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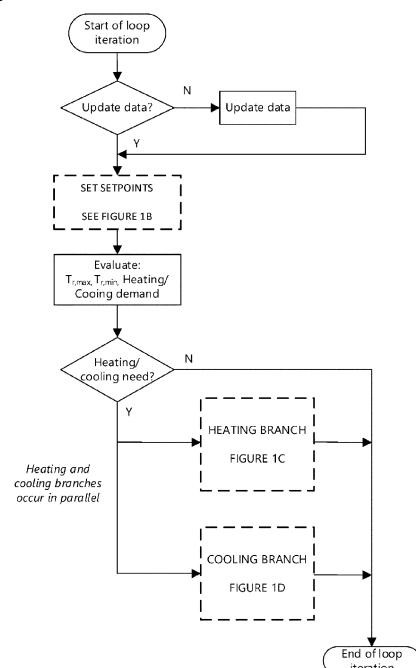
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(54) **SYSTEM FOR AIR CONDITIONING**

(57) A system for air conditioning is provided which comprises a HVAC system suitable to air condition a space, wherein the HVAC system has a heating mode in which heating of the building space is effected, a cooling mode in which cooling of the building space is effected, and a fan mode in which no heating and no cooling of the building space is effected and air is circulated within the building space. The system further comprises a building space to be air conditioned by the HVAC system, at least two air temperature sensors situated in different locations in the building space, at least one occupancy sensor for detecting the presence of at least one person in the building space and a controller for controlling an operation of the heating, ventilation and air-conditioning system. The controller is configured to make a selection between the heating mode, cooling mode and fan mode based on signals of the at least two air temperature sensors. The system allows the provision of a thermal comfort in the building space of the system at a reduced overall energy consumption and reduced carbon footprint.

Figure 1A



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Description

[0001] A system for air conditioning is provided which comprises a HVAC system suitable to air condition a space, wherein the HVAC system has a heating mode in which heating of the building space is effected, a cooling mode in which cooling of the building space is effected, and a fan mode in which no heating and no cooling of the building space is effected and air is circulated within the building space. The system further comprises a building space to be air conditioned by the HVAC system, at least two air temperature sensors situated in different locations in the building space, at least one occupancy sensor for detecting the presence of at least one person in the building space and a controller for controlling an operation of the heating, ventilation and air-conditioning system. The controller is configured to make a selection between the heating mode, cooling mode and fan mode based on signals of the at least two air temperature sensors. The system allows the provision of a thermal comfort in the building space of the system at a reduced overall energy consumption and reduced carbon footprint.

[0002] As people spend over 80% of their time in indoor environment, a need to provide a comfortable and healthy environment remains a great concern. However, providing a healthy and comfortable environment require the use of heating, ventilation, and air conditioning (HVAC) systems, which come with high energy outlay. High energy consumption of building HVAC systems has been identified as contributing to the adverse effects of the built environment on climate change. In the quest to move towards the carbon neutrality of the built environment, a need for building systems that adapt to climate change has increased in recent times.

[0003] Conventionally, controlling an indoor environment by HVAC systems depends on whether a space is designed as a total volume system and/or personalised system. In the total volume systems, the control is mainly based on a single-zone approach where the air in the space is assumed to be well mixed. Under this condition, the indoor thermal environmental conditions (e.g., temperature, velocity, and relative humidity) are assumed to be homogeneous and uniformly distributed. Hence, in controlling the thermal environment under this assumption, a single temperature is utilised. Whereas the assumption may be true in small spaces, such as personal offices, the situation differs in large spaces, such as shared office spaces.

[0004] The existing body of evidence on research and innovation in indoor air science suggest that the supply conditions (temperature, velocity, humidity, etc.), characteristics of air terminal devices (inlets and/or outlets), and magnitude of internal heating and/or cooling loads (e.g., occupancy and plug loads), have a significant effect on the spatial distribution of indoor environmental parameters. While it is easy to optimise the supply conditions and air terminal devices features during the design stage,

achieving optimal location of cooling and/or heating loads pose a great challenge in large spaces. This is because the locations of loads and furniture are mostly determined during the operation stage of shared spaces. Hence, single point measurement is used to control operations of the HVAC system, which mostly fails to achieve uniform spatial distribution of thermal environmental conditions across complex shared office spaces. Non-uniformity of the thermal environment can lead to thermal discomfort and energy inefficiency.

[0005] US 2022/0228756 discloses a system comprising an HVAC system and a controller which is configured to maintain a thermal comfort condition of a building space based on current indoor and outdoor conditions. The disadvantage of the system is that it is prone to provide thermal comfort in the building space at high energy consumption and with high carbon footprint.

[0006] In view of the above, it was the object according to the invention to provide a system which overcomes at least one disadvantage of the prior art systems. Preferably, the system should provide a thermal comfort in a building space at a reduced overall energy consumption and reduced carbon footprint.

[0007] The object is solved by the system having the features of claim 1. The dependent claims show advantageous embodiments of the system according to the invention.

[0008] According to the invention, a system for air conditioning is provided, comprising

- a) a heating, ventilation and air-conditioning system (HVAC system) suitable to air condition a building space, wherein the heating, ventilation and air-conditioning system has a heating mode in which heating of the building space is effected, a cooling mode in which cooling of the building space is effected, and a fan mode in which no heating and no cooling of the building space is effected and air is circulated within the building space;
- b) a building space to be air conditioned by the heating, ventilation and air-conditioning system;
- c) at least two air temperature sensors situated in different locations in the building space;
- d) at least one occupancy sensor for detecting the presence of at least one person in the building space;
- e) a controller for controlling an operation of the heating, ventilation and air-conditioning system;

characterized in that the controller is configured to make a selection between the heating mode, cooling mode and fan mode based on signals of the at least two air temperature sensors.

[0009] The HVAC system can comprise a fan. In the fan mode of the HVAC system, the controller is configured to switch on the fan of the HVAC system and to deactivate active cooling and to deactivate active heating (i.e. in the fan mode, the controller is configured to switch off the heating mode and the cooling mode of the HVAC sys-

tem).

[0010] The system according to the invention allows the provision of a thermal comfort in the building space of the system at a reduced overall energy consumption and reduced carbon footprint.

[0011] On the one hand, this advantage is achieved by the at least two air temperature sensors situated in different locations in the building space and by the controller which is configured to make a selection between the heating mode, cooling mode and fan mode based on signals of the at least two air temperature sensors.

[0012] The at least two temperature sensors allow the system to measure the room temperatures at two different locations in the building space and to control the HVAC system based on said measured room temperatures, specifically by using the measured room temperatures for making a selection on whether the HVAC system is operated in its heating mode, cooling mode and/or fan mode. By switching to the appropriate mode(s), the system according to the invention can reduce variations in a spatial temperature distribution across different locations in a building space (i.e. establish a uniform temperature distribution in a building space) in a manner which consumes a minimal amount of energy and produces a minimum amount of emission of carbon oxides.

[0013] For example, if a temperature difference across the building space is high, it can be more energy efficient and beneficial to carbon footprint to switch to the fan mode of the HVAC system instead of switching to a heating mode or cooling mode of the system. The fan mode of the HVAC system is then capable of establishing a uniform temperature distribution across the building space and establish a temperature in the building space which lies within a desired, predetermined temperature range so that comfort for persons in the building space is maximal. The fan mode also allows to reduce stratification of air in the building space and thus allows the provision of a uniform thermal environment not only regarding the air temperature, but also regarding e.g. air humidity. Achieving reduced thermal stratification boosts climate control capability, improves satisfaction, productivity and well-being of persons within the building space.

[0014] On the other hand, the advantage of the system according to the invention is achieved by the at least one occupancy sensor for detecting the presence of at least one person in the building space. Said occupancy sensor allows the controller of the system to control an operation of the heating, ventilation and air-conditioning system based on signals of the at least one occupancy sensor. This makes it possible to switch the HVAC system to an active preconditioning mode in which power consumption of the HVAC system is only allowed to be lower than maximal in a case in which no person is present in the building space (i.e. in which no person is detected by the at least one occupancy sensor). This reduces energy consumption and thus a waste of energy during times in which the building space is not occupied by users of the

building space and thus also contributes to achieve a lower carbon footprint with the system according to the invention.

[0015] The heating, ventilation and air-conditioning system (HVAC system) can have an active mode in which the heating mode, cooling mode and fan mode are selectable and in which power consumption is allowed to be maximal.

[0016] In a preferred embodiment, the HVAC system has an active preconditioning mode in which the heating mode, cooling mode and fan mode are selectable and in which power consumption is only allowed to be lower than maximal. This mode allows reducing energy consumption of the HVAC system its carbon footprint and is especially beneficial during times in which the building space of the system is not occupied, i.e. in times during which no persons are present in the building space. During said times, the temperature of the building space may be allowed to be below or above a predetermined temperature range which is defined for a case in which at least one person is present in the building space and thus temperature losses to the environment (e.g. colder outdoors temperature) or temperature gains from the environment (e.g. hotter outdoor temperatures) are minimized during said times because a temperature gradient to the environment (e.g. to outdoors) is allowed to be lower.

