.

In the system described below, the provision of vents in both the upper and lower surfaces of the cabin enhances its ability to combat natural convection and therefore refine temperature control within the vehicle cabin. In general terms, when warming is required warm air can be directed into the cabin through vents in the lower surface of the vehicle cabin, noting that warm air within the cabin will tend to rise naturally under convection and so operating in this manner compensates for this natural effect. Correspondingly, when cooling is required cool air can be delivered through vents disposed in the upper surface of the cabin.

In this respect, 'warm air' may refer to air that is warmer than air in the cabin, and 'cool air' may refer to air that is cooler than air in the cabin. Typically, 'warm air' is also warmer than a target cabin temperature, while 'cool air' is cooler than a target cabin temperature. At the very least, 'warm air' is intended to refer to air that is warmer than 'cool air', and so in the above example the air flowing through the vents in the lower surface of the cabin is warmer than air flowing through the vents in the upper surface.

A combination of the two airflows may even be possible to provide a more uniform temperature distribution throughout the cabin. So, warm air can be directed into the

cabin through vents in the lower surface of the vehicle cabin at the same time as delivering cool air through the vents in the upper surface of the cabin to counteract natural convection in both regions of the cabin.

- 5 Figure 1 illustrates in side view a vehicle 10 to which embodiments of the invention may be applied. The vehicle 10 has a vehicle body 12 supported on a plurality of wheels 14. A vehicle cabin is defined within the vehicle body 12 within which passengers of the vehicle 10 can be accommodated.
- 10 An airflow system 150 is provided to condition air in the vehicle cabin. The airflow system 150 is represented by dashed lines in Figure 1, which is purely illustrative of the presence of the system 150 in the vehicle 10 and is not intended to indicate any qualities of the system 150, which is described in more detail later.
- 15 In use, rotation of the wheels 14 by a motive source such as an engine causes the vehicle 10 to move, mainly in the forward direction of travel, indicated in Figure 1 by the arrow T. Of course, it will be appreciated that the vehicle 10 can also be caused to move in the opposite direction to the arrow T, when in a reverse gear.
- 20 References in the following description to left and right, front, rear, forward, or backward, are made with reference to the direction T. References to upper, lower, horizontal, and vertical are made relative to the conventional orientation of the vehicle, as shown in Figure 1. A lower surface of the vehicle is closer to the ground than an upper surface of the vehicle when the vehicle is supported by the wheels. The ground 16 may be used
- 25 as a reference point as shown in Figure 1.

The vehicle 10 shown in Figure 1 is an autonomous vehicle, for example a self-driving car. It is noted, however, that embodiments of the present disclosure find application in conventional vehicles also, as mentioned above.

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Being autonomous, the vehicle 10 is capable of operation with little or no user input. Autonomy is achieved by sensing the surrounding environment and using a control system to interpret the sensed environment in order to navigate through it as a manually operated vehicle would.

The independence of autonomous vehicles from user input during the entirety or the majority of a journey increases flexibility as to how the vehicle may be configured, and so new exterior and interior vehicle design is possible. Altering conventional vehicle design requires re-engineering of associated vehicle systems, and an example of a re-engineered vehicle cabin and an associated air conditioning system for an autonomous vehicle is the subject of the following description.

As noted above, the seating arrangement of an autonomous vehicle can be made more reconfigurable than for a conventional vehicle, noting that there may be no requirement for a fixed driver's seat. Seats may rotate about vertical axes to face other each, for example, and may rotate about horizontal axes to recline or fold. A conventional vehicle air conditioning system having manually controlled air outlets disposed in the dashboard may be inadequate for use with such a seating arrangement. For example, if a seat is rotated away from its default orientation, or simply translated away from a dashboard-mounted air outlet to a sufficient extent, the conventional airflow system may be incapable of delivering thermally conditioned air to the new position in an effective manner, reducing the ability of the air conditioning system to provide effective thermal comfort control.

To improve the effectiveness of the air conditioning within the autonomous vehicle 10, a vehicle system comprising a control system and an airflow system is provided that is adaptable based on the arrangement of users and the seating in the vehicle cabin. Although in this embodiment all required functions are provided by an integrated controller, in other embodiments the control system may comprise multiple controllers and/or control modules to implement the required functionality.

In general terms, the controller receives input signals relating to the state of the seating arrangement and generates output signals that cause the airflow system to thermally condition the vehicle cabin and users efficiently by selective operation of particular vents, based on the received inputs. The controller also receives inputs indicating a measured temperature inside the vehicle cabin together with a temperature demand, namely a target temperature, typically specified by a user through an interface such as an infotainment system.

An example vehicle cabin 50 along with occupants and an example seating arrangement is illustrated in Figures 2 to 4. Figure 2 shows the vehicle cabin 50 in plan view without an airflow system to provide a clear illustration of the seating arrangement, while Figure 3 corresponds to Figure 2 but also shows features of an airflow system within the cabin 50. Figure 4 is a side view of the vehicle 10 that complements Figure 3. The airflow system itself is shown schematically in Figure 5.

As Figure 2 shows, the cabin 50 is an enclosed interior volume of the vehicle 10, defined by the vehicle body 12. Taking T as a reference direction, the cabin 50 is surrounded and defined by respective interior surfaces of front and rear walls 55, 56, left and right side walls 57, 58, a roof, and a floor of the vehicle body 12. The front and rear surfaces of the front and rear walls, 55, 56 respectively, are substantially perpendicular to T. The left and right side walls 57, 58 are substantially parallel to T. The roof extends between the upper edges of the side walls 57, 58, above the cabin interior when the vehicle is in the orientation of Figure 1, and defines an upper surface 59. The floor extends between the lower edges of the side walls 57, 58, below the cabin interior when the vehicle is in the orientation of Figure 1, and defines a lower surface 60.

Within the cabin 50, a dashboard 62 extends along and is positioned adjacent to the front surface 55. In Figure 2, the dashboard 62 includes a steering wheel 64 for use by a driver when the vehicle 10 is operating in a non-autonomous mode. However, it will be appreciated that a steering wheel may not be a requirement in a fully autonomous vehicle and so may be omitted in some examples. The dashboard 62 may additionally, or instead of the steering wheel, include displays, user input systems, speakers, other output systems and/or air vents. As will be well understood, dashboards and the features incorporated into dashboards are well known to the skilled person, and so they will not be elaborated on further. In some autonomous vehicles, the dashboard may be omitted entirely.

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Disposed within the interior of the cabin 50 are four seats. Using direction T as a reference, the four seats are: a front right seat 66; a front left seat 67; a rear right seat 68; and a rear left seat 69. Although Figures 2 to 4 are only schematic diagrams, it can be seen that each seat comprises a seat portion 72, a back 73, and a headrest 74, as

is conventional. The seats are mounted to the lower surface 60 of the cabin by a mounting, which is not depicted in these schematics. Seats may also include a foot rest and/or one or more arm rests.

- 5 Each seat 66, 67, 68, 69 is movable to various positions. The seats are considered movable by virtue of being able to have their configuration, rotation/orientation, and/or location altered. Moving a seat may be performed manually or automatically. The term 'configuration' is intended to encompass at least one of: a folded status of the seat; an angle of recline of the seat; a height of the seat relative to the lower surface 60 of the cabin 50; a head rest position of the seat; and, if included, a position of a foot rest and/or an arm rest. Other measurable parameters that do not fall under rotation/orientation or location of the seat may also be considered to fall within the term 'configuration'. The folded status of the seat indicates whether the seat is in a folded position. The angle of recline of the seat is typically the angle at which the back 73 of the seat is reclined. The head rest position of the seat includes an angle of the headrest 74 and/or a height of the headrest 74 relative to the back 73.