[0017] In a preferred embodiment, the controller is configured to make a selection between the active mode and active preconditioning mode based on signals of the occupancy sensor. This allows the system to switch the system to the active preconditioning mode if no person is detected to be present in the building space and thus allows to save energy and minimize the carbon footprint in such cases i.e. during such periods of time.

[0018] The controller is preferably configured to select the active preconditioning mode at a predetermined time period before at least one person enters the building space. The predetermined time period is more preferably determined based on statistical data analysis regarding an occupation of the building space depending on time. The advantage of this configuration of the controller is that a comfort for persons entering the unoccupied building space is maximized (because a temperature within a desired temperature range can be slowly and energy-efficiently established in the building space before persons enter the unoccupied building space) while energy consumption and carbon footprint can be minimized (because a temperature of the building space is allowed to be outside a desired temperature range at a time before the predetermined period of time and when the building space is unoccupied).

[0019] Moreover, the controller is preferably configured to select the active mode if at least one person is detected to be present in the building space by the at least one occupancy sensor. The advantage is that power consumption of the HVAC system is allowed to be maximal when at least one person is present in the building space, which allows to achieve stable maintenance of a

temperature within the building space within a desired temperature range.

[0020] The at least two air temperature sensors can be situated in locations in the building space which are spaced apart at least 30%, preferably at least 40%, more preferably at least 50%, even more preferably at least 60%, especially at least 70%, optionally at least 80%, of a maximum spatial expansion of the building space. The further the at least two temperature sensors are located away from each other, the more precise can temperature gradients across the three dimensions of the building space be detected, i.e. the more reliable is the detection of a spatial temperature distribution in the building space. This also allows a more reliable switching to the fan mode of the HVAC system, e.g. in cases in which it is beneficial to establish a temperature of the building space within a desired temperature range by mixing the air in the building space by the action of the fan in the fan mode.

[0021] The at least one occupancy sensor can be selected from the group consisting of an image sensor, a video camera, a motion sensor, a time of flight sensor and a milli-meter wave sensor, and combinations thereof. The image sensor and/or video camera are optionally suitable to detect electromagnetic radiation having a wavelength in the visible spectrum and/or infrared spectrum of light, preferably electromagnetic radiation having a wavelength range in the range of 400 to 800 nm and/or a wavelength in the range of 5 to 25 μm . A wavelength in the range of 5 to 25 μm is especially suitable to detect infrared electromagnetic radiation which is emitted by at least one person in a room (having a body temperature of approx. 37 °C).

[0022] The building space of the system can comprise an air exchange device, which is suitable for exchanging air between the building space and outdoors. The air exchange device can comprise an actor, preferably a motor, that is suitable for opening and closing the air exchange device. The air exchange device is preferably a vent or window. The advantage of having the air exchange device is that the building space is allowed to exchange indoor air with outdoors air. By this measure, if the outdoors air is at a beneficial temperature, the indoor air within the building space can be brought to a temperature within a desired temperature range just by opening and/or closing the air exchange device, i.e. with minimum consumption of energy and zero carbon footprint.

[0023] The building space can also comprise at least one air exchange device status sensor for detecting an opening degree of the air exchange device. The advantage is that the controller of the system can receive signals from the at least one air exchange status device and thus can receive information whether the air exchange device is presently open or closed.

[0024] The controller can be configured to receive signals from the air exchange device status sensor. This allows the controller to control the system of the invention, or the HVAC system thereof, based on signals from

the at least one air exchange status device.

[0025] Moreover, the controller can be configured to control the actor of the air exchange device to adjust its opening degree based on signals of the at least two air temperature sensors and of the at least one occupancy sensor, preferably also based on signals of at least one air humidity sensor of the building space and/or also based on signals of at least one air velocity sensor of the building space. This allows the controller to bring at least the temperature (preferably also a humidity) of the building space to a desired temperature (preferably also to a desired humidity). If the control is also based on signals of at least one air velocity sensor (which can be located outdoors), the controller can also decide whether an opening of the air exchange device is beneficial for bringing the air of the building space to a desired condition (e.g. if air velocity outdoors is high and no person is located in the building space) or not beneficial for the comfort of persons in the building space (e.g. if air velocity outdoors is high and no person is located in the building space).

[0026] The building space can comprise at least one air humidity sensor. The advantage is that information about air humidity can be gathered by the system and used by the controller of the system.

[0027] The controller of the system can be configured to control the operation of the heating, ventilation and air-conditioning system based on signals of the air humidity sensor. This has the advantage that an air humidity of the building space can be brought within a desired air humidity range (e.g. by switching the cooling mode on or off).

[0028] The controller of the system can be configured to control an opening degree of an air exchange device for opening and closing an air passage between the building space and outdoors of the building space based on signals of the at least one air humidity sensor. This allows the system to bring an air humidity of the building space within a desired air humidity range by allowing or not allowing an exchange of air of the building space with outdoors air, i.e. with minimum energy consumption and zero carbon footprint.

[0029] The building space can comprise at least one air velocity sensor, wherein the at least one air velocity sensor is optionally located at an indoors side of the building space or located an outdoors side of the building space. This has the advantage that the system obtains information about an (indoors or outdoors) air velocity, which can be used by the controller. It is also possible that the building space comprises at least one air velocity sensor located at an indoors side of the building space and at least one further air velocity sensor located at an outdoors side of the building space.

[0030] The controller can be configured to control the operation of the heating, ventilation and air-conditioning system based on signals of the at least one air velocity sensor (optionally also based on at least one further air velocity sensor). The advantage is that the system can

make decision whether the fan mode of the HVAC system is activated dependent on an (indoors and/or outdoors) air velocity. For example, if the at least two temperature sensors of the system detect an undesired temperature gradient across the building space, the system can decide whether an indoors air velocity is high enough to reduce or abolish the temperature gradient within a reasonable time frame without a necessity of a fan of the HVAC system to be activated.

[0031] The controller of the system can be configured to control an opening degree of an air exchange device for opening and closing an air passage between the building space and outdoors of the building space based on signals of the at least one air velocity sensor. For example, this allows the system to decide whether an outdoors air velocity is high enough to reduce or abolish a temperature gradient in the building space within a reasonable time frame without a necessity of a fan of the HVAC system to be activated, e.g. by only opening an air exchange device of the system which is suitable for exchanging air between the building space and outdoors. Hence, energy can be saved and the carbon footprint can be reduced.

[0032] Moreover, the controller can be configured to receive weather data. This has the advantage that the controller obtains information about a present and/or future outdoors air temperature, outdoors air humidity and/or outdoors air velocity.

[0033] The controller of the system can be configured to control the heating, ventilation and air-conditioning system based on received weather data. This allows the controller e.g. to make a decision whether to open or close an air exchange device for opening and closing an air passage between the building space and outdoors of the building space. It also allows the controller to set or change a predetermined time period in which the HVAC system is switched to an active preconditioning mode (e.g. to shorten said time period if a present or future weather data is favourable regarding conditioning of the building space).

[0034] The controller of the system can be configured to control an actor of an air exchange device of the system, which is suitable for exchanging air between the building space and outdoors, to adjust an opening degree of the air exchange device based on received weather data. This allows the system to use a present or future outdoors air condition for conditioning the indoor building space, which minimizes the energy consumption and the carbon footprint of the system.

[0035] The weather data preferably includes data selected from the group consisting of outdoors air temperature, outdoors air humidity, outdoors air velocity, forecast outdoors air temperature, forecast outdoors air humidity, forecast outdoors air velocity, and combinations thereof.

[0036] The controller of the system can be configured to receive data regarding a thermal comfort temperature range from at least one person in the building space. The advantage is that persons in the building space can set

and/or change the thermal comfort temperature range.

[0037] The controller of the system can be configured to control the heating, ventilation and air-conditioning system based on the received data regarding a thermal comfort temperature range.

[0038] Moreover, the controller of the system can be configured to control an actor of an air exchange device of the system, which is suitable for exchanging air between the building space and outdoors, to adjust an opening degree of the air exchange device based on the received data regarding a thermal comfort temperature range. This allows the system e.g. to (dynamically) decide about a degree of opening of the air exchange device (e.g. fully closed, partially open or fully open) depending on a received thermal comfort temperature range, which can also change depending on the type of person(s) located in the building space. For example, should persons in the room submit data regarding a thermal comfort temperature range which embraces an outdoors temperature, the system can decide to use the air exchange device for air-conditioning of the building space and thus achieve a desired air-conditioning in a more energy efficient manner and with a lower carbon footprint.

[0039] The control unit of the system is preferably configured to determine a thermal comfort temperature range from at least one person in the building space from the received data based on a thermal comfort prediction model. The thermal comfort prediction model can be a predicted mean vote model and/or an adaptive comfort model.

[0040] Moreover, the controller can be configured to set a single temperature setpoint for heating to define a heating mode of the heating, ventilation and air-conditioning system and a single temperature setpoint for cooling to define a cooling mode of the heating, ventilation and air-conditioning system.

[0041] In this regard, the controller can be configured to set the single temperature setpoint for heating to a lower value than the single temperature setpoint for cooling.

[0042] Moreover, the controller can be configured to set the single temperature setpoint for cooling to a lower value in an active mode than in an active preconditioning mode of the heating, ventilation and air-conditioning system. This has the advantage that cooling by the system can be operated in a more energy efficient manner and with a lower carbon footprint.

[0043] Furthermore, the controller can be configured to set the single temperature setpoint for heating to a higher value in an active mode than in an active preconditioning mode of the heating, ventilation and air-conditioning system. This has the advantage that heating by the system can be operated in a more energy efficient manner and with a lower carbon footprint.

[0044] Besides, the controller can be configured to set the single temperature setpoints to a different value if a thermal comfort temperature range from at least one person in the building space, which is preferably determined by the controller based on a thermal comfort

prediction model, has changed. The thermal comfort prediction model can be a predicted mean vote model and/or an adaptive comfort model. This allows a flexible setting of the setpoints in dependence of preferences of users present in the building space at a certain period of time and allows an operation of the system which is more energy efficient and has a lower carbon footprint.

[0045] Alternatively, the controller can be configured to set a lower limit temperature setpoint for heating and an upper limit temperature setpoint for heating to define a heating mode of the heating, ventilation and air-conditioning system and a lower limit temperature setpoint for cooling and an upper limit temperature setpoint for cooling to define a cooling mode of the heating, ventilation and air-conditioning system.

[0046] In this regard, the controller is preferably configured to set the temperature setpoints for cooling lower in an active mode than in an active preconditioning mode of the heating, ventilation and air-conditioning system. This has the advantage that cooling by the system can be operated in a more energy efficient manner and with a lower carbon footprint.

[0047] Moreover, the controller can be configured to set the temperature setpoints for heating higher in an active mode than in an active preconditioning mode of the heating, ventilation and air-conditioning system. This has the advantage that heating by the system can be operated in a more energy efficient manner and with a lower carbon footprint.

[0048] Furthermore, the controller can be configured to set the temperature setpoints to a different value if a thermal comfort temperature range from at least one person in the building space, which is preferably determined by the controller based on a thermal comfort prediction model, has changed. The thermal comfort prediction model can be a predicted mean vote model and/or an adaptive comfort model. This allows a flexible setting of the setpoints in dependence of preferences of users present in the building space at a certain period of time and allows an operation of the system which is more energy efficient and has a lower carbon footprint.

[0049] What is more, the controller can be configured to perform a comparison of each of the set temperature setpoints for heating and each of the set temperature setpoints for cooling with a first temperature obtained from a first of the at least two air temperature sensors of the system and with a second temperature obtained from a second of the at least two air temperature sensors of the system, wherein the controller is configured to control the operation of the heating, ventilation and air-conditioning system based on said comparison. In this regard, the controller is preferably configured to, based on said comparison, activate or deactivate a heating mode, cooling mode and fan mode of the heating, ventilation and air-conditioning system or to switch off the heating, ventilation and air-conditioning system.

[0050] In this context, the controller can be configured to activate a heating mode of the heating, ventilation and

air-conditioning system and close an air exchange device of the building space, which is suitable for exchanging air between the building space and outdoors, if a minimum building space temperature obtained from the at least two air temperature sensors is below the lower limit temperature setpoint for heating.

[0051] Moreover, the controller can be configured to activate a cooling mode of the heating, ventilation and air-conditioning system and close an air exchange device of the building space, which is suitable for exchanging air between the building space and outdoors, if a maximum building space temperature obtained from the at least two air temperature sensors is above the upper limit temperature setpoint for cooling.

[0052] Furthermore, the controller can be configured to deactivate a heating mode and a cooling mode of the heating, ventilation and air-conditioning system, to close an air exchange device of the building space, which is suitable for exchanging air between the building space and outdoors, and to activate a fan mode of the of the heating, ventilation and air-conditioning system, if

- i) a minimum building space temperature obtained from the at least two air temperature sensors is identical to or above the lower limit temperature setpoint for heating and is identical to or below the upper limit temperature setpoint for heating, and if a maximum building space temperature obtained from the at least two air temperature sensors is above the upper limit temperature setpoint for heating; and/or
- ii) a maximum building space temperature obtained from the at least two air temperature sensors is identical to or below the upper limit temperature setpoint for cooling and is identical to or above the lower limit temperature setpoint for cooling, and if a minimum building space temperature obtained from the at least two air temperature sensors is below the lower limit temperature setpoint for cooling.

[0053] This configuration of the controller allows to reduce energy consumption and the carbon footprint because no heating and cooling is performed and only energy for operating a fan of the system (e.g. the HVAC system) is needed to achieve a desired temperature in the building space.

[0054] Apart from the above, the controller can be configured to switch off the heating, ventilation and air-conditioning system and to close an air exchange device of the building space, which is suitable for exchanging air between the building space and outdoors, if

- i) a minimum building space temperature obtained from the at least two air temperature sensors is identical to or above the lower limit temperature setpoint for heating and is identical to or below the upper limit temperature setpoint for heating, and if a maximum building space temperature obtained from the at least two air temperature sensors is identical to

or below the upper limit temperature setpoint for heating; and/or

ii) a maximum building space temperature obtained from the at least two air temperature sensors is identical to or lower than the upper limit temperature setpoint for cooling and is identical to or above the lower limit temperature setpoint for cooling, and if a minimum building space temperature obtained from the at least two air temperature sensors is identical or above the lower limit temperature setpoint for cooling.

[0055] This configuration of the controller allows to reduce energy consumption and the carbon footprint because the HVAC system is switched off and an unfavourable air exchange with outdoors air is prevented in the illustrated case(s).

[0056] Moreover, the controller can be configured to switch off the heating, ventilation and air-conditioning system and to open an air exchange device of the building space, which is suitable for exchanging air between the building space and outdoors, if

i) a minimum building space temperature obtained from the at least two air temperature sensors is above the upper limit temperature setpoint for heating, and if a maximum building space temperature obtained from the at least two air temperature sensors is above an outdoors temperature; and/or
ii) a maximum building space temperature obtained from the at least two air temperature sensors is below the lower limit temperature setpoint for cooling, and if a minimum building space temperature obtained from the at least two air temperature sensors is below an outdoors temperature.

[0057] This configuration of the controller allows to reduce energy consumption and the carbon footprint because the HVAC system is switched off and a favourable air exchange with outdoors air is allowed in the illustrated case(s), i.e. outdoors air is allowed to participate in conditioning of the building space.

[0058] Furthermore, the controller can be configured to set the temperature setpoints to new temperature setpoints if

i) a minimum building space temperature obtained from the at least two air temperature sensors is above the upper limit temperature setpoint for heating, and if a maximum building space temperature obtained from the at least two air temperature sensors is identical to or below an outdoors temperature, and if a thermal comfort temperature range from at least one person in the building space, which is preferably determined by the controller based on a thermal comfort prediction model, has changed (The thermal comfort prediction model can be a predicted mean vote model and/or an adaptive comfort model);

and/or

ii) a maximum building space temperature obtained from the at least two air temperature sensors is below the lower limit temperature setpoint for cooling, and if a minimum building space temperature obtained from the at least two air temperature sensors is identical to or above an outdoors temperature, and if a thermal comfort temperature range from at least one person in the building space, which is preferably determined by the controller based on a thermal comfort prediction model, has changed (The thermal comfort prediction model can be a predicted mean vote model and/or an adaptive comfort model).

[0059] This configuration of the controller allows to reduce energy consumption and the carbon footprint because the operation of the HVAC system is made dependent on temperature preferences of at least one person (currently) present in the building space. For example, if persons present in the building space at a certain point in time have a less ambitious temperature preferences than persons which were present in the building space at a previous point in time, an unduly high activity of the HVAC system can be prevented and energy saved and carbon footprint reduced.

[0060] In this context, the controller is preferably configured to perform a comparison of each of the new temperature setpoints for heating and each of the new temperature setpoints for cooling with a first temperature obtained from a first of the at least two air temperature sensors of the system and with a second temperature obtained from a second of the at least two air temperature sensors of the system, and control the operation of the heating, ventilation and air-conditioning system based on said comparison, wherein the controller is preferably configured to, based on said comparison, activate or deactivate a heating mode, cooling mode and fan mode of the heating, ventilation and air-conditioning system or to deactivate the whole heating, ventilation and air-conditioning system.

[0061] The controller of the system can be a local controller of the heating, ventilation and air-conditioning system.

[0062] Alternatively, the controller of the system can be a remote controller that has a communicative connection, optionally by cable or wireless, to a local controller of the heating, ventilation and air-conditioning system. In this regard, the controller of the system (remote controller) can be a cloud controller.