In the arrangement in Figure 2, the rear left seat 69 is in a conventional seating position; it is facing the forward direction of travel T, is in its default position and is not reclined or reconfigured. A seat is 'facing' a direction of travel if an occupant seated in that seat would be facing the direction of travel. This conventional position may be considered to be the 'default' position of the seats.

The front right seat 66 is rotated by 180 degrees about a vertical axis from its default position to face in the opposite direction to the forward direction T. The rear right seat 68 is rotated through an angle of approximately 45 degrees about a vertical axis towards the right surface 58 of the cabin 50. The front left seat 67 is facing the direction T, so is not rotated from its default position, and is partially reclined. The front and rear right seats 66, 68 are each occupied by a respective user 70.

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Figure 5 shows that the airflow system 150 comprises a first airflow apparatus 158a and a second airflow apparatus 158b, both of which are controlled by a control system comprising a controller 160 to provide effective and efficient thermal conditioning for users occupying the cabin 50 to satisfy a temperature demand input by a user.

The controller 160 comprises, at least: an input 160a configured to receive one or more input signals; a memory 160b storing instructions and/or data; a processor 160c configured to access the memory 160b and to process the or each input signal based on the instructions and/or data contained in the memory 160b to generate one or more control signals, for example by implementing one or more algorithms; and an output 160d configured to transmit the control signals generated by the processor 160c.

The controller 160 acts in response to signals received at its input 160a from a sensing system 152 regarding vehicle occupants and the position of their seat(s), and also signals received from a user preferences module 168 indicating control parameters input by a user.

User preferences stored in the user preference module 168 may include any user-selectable variable that the system is capable of implementing, such as a temperature demand, air flow speed or air flow temperature.

Although the airflow system 150 is shown as self-contained in Figure 5, in practice parts of the system may be dispersed around the vehicle 10 and may even form part of other vehicle sub-systems. For example, the controller 160 or control system may be implemented as a sub-module within a body control module of the vehicle 10 instead of providing a dedicated controller. Similarly, the user preferences module 168 may be embodied as a module of an infotainment system, a module of the controller 160, or a separate, dedicated module providing a suitable interface to enable the user to define control parameters.

In a similar way, the airflow system 150 and the vehicle cabin 50 may be considered together to form an overall vehicle system representing an embodiment of the invention.

The sensing system 152 monitors the position and occupancy status of each seat 66, 67, 68, 69. The sensing system 152 is represented as part of the airflow system 150 in Figure 5, although in practice the sensing system 152 may also be used for other purposes and so may be implemented independently of the airflow system 150. In any

event, the controller 160 has access to readings gathered by the sensing system 152 on which to base control of the airflow apparatus 158.

5 The sensing system 152 is capable of generating signals indicative of the occupancy and/or position of each seat 66, 67, 68, 69, as well as the temperature of the cabin 50. In other words, the sensing system 152 outputs signals from which a determination can be made about the position of each seat and whether or not each seat is occupied.

10 Accordingly, the sensing system 152 comprises at least one temperature sensor 153 configured to provide to the controller 160 a temperature signal indicative of a temperature of the cabin 50.

The sensing system 152 also includes one or more occupancy sensors 154, typically with a respective occupancy sensor 154 for each seat 66, 67, 68, 69 to monitor the
15 occupancy status of that seat 66, 67, 68, 69. In some examples, an occupancy sensor 154 may monitor more than one seat 66, 67, 68, 69, and so the sensing system 152 may include a single occupancy sensor to monitor all seats.

The sensing system 152 also comprises position sensors 156 that monitor the position
20 of each seat 66, 67, 68, 69 within the cabin 50. The 'position' of a seat 66, 67, 68, 69 encompasses its location within the cabin 50, its orientation and its configuration. It follows that the position sensors 156 comprise configuration sensors 170, rotation/orientation sensors 172, and/or location sensors 174. The sensing system 152 may include a single position sensor only in some examples.

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In some examples, the occupancy sensors 154 may generate a signal only when a seat is occupied, while in other examples, the occupancy sensors 154 may generate a signal when the seat is unoccupied. Similarly, the position sensors 156 may generate signals based on the position of each seat 66, 67, 68, 69 relative to a default position, relative
30 to the sensor, or relative to a coordinate system generated for the cabin 50.

In one example, each occupancy sensor 154 is a pressure sensor in a respective seat. The position sensors 156 may be individual sensors configured to measure different position parameters. Position parameters include: a folded status of the seat; an angle

of recline of the seat; a height of the seat relative to the lower surface 60 of the cabin 50; a head rest position of the seat; a position of a foot rest and/or an arm rest; an orientation of the seat; and/or a location of the seat within the cabin 50. A camera or a plurality of cameras may be used in other examples as the occupancy and/or position sensors or in addition to the occupancy and position sensors, where image frames
5 obtained by the camera are used to analyse the seat position and its occupancy based, for example, on a three-dimensional model.

In the example of Figure 5, the occupancy sensors 154 and position sensors 156 are
10 separate sensors, although it will be appreciated that in other examples at least some of the occupancy sensors and position sensors may be combined.

The airflow system 150 comprises a set of air vents 162 positioned within the cabin 50 that cooperate with the airflow apparatus 158 to direct air into or out from the cabin 50.
15 In this example, air may flow through each air vent 162 in two directions, namely into or out from the cabin 50. In other words, each vent 162 may act as either an air inlet or an air outlet. In other examples, some or all vents 162 may be configured for air flow in one direction only. An example arrangement of the air vents 162 in a cabin 50 is shown in Figures 3 and 4.

20 As Figure 3 shows, the upper surface 59 of the cabin 50 includes a two-dimensional array of upper air vents 162a, the array covering substantially the entire seating area within the cabin 50. A corresponding opposed array of lower air vents 162b is provided in the lower surface 60 of the cabin 50, so that each upper air vent 162a is in vertical
25 alignment with a respective lower air vent 162b. In alternatives, the upper and lower air vents 162a, 162b may not be directly aligned with one another.

The first airflow apparatus 158a is configured to control air flow through the upper air vents 162a, and so in general terms is used to provide cool air to cool the vehicle cabin
30 50 when a temperature demand is below the cabin temperature. Accordingly, the first airflow apparatus includes means for cooling air, for example an air conditioning unit.

Correspondingly, the second airflow apparatus 158b is responsible for air flow through the lower air vents 162b and so is primarily used to deliver warm air to warm the cabin 50 when needed. The second airflow apparatus 158b therefore includes a heater.

- 5 However, each airflow apparatus 158a, 158b may also be used in other ways as shall become clear in the following description. For example, the first and second airflow apparatuses 158a, 158b may each include provisions for both heating and cooling air to increase flexibility in the available modes of operation.
- 10 The first and second airflow apparatuses 158a, 158b comprise, respectively, first and second thermal sources 164a, 164b configured to thermally condition air and to supply it to selected ones of the plurality of air vents 162. Each thermal source 164a, 164b is capable of heating or cooling air it receives, in order to deliver air to vents 162 at a predetermined temperature. Each thermal source 164 may provide air to different air
- 15 vents 162 at different temperatures.