[0063] In the following figures and examples, the subject-matter according to the invention shall be illustrated in more detail without wishing to limit the subject-matter according to the invention to the specific embodiments shown here.

Figure 1A schematically shows a control of a single control loop iteration which the controller of the system according to the invention can be configured to

implement.

Figure 1B shows an overview of a control for setting the temperature setpoints which the controller of the system according to the invention can be configured to implement. The temperature setpoints can relate to an active mode of the HVAC system in which the heating mode, cooling mode and fan mode of the HVAC system are selectable and in which power consumption is allowed to be maximal (in this case: the answer to active hours is yes). The temperature setpoints can also relate to an active preconditioning mode of the HVAC system in which the heating mode, cooling mode and fan mode of the HVAC system are selectable and in which power consumption is only allowed to be lower than maximal (in this case: the answer to active hours is no and the answer to preconditioning hours is yes).

Figure 1C shows an overview of a control for the heating branch which the controller of the system according to the invention can be configured to implement. "Heating ON" means that the heating mode of the HVAC system is switched on. "Heating OFF" means that the heating mode of the HVAC system is switched off. "HVAC OFF" means that the HVAC system is switched (completely) off. "Fan ON" means that the fan mode is switched on, i.e. that a fan of the HVAC system is activated. "Window OPEN" means that a window of the building space of the system is opened. "Window CLOSED" means that a window of the building space of the system is closed.

Figure 1D shows an overview of a control for the cooling branch which the controller of the system according to the invention can be configured to implement. "Cooling ON" means that the cooling mode of the HVAC system is switched on. "Cooling OFF" means that the cooling mode of the HVAC system is switched off. "HVAC OFF" means that the HVAC system is switched (completely) off. "Fan ON" means that the fan mode is switched on, i.e. that a fan of the HVAC system is activated. "Window OPEN" means that a window of the building space of the system is opened. "Window CLOSED" means that a window of the building space of the system is closed.

Figure 2 schematically shows a first system according to the invention. The system comprises a heating, ventilation and air-conditioning system 1, 2, 7, 19 (HVAC system 1, 2, 19) having an outdoor unit 1, an indoor unit 2, a local controller 7 and a duct 19 for air supply and air return, wherein the HVAC system 1, 2, 7, 19 is suitable to air condition a building space 3. The HVAC system 1, 2, 7, 19 has a heating mode in which heating of the building space 3 is effected, a cooling mode in which cooling of the building space 3 is effected, and a fan mode in which no heating and

no cooling of the building space 3 is effected and air is circulated within the building space. The system further comprises a building space 3 to be air conditioned by the HVAC system 1, 2, 6, 19, at least two air temperature sensors 4, 4' situated in different locations in the building space 3 and at least one occupancy sensor 5 for detecting the presence of at least one person 18, 18', 18'', 18''' in the building space 3. Here, the at least one occupancy sensor 5 is located in one sensing device together with a first air temperature sensor 4 of the at least two air temperature sensors 4, 4'. The system further comprises a controller 6 for controlling an operation of the HVAC system 1, 2, 7, 19, wherein the controller 6 is configured to make a selection between the heating mode, cooling mode and fan mode based on signals of the at least two air temperature sensors 4, 4'. The system further comprises three air exchange devices 8, 8', 8'' (here: windows to outdoors), wherein the air exchange devices 8, 8', 8'' each have an actuator 9 suitable for opening and closing each air exchange device 8, 8', 8'' (here: a motor) and an air exchange device status sensor 10 for detecting an opening degree of each air exchange device 8, 8', 8''. The system further comprises at least one air humidity sensor 11. Here, the at least one air humidity sensor 11 is located in one sensing device together with a second air temperature sensor 4' of the at least two air temperature sensors 4, 4'. The system also comprises at least one first air velocity sensor 12 which is located within the building space 3 (i.e. indoors) and in one sensing device together with the first air temperature sensor 4 and the at least one occupancy sensor 5. The system further comprises at least one second air velocity sensor 12' which is located outside of the building space 3 (i.e. outdoors) and in one sensing device together with the air exchange device status sensor 10. Here, the building space 3 of the system comprises several desks 17, 17', 17'', 17''' and occupants/persons 18, 18', 18'', 18''' located within the building space 3. In this first system according to the invention, the controller 6 of the system is a remote controller which is connected to the local controller 7 of the HVAC system and is configured to receive weather data 13, data from a HVAC cloud 14, and sensor data 15 which is provided by a sensing manager 16.

Figure 3 schematically shows a second system according to the invention which is identical to the first system according to the invention shown in Figure 2 with the following exception: The controller 6 of the system is special remote controller, namely a remote cloud controller.

Figure 4 schematically shows a third system according to the invention which is identical to the first system according to the invention shown in Figure

2 with the following exception: The controller 6 of the system is no remote controller, but a local controller 7 of the HVAC system 1, 2, 7, 19.

Example 1 - Features of a system according to the present invention

[0064] The system according to the invention can include the following features:

Connected devices

[0065] At least one HVAC system, optionally being:

- a) A split HVAC system comprising an outdoor unit having a compressor, pipe and valve connections and heat exchangers, and comprising an indoor unit having an air conditioning mechanism, an air supply and return mechanism, a HVAC energy manager, a pipe and valve connections; or
- b) A packaged HVAC system comprising a compressor, pipe and valve connections, heat exchangers, an air conditioning mechanism, an air supply and return mechanism, a HVAC energy manager, a pipe, and valve connections.

[0066] Sensing devices, comprising:

- Two Temperature measuring devices (optionally more).
- One occupancy monitoring device (optionally more).
- A window opening status monitoring devices (optionally more).
- A measuring device for other indoor thermal environment parameters like e.g., velocity, and relative humidity (optionally more).

[0067] Sensing manager to collect and manage data from sensing devices.

[0068] Automatic windows including actuators, electric drives, etc.

Connected software

[0069]

- Application programming interface (API) for HVAC systems.
- API for weather data.
- API for connected sensors data.
- Communication protocols for automatic window operation.

Inputs

[0070]

- External data like e.g. weather data (e.g. tempera-

ture, humidity, solar irradiance, etc.)

- Room temperature
- User settings like e.g. maximum and minimum temperature setpoint, active (occupied/unoccupied) and preconditioning hours.
- HVAC operation modes/status like e.g., heating, cooling, fan modes, etc.
- Sizes and location of air terminal devices (inlets and/or outlets).
- Location of sensors.
- Window open/close status.
- Occupancy data.
- Indoor space volume.

Internal processing components

[0071]

- Indoor temperature distribution monitoring system.
- Heating demand.
- Cooling demand.
- Occupancy monitoring system.
- Thermal comfort monitoring system, e.g., Predicted Mean Vote (PMV) model and Adaptive Comfort Model (ACM).
- HVACs operating hours monitoring system.
- Building management system for monitoring HVACs energy use.

Outputs

[0072]

- System status/operating modes, e.g.

Decision of heating/cooling needs,
HVAC heating/cooling modes to provide heating or cooling,
HVAC Fan mode to increase mixing of air and to reduce thermal stratification in indoor spaces, and/or
Automatic window operations to enable natural heating/cooling.

- Provide space heating from HVAC units with uniformly distributed air temperature across the targeted indoor spaces.
- Provide space cooling from HVAC units with uniformly distributed air temperature across the targeted indoor spaces.
- If conditions are suitable, use automatic windows to provide heating and cooling or to reduce temperature variations in the targeted indoor spaces.
- Improve thermal comfort by dynamically adjusting the setpoints prompted by thermal comfort models such as PMV and ACM.
- Reduce energy consumption of HVAC sys-

tems by automatic setting of temperature setpoints during the occupied, unoccupied or preconditioning hours.

Example 2 - Configurations of the controller of the system according to the invention

[0073] A configuration of the controller of the system according to the invention is shown schematically in Figures 1A to 1D. More details to the configuration are given below.

Control of loop iterations

[0074] The controller can be configured to perform an iteration of its parameters periodically and to use updated system information based on operating states of connected devices and measured variables.

[0075] Updated system information can include weather forecasts to decide heating or cooling needs, occupant centric data such as thermal comfort temperature range driven by PMV or ACM, predefined HVAC operation schedules such as active and preconditioning hours, and day of the week including information on public holidays. Active hours are a period when the HVAC system should be operating at its full capacity (= active mode of the HVAC system), whereas preconditioning hours are a period preceding the active hours to ensure the indoor spaces are slowly heated up or cooled down before occupants start occupying the space (= active preconditioning mode of the HVAC system).

Control of setpoints

[0076] During each loop iteration, the controller can be configured to set setpoints for room temperature for heating and cooling.

[0077] The controller can be configured to set a single setpoint for both the heating mode and the cooling mode. However, it is preferred that the controller is configured to set two temperatures for the heating mode and for the cooling mode, respectively, instead of a single setpoint for each mode. To reduce energy costs, heating setpoints are preferably set to lower values in comparison to cooling set points.

[0078] The heating setpoints and cooling setpoints can respectively define a range. As an example for heating, the lower level temperature setpoint can be $T_{\text{heat,LL}}$ while the upper level temperature setpoint can be $T_{\text{heat,UL}}$. These temperature setpoints can be fixed for the defined active (occupied/occupied) and preconditioning hours or they can be dynamic and can be changed by the controller depending on the perceived thermal comfort in the indoor spaces via PMV and/or ACM. In general, it is preferred that the heating and cooling setpoints for active-occupied hours are higher for heating and lower for cooling than their corresponding values in active-unoccupied hours.

Control regarding evaluation

[0079] The controller can be configured to monitor a room temperature distribution from the signals obtained from the at least two temperature sensors and to evaluate a maximum and minimum temperature of the building space. The controller can be configured to compare the measured data with predefined and fixed, or live and dynamic, setpoint temperatures to decide heating or cooling needs. Also, the controller can be configured to use the data to compute a cooling load or a heating load for energy performance monitoring.

Control of heating and cooling branches

[0080] Heating and cooling branches of the HVAC system can occur in parallel and are split into two separate decision branches. This is applicable for single or multi zone building spaces. In single zone building spaces, either the heating or cooling branch operates at one time. In multi-zone spaces, either or both heating branches and/or cooling branches can operate simultaneously.

[0081] On the heating branch, the controller can be configured to monitor the minimum room temperature and to initiate a heating cycle if the room temperature is below a lower limit heating threshold.

[0082] To reduce heat losses, the controller can be configured to keep all air exchange device suitable for exchanging air between the building space and outdoors (e.g. windows) automatically closed.

[0083] If the minimum room temperature is below an upper limit threshold and the maximum room temperature is above an upper limit threshold, the controller can be configured to stop the heating and to start circulating the room air using HVAC fan mode. Air circulation helps to increase the air mixing in the building space and helps to reduce the hot and cold spots.

[0084] If both the minimum and maximum room temperatures are within the defined upper and lower threshold values, the controller can be configured to turn the HVAC system off.

[0085] If both the minimum and maximum room temperatures are above the upper threshold value, the controller can be configured to open the windows automatically, provided that outdoor air temperature is below the maximum room temperature, to allow natural cooling to bring the room temperature range within the defined threshold values. One advantage of this natural cooling is that it avoids the need for a cooling operation of the HVAC system and hence saves energy.

[0086] On the cooling branch, the controller can be configured to function in an opposite way to the heating branch.

[0087] For instance, the controller can be configured to initiate a cooling mode once the maximum room temperature is above an upper limit cooling threshold.

[0088] The controller can be configured to turn the

cooling mode off and to turn the fan mode on once the maximum room temperature is above a lower limit cooling threshold and the minimum room temperature is below a lower limit cooling threshold. The temperature range at these conditions is cooler than it should be and hence a fan operation is initiated by the controller to increase the air mix and to reduce the temperature variation in the room.

[0089] If both the minimum and maximum room temperatures are below the lower threshold value, the controller can be configured to open the windows automatically, provided that outdoor air temperature is above the minimum room temperature, to allow natural heating to bring the room temperature range within the defined threshold values. The use of natural heating and cooling to reduce variation of temperatures in the room could save energy as they avoid the need for HVAC system operation in heating and/or cooling modes.

Example 3 - System according to the present invention with a remote controller

[0090] In this system according to the present invention, the controller of the system (master controller) is a non-local remote controller that is connected to all building's energy hardware and software including an HVAC system (e.g. a split system having an outdoor unit and indoor unit), an HVAC controller (e.g. an HVAC energy manager), a window opening mechanisms with electric drives, sensing devices (temperature, relative humidity, occupancy and window opening status monitoring, etc.) and a sensing manager, wherein weather data and building energy data is measured via API services (see Figure 2).

[0091] The remote controller of the system is configured to exchange data with the connected hardware via API services and controls the hardware indirectly by feeding the settings into the hardware's individual controllers (slave controllers) (e.g. HVAC controller). For example, HVAC mode selection settings (heating/cooling/fan modes on/off), HVAC room temperature set-points, and on/off mode for automatic window operation are controlled by the remote controller (master controller).

Example 4 - System according to the present invention with a remote cloud controller

[0092] In this system according to the invention, the controller of the system (master controller) is a non-local remote controller located in a cloud platform (remote cloud controller) that is connected to all building's energy hardware and software including an HVAC system (e.g. a split system having an outdoor unit and indoor unit), an HVAC controller (e.g. an HVAC energy manager), a window opening mechanisms with electric drives, sensing devices (temperature, relative humidity, occupancy and window opening status monitoring, etc.) and a sen-

sing manager, wherein weather data and building energy data is measured via API services (see Figure 3).

[0093] With the remote cloud controller, a dedicated system for remote control can be eliminated and the remote cloud controller (master controller) relies on at least one controller on the device level (slave, e.g. a separate controller of the HVAC system) to perform control actions.

Example 5 - System according to the present invention with a local controller

[0094] In this system according to the invention, the controller of the system (master controller) is a local controller of the HVAC system (see Figure 4).

[0095] In this system, all the device level controllers are eliminated by the system comprising only one single local controller. Said local controller has all the capabilities and functions needed to operate the system according to the invention.

List of abbreviations and reference signs

[0096]

1:	outdoor unit of heating, ventilation and air-conditioning system;
2:	indoor unit of heating, ventilation and air-conditioning system;
3:	building space to be air-conditioned by the HVAC system;
4, 4':	air temperature sensor(s);
5:	occupancy sensor;
6:	controller of the system;
7:	local controller of HVAC system;
8, 8', 8":	air exchange device (e.g. window);
9:	actor suitable for opening and closing the air exchange device (e.g. motor);
10:	air exchange device status sensor for detecting an opening degree of the air exchange device;
11:	air humidity sensor;
12, 12':	air velocity sensor;
13:	weather data;
14:	HVAC cloud;
15:	sensors data;
16:	sensing manager;
17, 17', 17", 17"":	desk(s);
18; 18', 18", 18"":	occupant(s), i.e. person(s);
19:	duct for air supply and air return of HVAC system;
ACM:	Adaptive comfort model;
$C_{UL,unocp}$:	Upper limit cooling threshold in unoccupied/preconditioning period;
$C_{LL,unocp}$:	Lower limit cooling threshold in unoccupied/preconditioning period;
$C_{UL,ocp}$:	Upper limit cooling threshold in oc-

	cupied period;	
$C_{LL,ocp}$:	Lower limit cooling threshold in occupied period;	
HVAC:	Heating, ventilation and air conditioning;	5
$H_{UL,unocp}$:	Upper limit heating threshold in unoccupied/preconditioning period;	
$H_{LL,unocp}$:	Lower limit heating threshold in unoccupied/preconditioning period;	
$H_{UL,ocp}$:	Upper limit heating threshold in occupied period;	10
$H_{LL,ocp}$:	Lower limit heating threshold in occupied period;	
N:	Decision result negative = "No";	
PMV:	Predictive mean vote;	15
$T_{cool,LL}$:	Lower limit temperature setpoint for cooling;	
$T_{heat,LL}$:	Lower limit temperature setpoint for heating;	
$T_{cool,UL}$:	Upper limit temperature setpoint for cooling;	20
$T_{heat,UL}$:	Upper limit temperature setpoint for heating;	
$T_{r,min}$:	Minimum room temperature;	
$T_{r,max}$:	Maximum room temperature;	25
T_{amb} :	Ambient temperature = outdoors temperature;	
Y:	Decision result positive = "Yes".	

Claims

1. A system for air-conditioning, comprising

- a) a heating, ventilation and air-conditioning system suitable to air condition a building space, wherein the heating, ventilation and air-conditioning system has a heating mode in which heating of the building space is effected, a cooling mode in which cooling of the building space is effected, and a fan mode in which no heating and no cooling of the building space is effected and air is circulated within the building space;
- b) a building space to be air conditioned by the heating, ventilation and air-conditioning system;
- c) at least two air temperature sensors situated in different locations in the building space;
- d) at least one occupancy sensor for detecting the presence of at least one person in the building space;
- e) a controller for controlling an operation of the heating, ventilation and air-conditioning system;

characterized in that the controller is configured to make a selection between the heating mode, cooling mode and fan mode based on signals of the at least two air temperature sensors.

2. The system according to the preceding claim, **characterised in that**

the heating, ventilation and air-conditioning system further has

- i) an active mode in which the heating mode, cooling mode and fan mode are selectable and in which power consumption is allowed to be maximal; and/or
- ii) an active preconditioning mode in which the heating mode, cooling mode and fan mode are selectable and in which power consumption is only allowed to be lower than maximal; wherein the controller is configured to make a selection between the active mode and active preconditioning mode based on signals of the occupancy sensor, wherein the controller is preferably configured to

- i) select the active preconditioning mode at a predetermined time period before at least one person enters the building space, wherein the predetermined time period is more preferably determined based on statistical data analysis regarding an occupation of the building space depending on time; and/or
- ii) select the active mode if at least one person is detected to be present in the building space by the at least one occupancy sensor.