In simpler embodiments, the first thermal source 164a may only be capable of cooling air to satisfy the primary function of the first airflow apparatus 158a, while the second thermal source 164b is a heater that acts only to warm air for the second airflow

20 apparatus 158b.

Although Figure 4 shows the first and second airflow apparatuses 158a, 158b as entirely separate, in practice they may be integrated with one another, at least to some extent. For example, the airflow apparatuses 158a, 158b may share thermal sources.

25

In other embodiments, the upper and lower air vents 162a, 162b may all be connected to a common airflow apparatus, which supplies air to all vents at the same temperature and flow rate. The vents 162 may nonetheless be capable of moderating air flow individually by the inclusion of valves as described below.

30

Each airflow apparatus 158a, 158b also comprises a pump mechanism (not shown in the figures), to urge air from the thermal source 164 to the vents 162, and to draw air into the thermal source 164, either from the vents 162 or from another air inlet on the

vehicle 10. In use, the pump mechanism directs air from the thermal source 164 through air ducts 166 towards the air vents 162.

Each pump mechanism may be bi-directional, so that the pump mechanism is able to
5 draw a vacuum to generate suction at its respective air vents 162 to suck air out of the cabin 50.

The first airflow apparatus 158a directs air through a first air duct 166a positioned along a pillar of the front and surface 55 of the cabin 50, and the second airflow apparatus
10 158b directs air through a second air duct 166b positioned along the floor of the cabin 50 beneath the lower surface 60. It will be appreciated that the ducts 166 may be routed in any appropriate way.

The first and second airflow apparatuses 158a, 158b may be in fluid communication with
15 one another to enable recirculation of air between the two.

Although not shown in the figures, each airflow apparatus 158a, 158b incorporates at least one mechanism for regulating and selectively controlling the flow of air through the vents 162 with which the apparatus is associated. For example, each vent 162 may
20 include a valve to regulate air flow through the vent 162. The valve may be manually or electrically controllable. The valves may also serve to direct air as required, for example using pivotable flaps as is conventional.

Valve systems may also be incorporated to control air flow to subsets of air vents 162, so that air flow can be controlled for particular zones within the vehicle cabin 50. It is envisaged that at least subsets of air vents 162 will be controllable, either by control of
25 valves at the vents, by control of valves positioned in the ducts, or by a combination of valves at the vents and within the ducts. An example of subsets of vents is shown by dashed squares in Figure 3, so that each seat is effectively zoned.

30

By allocating air vents 162 into seat-specific groups, the air flow from those vents is controllable by the controller 160 according to the occupancy signals and position signals received from the sensing system 152 to achieve an effective air flow for each user.

In this respect, the controller 160 acts based on the input signals received from the sensing system 152 and the user preference module 168 to generate and transmit a first control signal 176a to the first airflow apparatus 158a, and a second control signal 176b to the second airflow apparatus 158b. More specifically, the input signals are received by the input 160a of the controller 160, processed by the processor 160c to generate the control signals 176, which are then transmitted from the output 160d. The control signals 176 dictate which of the plurality of air vents 162 air is directed to flow through, as well as the flow rate and temperature of the air flow in each case.

If the position or occupation of a seat 66, 67, 68, 69 is indicated as having changed by the sensing system 152, the controller 160 automatically updates a status of the seat 66, 67, 68, 69 and issues new control signals to the airflow apparatuses 158a, 158b to reflect the change in position or occupation.

The control signals 176 dispatched from the controller 160 may comprise respective control signals to alter the temperature of the air flow, to direct air flow to a set of vents only, to operate valves associated with one or more vents to achieve an open, closed, or partially closed position, or to alter a direction of air flow from one or more vents.

So, taking the arrangement shown in Figures 2 to 4 as a worked example, the occupancy sensors 154 that monitor the cabin 50 generate occupancy signals to indicate that the front right and rear right seats 66, 68 are occupied (and that the front and rear left seats 67, 69 are unoccupied). Configuration sensors 170 indicate that the front left seat 67 is reclined. Orientation sensors 172 indicate that the front right seat 66 is rotated 180 degrees from its default position and that the rear right seat 68 is rotated 45 degrees to the right from its default position, while the front and rear left seats 67, 69 are at 0 degrees (i.e. no rotation from default position). A temperature signal and a temperature demand signal received from the temperature sensor 153 and the user preferences module respectively may indicate that the measured temperature is above the desired temperature.

The controller 160 receives these signals from the occupancy sensors 154 as inputs, and determines that air conditioning is required for the front and rear right seats 66, 68

because these seats are occupied. As the orientation of each seat is different, the controller 160 operates the vents 162 above the occupied seats according to the orientation. For example, for the front right seat 66, the controller 160 may decrease airflow through vents 162 that are disposed above the back of the seat 66, while
5 increasing airflow through vents 162 disposed above the user. For each seat, the airflow from vents 162 relating to the seat is therefore controlled in an appropriate manner, taking into consideration the relevant seat configuration, orientation and/or location. In addition, user preference data within the user preference module 168 is also taken into consideration in generating the control signal for each seat.

10

By determining the occupancy and position of each seat, the controller 160 is capable of implementing a controlled, targeted air flow within the vehicle cabin 50. The airflow apparatuses 158a, 158b may be controlled to implement direct air flow onto the user or towards an assumed position of the user determined from the seating position.

15

The airflow apparatuses 158a, 158b may also be controlled to create a thermal curtain, namely a substantially laminar vertical air flow that inhibits horizontal convection, around a selected area, for example surrounding the user or seat. A thermal curtain has the benefit that the air flow provides a barrier to convection across the flow, and so creates
20 a volume that is thermally isolated from the rest of the cabin. Hence, the volume within which the user is seated can be maintained at a comfortable temperature, whilst reducing energy consumption by avoiding heating or cooling areas of the cabin 50 that are not occupied.

25

The array of air vents 162 creates flexibility as to where thermal curtains may be established, and in turn the areas of the cabin 50 that the airflow system 150 is able to isolate as temperature controlled volumes.

30

This ability is enhanced by the presence of opposed air vents in the upper and lower surfaces 59, 60 of the cabin 50, especially if one set is operated to direct air into the cabin 50 while the opposing set draws air out of the cabin 50.

For example, if warm air is directed into the cabin through a line of lower air vents 162b while an opposing line of upper air vents 162a each generate a vacuum to draw air out

of the cabin 50, the effect will be to encourage flow directly from each lower vent 162b to its respective upper vent 162a. Moreover, in this condition the vents 162 will work in harmony with natural convection, which will therefore assist in providing a vertical flow. Thus, operating the vents 162 in this manner will enhance the extent to which air is
5 directed to flow vertically through the cabin 50 and in turn the performance of the thermal curtain that is created.

Similarly, the use of opposed blowing and suction with the upper and lower air vents (162a, 162b) may enhance the capacity of the airflow system 150 to cool or warm the
10 cabin 50 according to a temperature demand, by dispersing warmed or cooled air throughout the cabin 50 more quickly than is possible for conventional systems.

For example, if the temperature demand exceeds the temperature in the cabin 50 so that overall warming is required, an effective mode of operation may be to operate the
15 lower air vents 162b as outlets to direct warm air into the cabin 50 while operating the upper air vents 162a as inlets to generate suction to draw air out of the cabin 50, therefore assisting with drawing the warm air into the cabin 50. Conversely, when the temperature demand is below the measured cabin temperature, cool air may be directed into the cabin 50 through the upper air vents 162a while the lower air vents 162b are
20 operated as inlets to remove air from the cabin 50.

In these modes of operation, the airflow system 150 may be configured such that air drawn in from the cabin 50 through any of the air vents 162 is recirculated to the cabin 50 through other air vents 162, thereby minimising the energy consumption of the
25 system 150. For example, in a warming mode air sucked out of the cabin 50 through the upper air vents 162a may be recirculated to the lower air vents 162b. This ensures that warm air rising by convection is not wasted. The recirculated air may be supplemented with air drawn in from outside the vehicle 10 to ensure good ventilation.

30 In an alternative mode of operation, as noted previously air may flow into the cabin 50 through vents 162 in the upper and lower surfaces 59, 60 at different temperatures at the same time. In this respect, it is noted that the first and second airflow apparatuses 158a, 158b are independently operable to provide respective airflows at different

temperatures and/or flow rates. For example, air flow through the upper air vents 162a may be at a lower temperature than air flow through the lower air vents 162b.

In this way, hot air in the lower region of the cabin 50, which tends to rise, is replenished
5 by the warmer air that is provided through the lower air vents 162b.

Figure 6 illustrates a plan view of an alternative vehicle cabin 650. In the alternative vehicle cabin 650, in addition to reconfiguration and rotation, each seat 666, 667, 668, 669 is capable of translational movement in two axes within the horizontal plane to
10 change its location within the vehicle cabin 650.

In Figure 6, the default position of each seat is depicted using a dashed outline. The front right seat 666 is occupied and rotated to face the rear surface 656 of the vehicle cabin 650. The other three seats, the front left 667, rear right 668 and rear left seats 669,
15 are moved relative to their original, default locations. Particularly, the rear right seat 668 is moved laterally, the rear left seat 669 is moved longitudinally, and the front left seat 667 is moved both laterally and longitudinally.

The airflow system 150 described above is equally applicable to the cabin 650 of Figure
20 6, but the air vents are not shown in Figure 6 for clarity. In examples where seats are also capable of relocation in the cabin, the position sensors also comprise location sensors, and the controller 160 is configured to control the airflow system 150 based on the location of each occupied seat within the cabin. For example, the controller 160 may operate a group of vents to provide air flow to a relocated occupied seat, where air flow
25 through those vents would provide air flow to the seat and within a predetermined distance or area around the seat. This may include adjusting the positions of thermal curtains created by lines of vents around the seat by altering the vents used to create said curtains.

30 In an example, the position sensors comprise at least one camera that obtains image frames relating to one or more seats in the cabin. The controller analyses the image frames to update a three-dimensional model of the vehicle interior to determine the position of the occupied seat within the reference system formed by the vehicle cabin.

Figure 7 illustrates a method 700 of operation of the airflow system 150 described above. In the method 700, a temperature signal is received (step 702) by the controller 160 at an input. The temperature signal indicates a measured temperature of the cabin 50. The controller 160 also receives (step 704) a temperature demand signal at an input
5 indicating a target temperature for the cabin as input by a user. The controller 160 then compares (at step 706) the temperature signal with the temperature demand signal and determines (at step 708) whether the target temperature exceeds the measured temperature. If so, indicating that warming of the cabin 50 is required, the controller 160 issues control signals 176a, 176b (at step 710) to effect pumping of warm air through
10 the lower vents 162a into the cabin 50 while air is drawn out of the cabin 50 through the upper vents 162b.

If the temperature demand is found to be below the measured temperature, the controller 160 takes the opposite action and issues control signals 176a, 176b (at step
15 712) to operate the airflow apparatuses 158 to direct cool air into the cabin 50 through the upper vents 162a while drawing air out of the cabin 50 through the lower vents 162b.

In either of the above scenarios, the controller 160 applies a threshold to the comparison between the measured and demanded temperatures. If the difference between the two
20 is below the threshold, the controller 160 assumes that the cabin temperature is approximately as required and so takes no action.

It will be appreciated that various changes and modifications can be made to the present invention without departing from the scope of the present application.

25

In this respect, it is reiterated that the vehicle described above is offered as an example only, and embodiments of the invention are applicable to any type of vehicle. The benefits of a vehicle airflow system having vents in both upper and lower surfaces of a vehicle cabin are common to many situations.

30

For example, the ability that such an arrangement offers in terms of enhancing a thermal curtain effect, and therefore isolating sub-volumes within a vehicle cabin for temperature control, are useful in any context, even where the seats are not moveable to any extent.

Similarly, the ability of such airflow systems to operate in a manner that counteracts natural convection, and therefore refine control of a vertical temperature gradient within a vehicle cabin, will find wide application.

Claims

1. A vehicle system for use in a vehicle, the vehicle system including an airflow system and a vehicle cabin defined, at least in part, by an upper cabin surface and a lower cabin surface, the airflow system being configured to condition air in the vehicle cabin and comprising:
- at least one upper air vent disposed in the upper cabin surface and at least one lower air vent disposed in the lower cabin surface;
- an airflow apparatus configured to direct an airflow through the at least one lower air vent and the at least one upper air vent; and
- a control system comprising one or more controllers configured to control the airflow through the at least one lower air vent and the at least one upper air vent.
2. The vehicle system as claimed in claim 1, comprising a first airflow apparatus configured to direct a first airflow through at least one upper air vent in the upper cabin surface, and a second airflow apparatus configured to direct an airflow through at least one lower air vent in the lower cabin surface.
3. The vehicle system as claimed in claim 2, wherein the first airflow apparatus is configured to direct an airflow which is at a lower temperature than an airflow directed by the second airflow apparatus.
4. The vehicle system as claimed in claim 2, wherein the first airflow apparatus is configured to direct an airflow which is at a higher temperature than an airflow directed by the second airflow apparatus.
5. The vehicle system as claimed in any of claims 2 to 4, wherein the first airflow apparatus comprises an air conditioning unit.
6. The vehicle system as claimed in any of claims 2 to 5, wherein the second airflow apparatus comprises a heater.

7. The vehicle system as claimed in any of claims 2 to 6, wherein the first airflow apparatus comprises a first pump configured to direct a first airflow to at least one upper air vent in the upper cabin surface, and the second airflow apparatus comprises a second pump configured to direct an airflow to at least one lower air vent in the lower cabin surface.
8. The vehicle system as claimed in any of claims 2 to 7, wherein the first airflow apparatus is operable to provide suction that draws air into at least one upper air vent.
9. The vehicle system as claimed in any of claims 2 to 8, wherein the second airflow apparatus is operable to provide suction that draws air into at least one lower air vent.
10. The vehicle system as claimed in any of claims 1 to 9, wherein the at least one upper air vent and the at least one lower air vent are in vertical alignment with one another.
11. The vehicle system as claimed in any of claims 1 to 10, comprising an array of upper air vents disposed in the upper cabin surface.
12. The vehicle system as claimed in any of claims 1 to 11, comprising an array of lower air vents disposed in the lower cabin surface.
13. The vehicle system as claimed in any of claims 1 to 12, wherein the vehicle cabin has a seat, the seat is moveable into a plurality of positions, and wherein the one or more controllers are configured to receive a seat signal relating to at least one of:
- (i) whether or not the seat is occupied, and
 - (ii) the position of the seat,
- the one or more controllers being configured to generate a control signal to control the airflow apparatus in response to the seat signal.