3. The system according to any one of the preceding claims, **characterised in that** the at least two air temperature sensors are situated in locations in the building space which are spaced apart at least 30%, preferably at least 40%, more preferably at least 50%, even more preferably at least 60%, especially at least 70%, optionally at least 80%, of a maximum spatial expansion of the building space.

4. The system according to any one of the preceding claims, **characterised in that** the at least one occupancy sensor is selected from the group consisting of an image sensor, a video camera, a motion sensor, a time of flight sensor, a milli-meter wave sensor, and combinations thereof, wherein the image sensor and/or video camera are optionally suitable to detect electromagnetic radiation having a wavelength in the visible spectrum and/or infrared spectrum of light, preferably electromagnetic radiation having a wavelength range in the range of 400 to 800 nm and/or a wavelength in the range of 5 to 25 μm .

5. The system according to any one of the preceding claims, **characterised in that** the building space comprises

- a) an air exchange device, which is suitable for exchanging air between the building space and

- outdoors, wherein the air exchange device comprises an actor, preferably a motor, that is suitable for opening and closing the air exchange device, wherein the air exchange device is preferably a vent or window; and
 b) at least one air exchange device status sensor for detecting an opening degree of the air exchange device;
- wherein the controller is configured to
- i) receive signals from the air exchange device status sensor; and/or
 - ii) control the actor of the air exchange device to adjust its opening degree based on signals of the at least two air temperature sensors and of the at least one occupancy sensor, preferably also based on signals of at least one air humidity sensor of the building space and/or also based on signals of at least one air velocity sensor of the building space.
6. The system according to any one of the preceding claims, **characterised in that** the building space comprises at least one air humidity sensor, wherein the controller is configured to
- i) control the operation of the heating, ventilation and air-conditioning system based on signals of the air humidity sensor; and/or
 - ii) control an opening degree of an air exchange device for opening and closing an air passage between the building space and outdoors of the building space based on signals of the at least one air humidity sensor.
7. The system according to any one of the preceding claims, **characterised in that** the building space comprises at least one air velocity sensor, wherein the at least one air velocity sensor is optionally located at an indoors side of the building space or located at an outdoors side of the building space, wherein the controller is configured to
- i) control the operation of the heating, ventilation and air-conditioning system based on signals of the at least one air velocity sensor; and/or
 - ii) control an opening degree of an air exchange device for opening and closing an air passage between the building space and outdoors of the building space based on signals of the at least one air velocity sensor.
8. The system according to any one of the preceding claims, **characterised in that** the controller is configured to receive weather data and is configured to control
- i) the heating, ventilation and air-conditioning system based on received weather data; and/or
 - ii) an actor of an air exchange device of the system, which is suitable for exchanging air between the building space and outdoors, to adjust an opening degree of the air exchange device based on received weather data;
- wherein the weather data preferably includes data selected from the group consisting of outdoors air temperature, outdoors air humidity, outdoors air velocity, forecast outdoors air temperature, forecast outdoors air humidity, forecast outdoors air velocity, and combinations thereof.
9. The system according to any one of the preceding claims, **characterised in that** the controller is configured to receive data regarding a thermal comfort temperature range from at least one person in the building space and is configured to control
- i) the heating, ventilation and air-conditioning system based on the received data regarding a thermal comfort temperature range; and/or
 - ii) an actor of an air exchange device of the system, which is suitable for exchanging air between the building space and outdoors, to adjust an opening degree of the air exchange device based on the received data regarding a thermal comfort temperature range;
- wherein the control unit is preferably configured to determine a thermal comfort temperature range from at least one person in the building space from the received data based on a thermal comfort prediction model, optionally a predicted mean vote model and/or an adaptive comfort model.
10. The system according to any one of the preceding claims, **characterised in that** the controller is configured to set
- a) a single temperature setpoint for heating to define a heating mode of the heating, ventilation and air-conditioning system; and
 - b) a single temperature setpoint for cooling to define a cooling mode of the heating, ventilation and air-conditioning system;
- wherein the controller is more preferably configured to set the
- i) single temperature setpoint for heating to a lower value than the single temperature setpoint for cooling; and/or
 - ii) single temperature setpoint for cooling to a lower value in an active mode than in an active preconditioning mode of the heating, ventilation

and air-conditioning system; and/or
 iii) single temperature setpoint for heating to a higher value in an active mode than in an active preconditioning mode of the heating, ventilation and air-conditioning system; and/or
 iv) single temperature setpoints to a different value if a thermal comfort temperature range from at least one person in the building space, which is preferably determined by the controller based on a thermal comfort prediction model, optionally a predicted mean vote model and/or an adaptive comfort model, has changed.

11. The system according to one of the claims 1 to 9, **characterised in that** the controller is configured to set

a) a lower limit temperature setpoint for heating and an upper limit temperature setpoint for heating to define a heating mode of the heating, ventilation and air-conditioning system; and
 b) a lower limit temperature setpoint for cooling and an upper limit temperature setpoint for cooling to define a cooling mode of the heating, ventilation and air-conditioning system;

wherein the controller is more preferably configured to set the

i) temperature setpoints for cooling lower in an active mode than in an active preconditioning mode of the heating, ventilation and air-conditioning system; and/or
 ii) temperature setpoints for heating higher in an active mode than in an active preconditioning mode of the heating, ventilation and air-conditioning system; and/or
 iii) temperature setpoints to a different value if a thermal comfort temperature range from at least one person in the building space, which is preferably determined by the controller based on a thermal comfort prediction model, optionally a predicted mean vote model and/or an adaptive comfort model, has changed.

12. The system according to claim 11, **characterised in that** the controller is configured to perform a comparison of each of the set temperature setpoints for heating and each of the set temperature setpoints for cooling with a first temperature obtained from a first of the at least two air temperature sensors of the system and with a second temperature obtained from a second of the at least two air temperature sensors of the system, and wherein the controller is configured to control the operation of the heating, ventilation and air-conditioning system based on said comparison, wherein the controller is preferably configured to, based on said comparison, activate or

deactivate a heating mode, cooling mode and fan mode of the heating, ventilation and air-conditioning system or to switch off the heating, ventilation and air-conditioning system.

13. The system according to one of claims 11 or 12, **characterised in that** the controller is configured to activate

i) a heating mode of the heating, ventilation and air-conditioning system and close an air exchange device of the building space, which is suitable for exchanging air between the building space and outdoors, if a minimum building space temperature obtained from the at least two air temperature sensors is below the lower limit temperature setpoint for heating; and/or
 ii) a cooling mode of the heating, ventilation and air-conditioning system and close an air exchange device of the building space, which is suitable for exchanging air between the building space and outdoors, if a maximum building space temperature obtained from the at least two air temperature sensors is above the upper limit temperature setpoint for cooling.

14. The system according to any one of claims 11 to 13, **characterised in that** the controller is configured to deactivate a heating mode and a cooling mode of the heating, ventilation and air-conditioning system, to close an air exchange device of the building space, which is suitable for exchanging air between the building space and outdoors, and to activate a fan mode of the of the heating, ventilation and air-conditioning system, if

i) a minimum building space temperature obtained from the at least two air temperature sensors is identical to or above the lower limit temperature setpoint for heating and is identical to or below the upper limit temperature setpoint for heating, and if a maximum building space temperature obtained from the at least two air temperature sensors is above the upper limit temperature setpoint for heating; and/or
 ii) a maximum building space temperature obtained from the at least two air temperature sensors is identical to or below the upper limit temperature setpoint for cooling and is identical to or above the lower limit temperature setpoint for cooling, and if a minimum building space temperature obtained from the at least two air temperature sensors is below the lower limit temperature setpoint for cooling.