14. The vehicle system as claimed in claim 13, wherein the seat is moveable to each of the plurality of positions by any one or more of: longitudinal movement; lateral movement; rotational movement; reclining movement; and folding movement.
- 5 15. The vehicle system as claimed in claim 13 or claim 14, wherein the control signal is configured to adjust automatically a status of one or more of the air vents in response to the seat signal.
- 10 16. The vehicle system as claimed in any of claims 13 to 15, comprising a user preference module for providing user preference data to the one or more controllers, the one or more controllers being configured to provide a control signal to the airflow apparatus to selectively control which of the plurality of air vents to direct the airflow through in dependence on the occupancy signal, on
- 15 the seat signal, and on the user preference data.
17. The vehicle system as claimed in claim 16, wherein the user preference data includes at least one of: a temperature of the airflow; and a speed of the airflow.
- 20 18. The vehicle system as claimed in any of claims 1 to 17, wherein the or each airflow is substantially orthogonal to the upper and lower cabin surfaces.
19. The vehicle system of any of claims 1 to 18, wherein the one or more controllers are configured to:
- 25 receive a temperature demand signal and a temperature signal;
compare the temperature demand signal and the temperature signal; and
generate a control signal to control the airflow apparatus based on the comparison between the temperature demand signal and the temperature signal.
- 30 20. A control system for a vehicle airflow apparatus configured to control airflow through at least one lower air vent in a lower surface of a vehicle cabin and at least one upper air vent in an upper surface of the vehicle cabin, the control system comprising one or more controllers configured to:

receive a temperature demand signal indicative of a temperature demand;

receive a temperature signal indicative of a temperature in the cabin;

5 compare the temperature demand signal with the temperature signal;

 determine a control signal in dependence on the comparison between the demand signal and the temperature signal; and

10 output the control signal to the airflow apparatus to control airflow to the lower air vent and the upper air vent.

21. A vehicle comprising the vehicle system as claimed in any of claims 1 to 19 and/or the control system of claim 20.

15

22. A method of controlling airflow through at least one lower air vent in a lower surface of a vehicle cabin and at least one upper air vent in an upper surface of the vehicle cabin, the method comprising:

20 receiving a temperature demand signal indicative of a desired temperature for the vehicle cabin;

 receiving a temperature signal indicative of a temperature in the vehicle cabin;

25

 comparing the temperature signal with the temperature demand signal; and

 generating a control signal arranged to operate airflow apparatus to direct an airflow through at least one of the at least one upper air vent and the at least one lower air vent in dependence on the comparison between the temperature signal with the temperature demand signal.

30

23. The method as claimed in claim 22, comprising directing an airflow through the at least one upper air vent into the cabin if the temperature signal exceeds the

temperature demand signal, and directing an airflow through the at least one lower air vent into the cabin if the temperature demand signal exceeds the temperature signal.

- 5 24. The method as claimed in claim 23, comprising directing an airflow out of the cabin through the at least one upper air vent if the temperature demand signal exceeds the temperature signal, and directing an airflow out of the cabin through the at least one lower air vent if the temperature signal exceeds the temperature demand signal.

10

25. Computer software that, when executed by one or more processors, causes performance of a method according to any of claims 22 to 24.

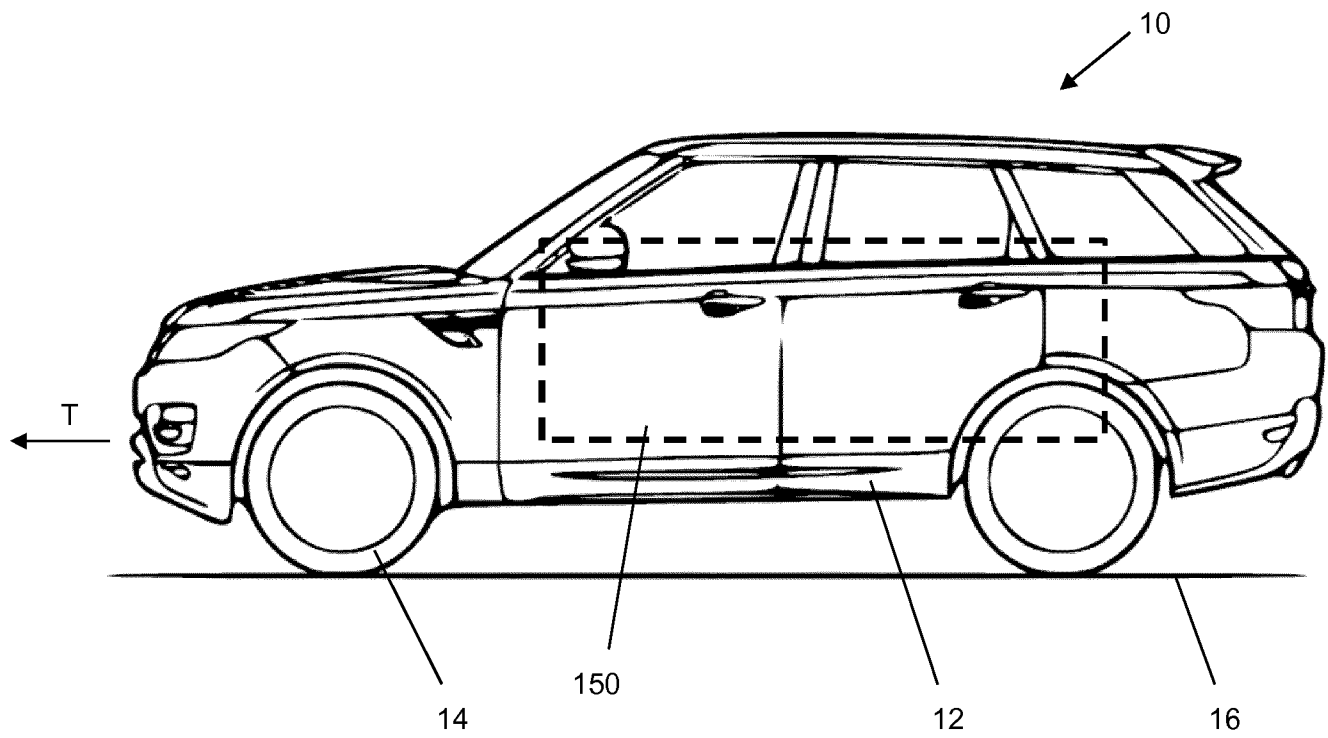


Fig. 1

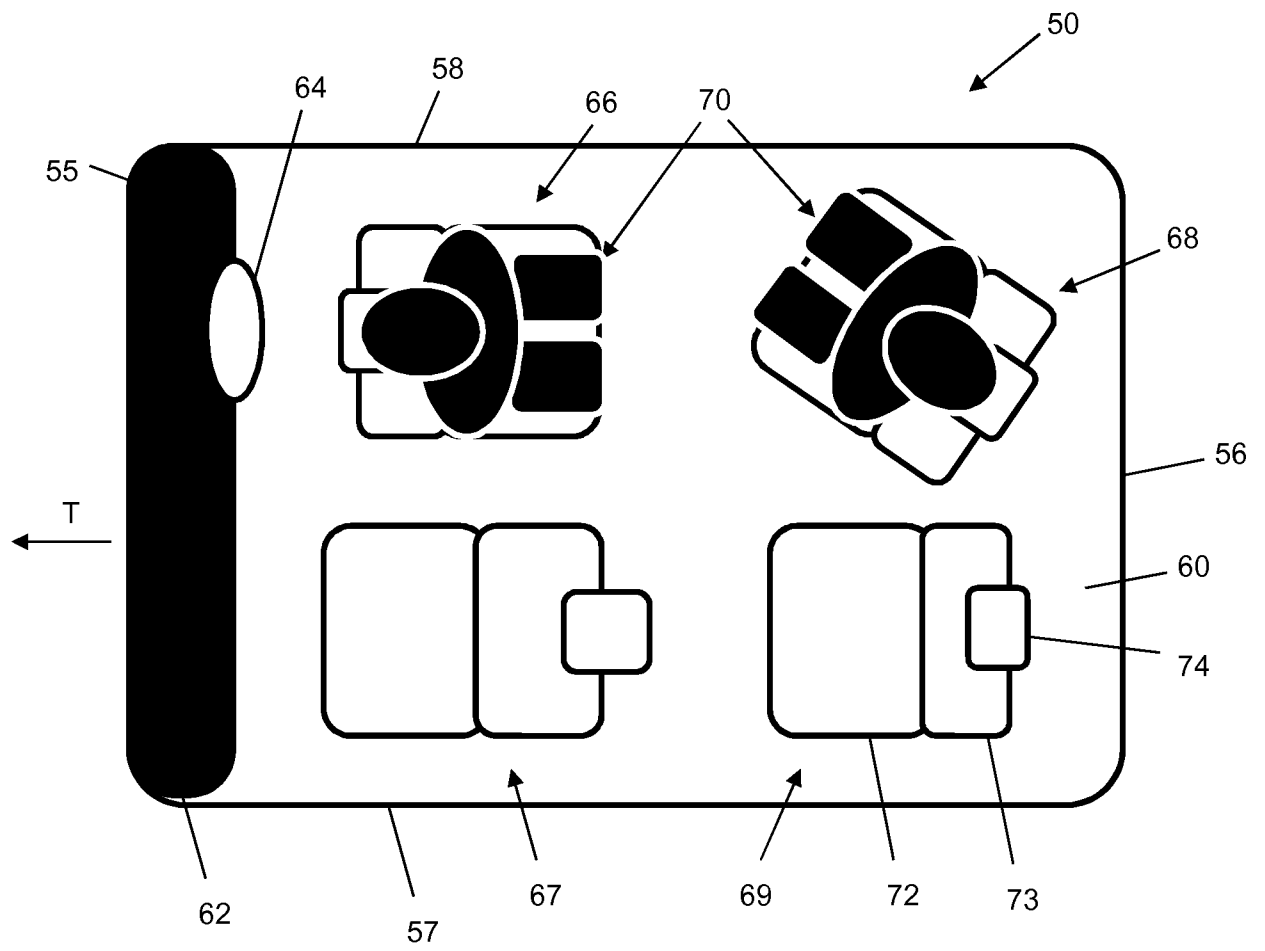


Fig. 2

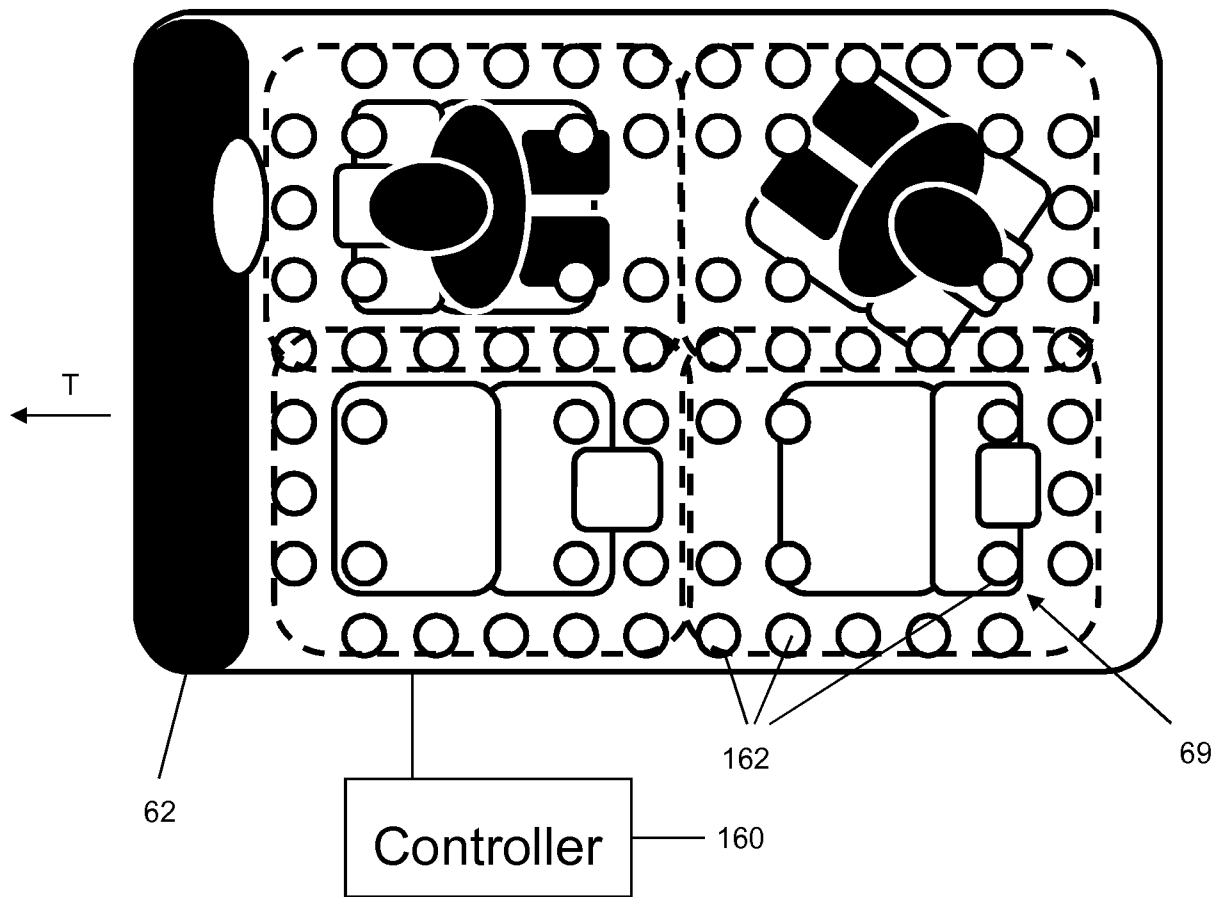


Fig. 3

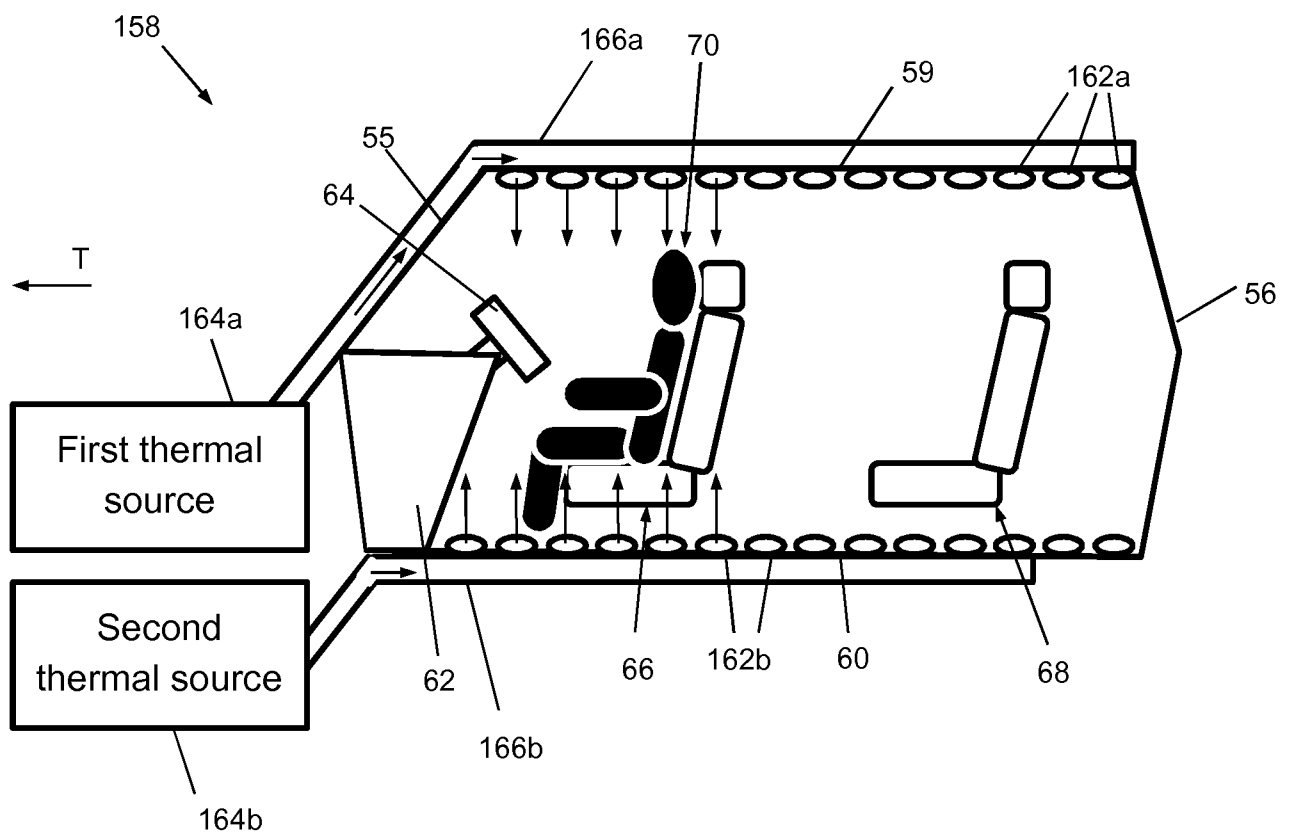


Fig. 4

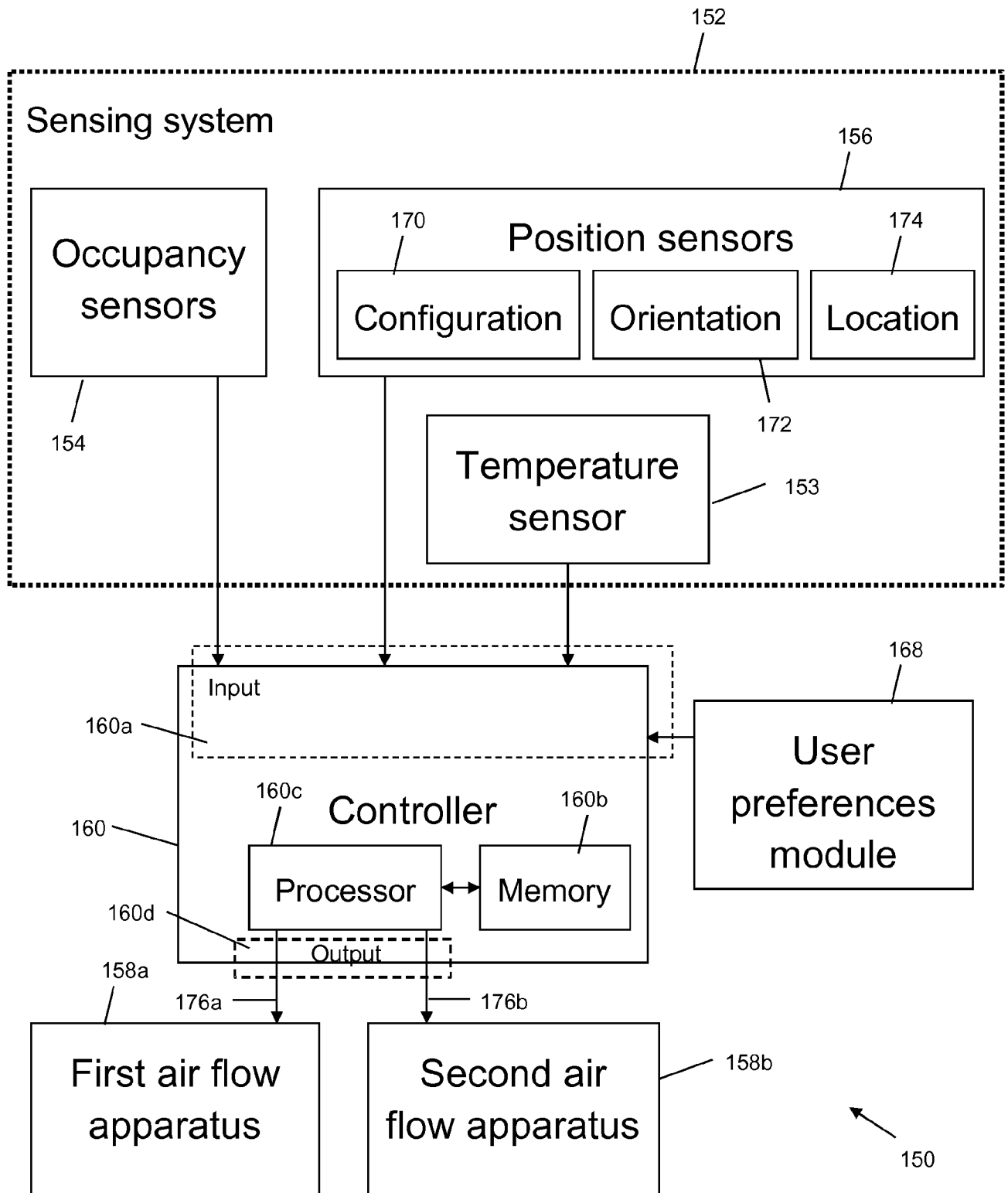


Fig. 5

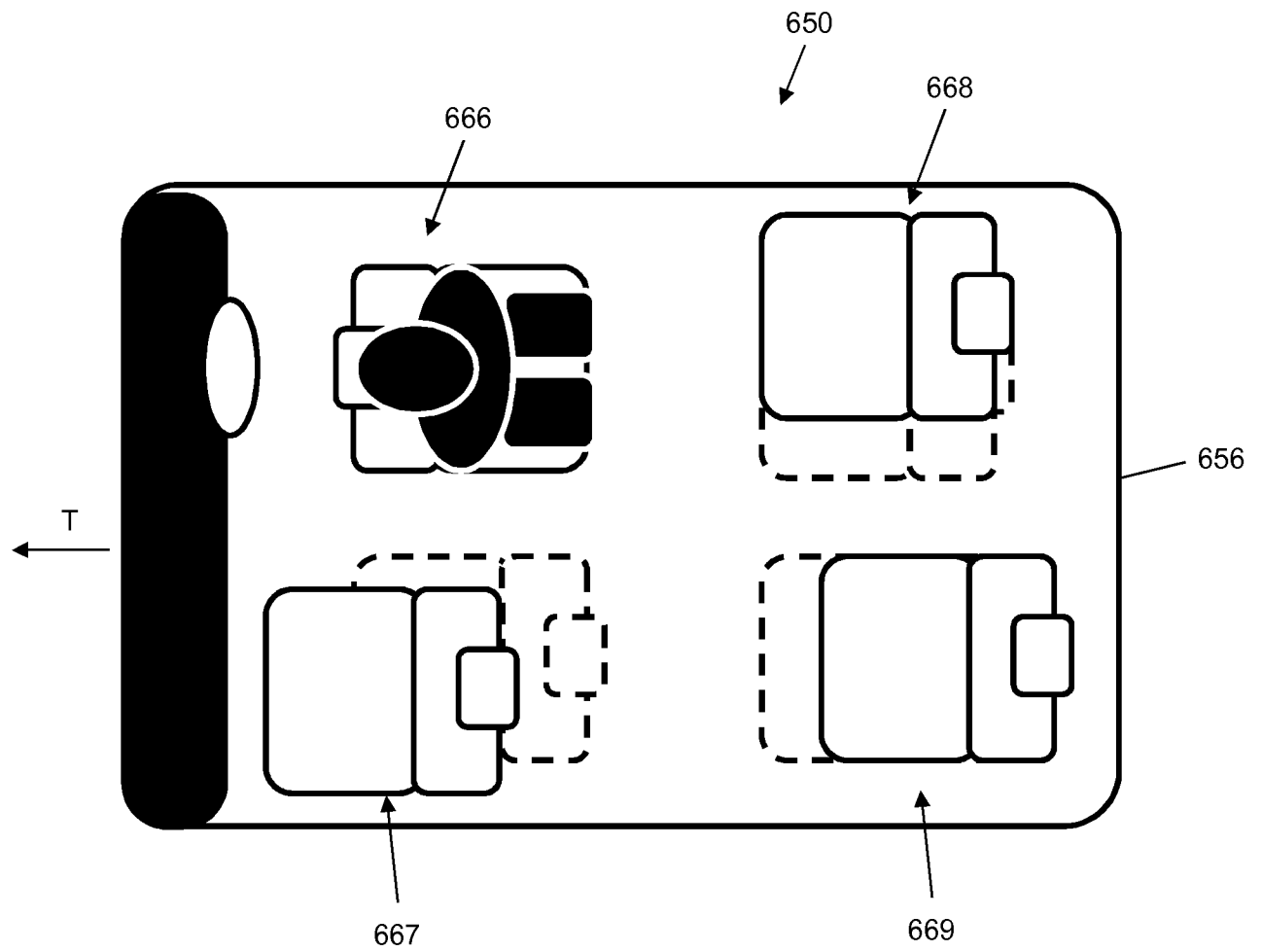


Fig. 6