15. The system according to any one of claims 11 to 14, **characterised in that** the controller is configured to switch off the heating, ventilation and air-condition-

ing system and to close an air exchange device of the building space, which is suitable for exchanging air between the building space and outdoors, if

- i) a minimum building space temperature obtained from the at least two air temperature sensors is identical to or above the lower limit temperature setpoint for heating and is identical to or below the upper limit temperature setpoint for heating, and if a maximum building space temperature obtained from the at least two air temperature sensors is identical to or below the upper limit temperature setpoint for heating; and/or
 - ii) a maximum building space temperature obtained from the at least two air temperature sensors is identical to or lower than the upper limit temperature setpoint for cooling and is identical to or above the lower limit temperature setpoint for cooling, and if a minimum building space temperature obtained from the at least two air temperature sensors is identical or above the lower limit temperature setpoint for cooling.
16. The system according to any one of claims 11 to 15, **characterised in that** the controller is configured to switch off the heating, ventilation and air-conditioning system and to open an air exchange device of the building space, which is suitable for exchanging air between the building space and outdoors, if
- i) a minimum building space temperature obtained from the at least two air temperature sensors is above the upper limit temperature setpoint for heating, and if a maximum building space temperature obtained from the at least two air temperature sensors is above an outdoors temperature; and/or
 - ii) a maximum building space temperature obtained from the at least two air temperature sensors is below the lower limit temperature setpoint for cooling, and if a minimum building space temperature obtained from the at least two air temperature sensors is below an outdoors temperature.
17. The system according to any one of claims 11 to 16, **characterised in that** the controller is configured to set the temperature setpoints to new temperature setpoints if
- i) a minimum building space temperature obtained from the at least two air temperature sensors is above the upper limit temperature setpoint for heating, and if a maximum building space temperature obtained from the at least two air temperature sensors is identical to or below an outdoors temperature, and if a thermal

comfort temperature range from at least one person in the building space, which is preferably determined by the controller based on a thermal comfort prediction model, optionally a predicted mean vote model and/or an adaptive comfort model, has changed; and/or

ii) a maximum building space temperature obtained from the at least two air temperature sensors is below the lower limit temperature setpoint for cooling, and if a minimum building space temperature obtained from the at least two air temperature sensors is identical to or above an outdoors temperature, and if a thermal comfort temperature range from at least one person in the building space, which is preferably determined by the controller based on a thermal comfort prediction model, optionally a predicted mean vote model and/or an adaptive comfort model, has changed;

wherein the controller is preferably configured to perform a comparison of each of the new temperature setpoints for heating and each of the new temperature setpoints for cooling with a first temperature obtained from a first of the at least two air temperature sensors of the system and with a second temperature obtained from a second of the at least two air temperature sensors of the system, and control the operation of the heating, ventilation and air-conditioning system based on said comparison, wherein the controller is preferably configured to, based on said comparison, activate or deactivate a heating mode, cooling mode and fan mode of the heating, ventilation and air-conditioning system or to deactivate the whole heating, ventilation and air-conditioning system.

18. The system according to any one of the preceding claims, **characterised in that** the controller is

- i) a local controller of the heating, ventilation and air-conditioning system;
- ii) a remote controller that has a communicative connection, optionally by cable or wireless, to a local controller of the heating, ventilation and air-conditioning system, wherein the remote controller is preferably a cloud controller.