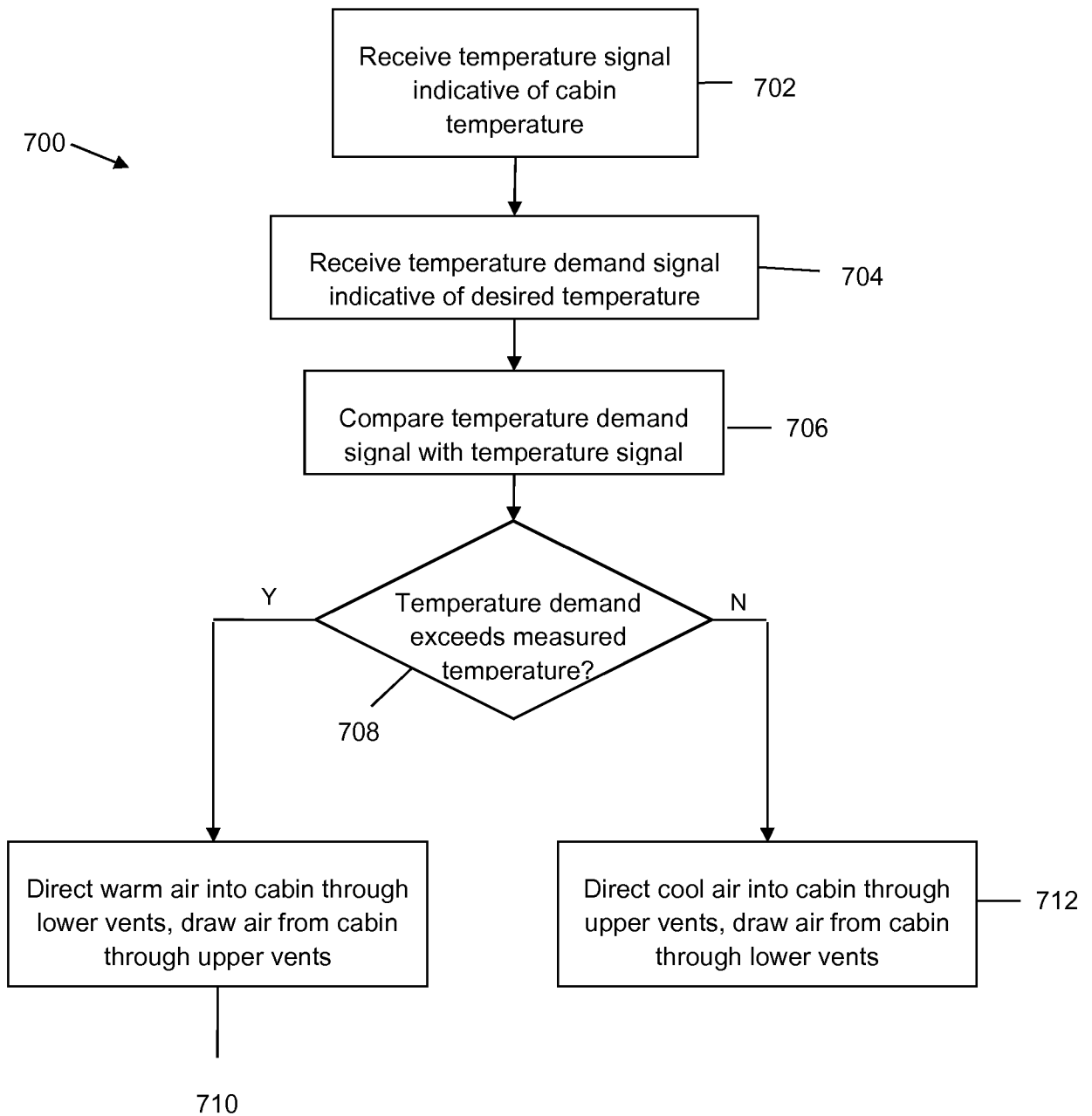


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/078416

A. CLASSIFICATION OF SUBJECT MATTER
INV. B60H1/00 B60H1/24
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)
B60H

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)

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Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

20 January 2020

Date of mailing of the international search report

30/01/2020

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/078416

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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