Figure 1A

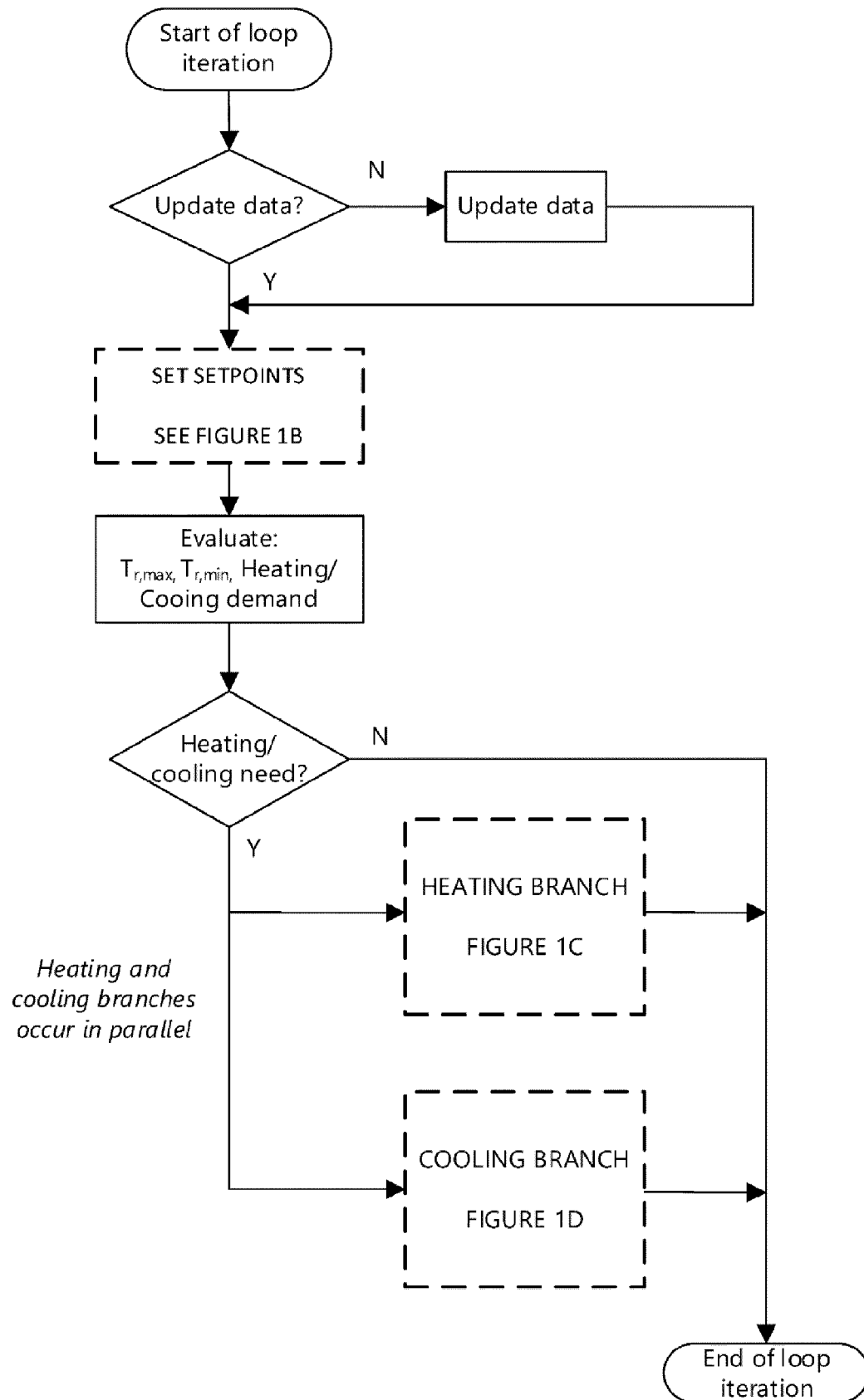


Figure 1B

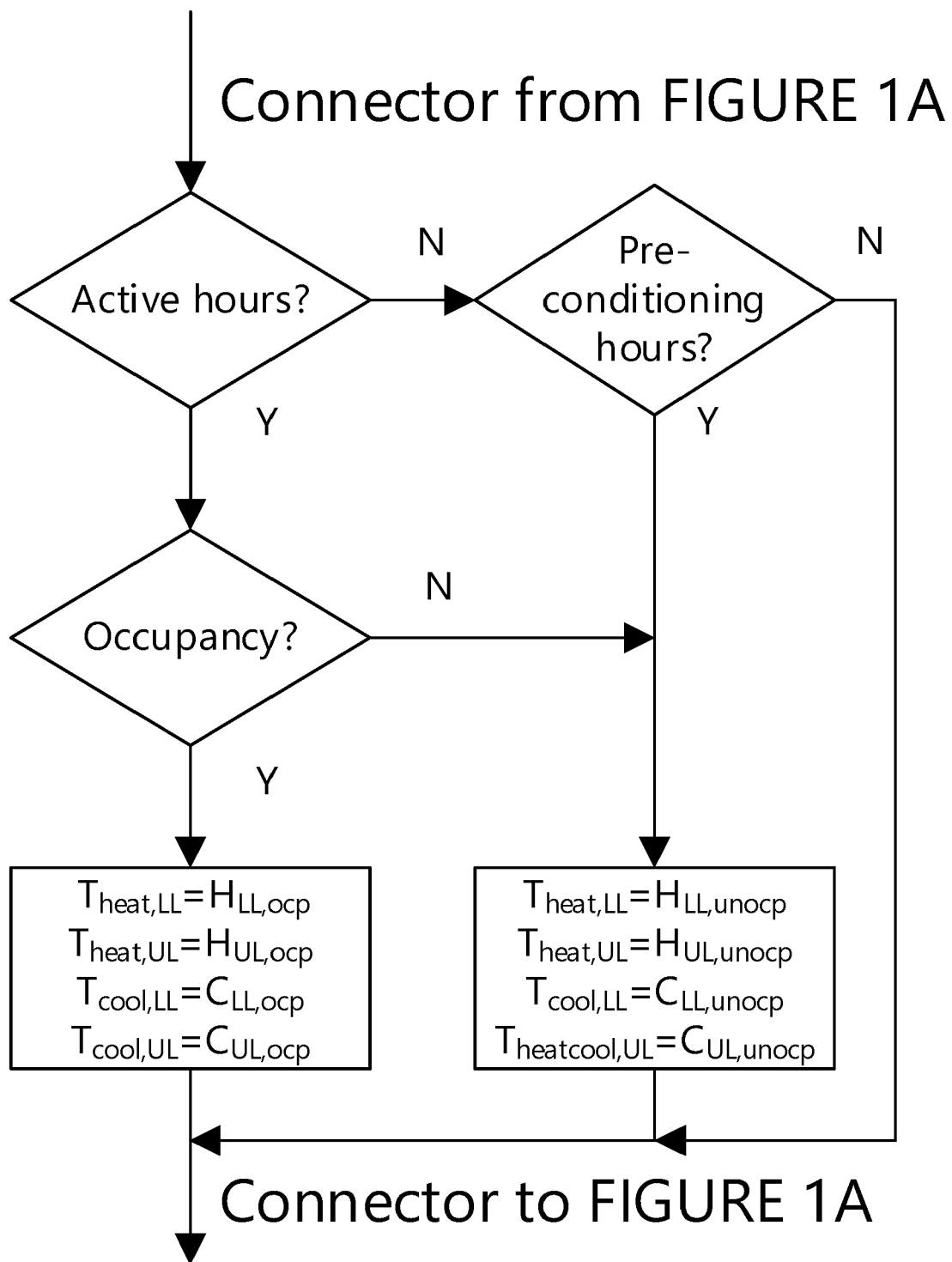


Figure 1C

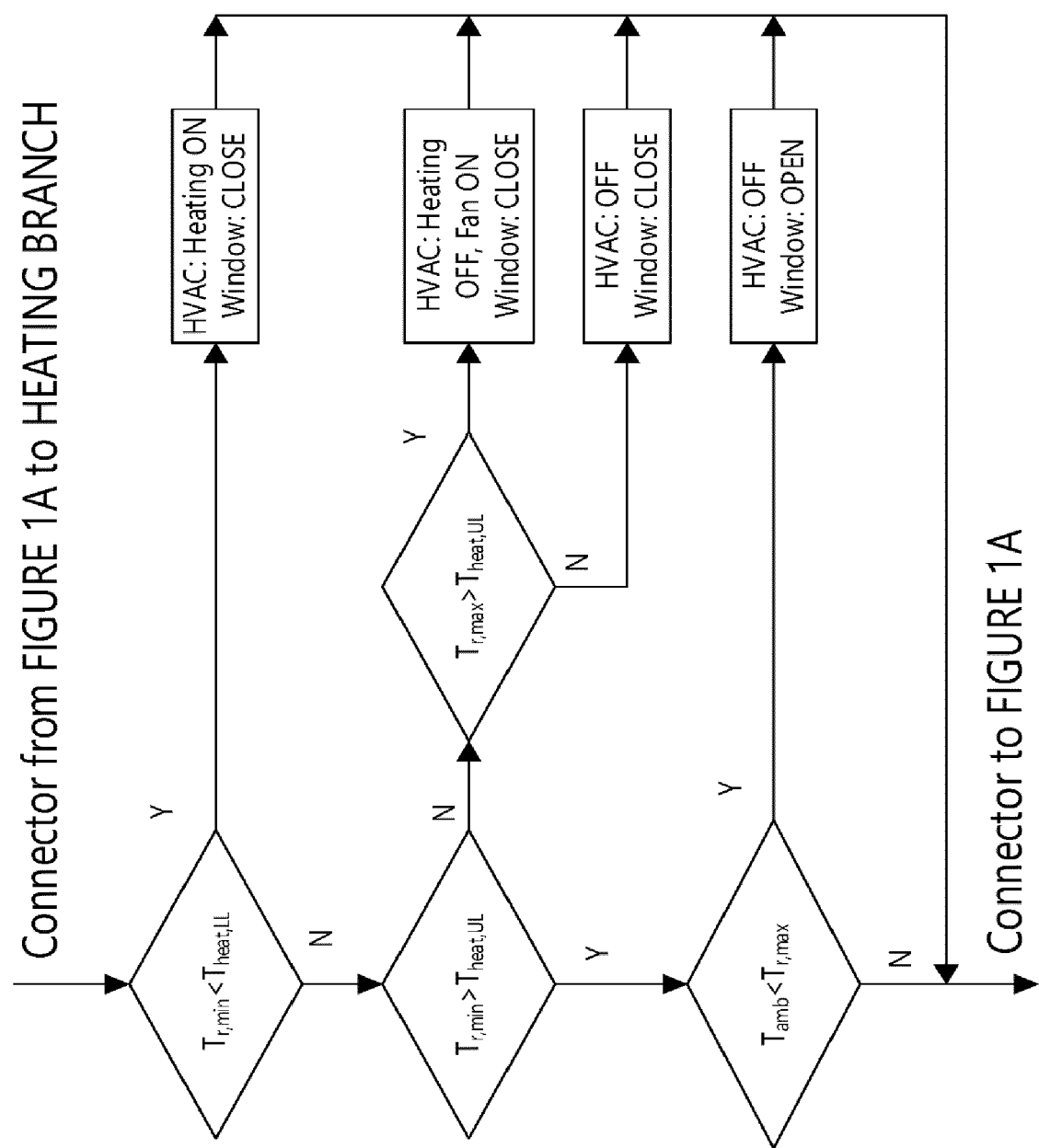


Figure 1D

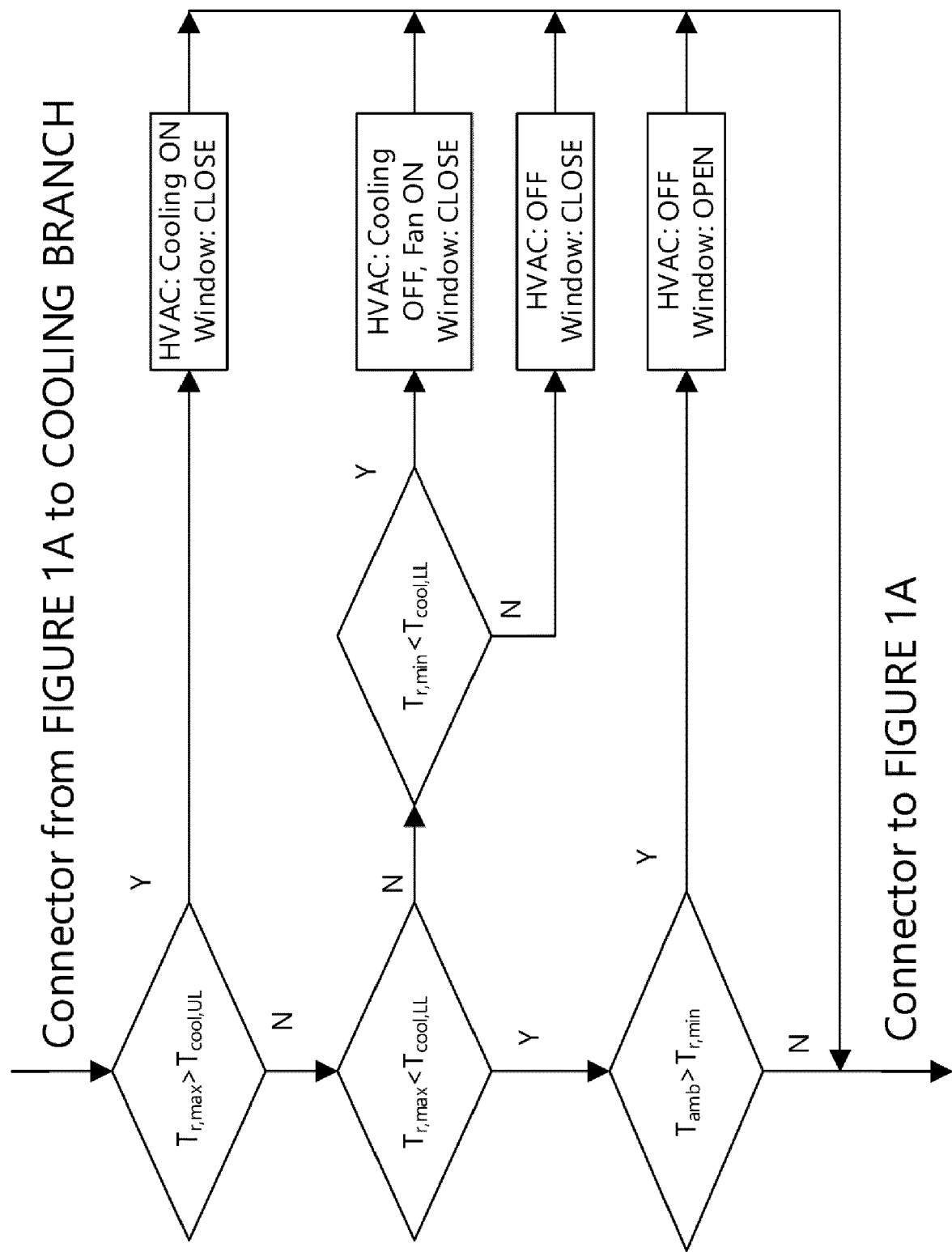


Figure 2

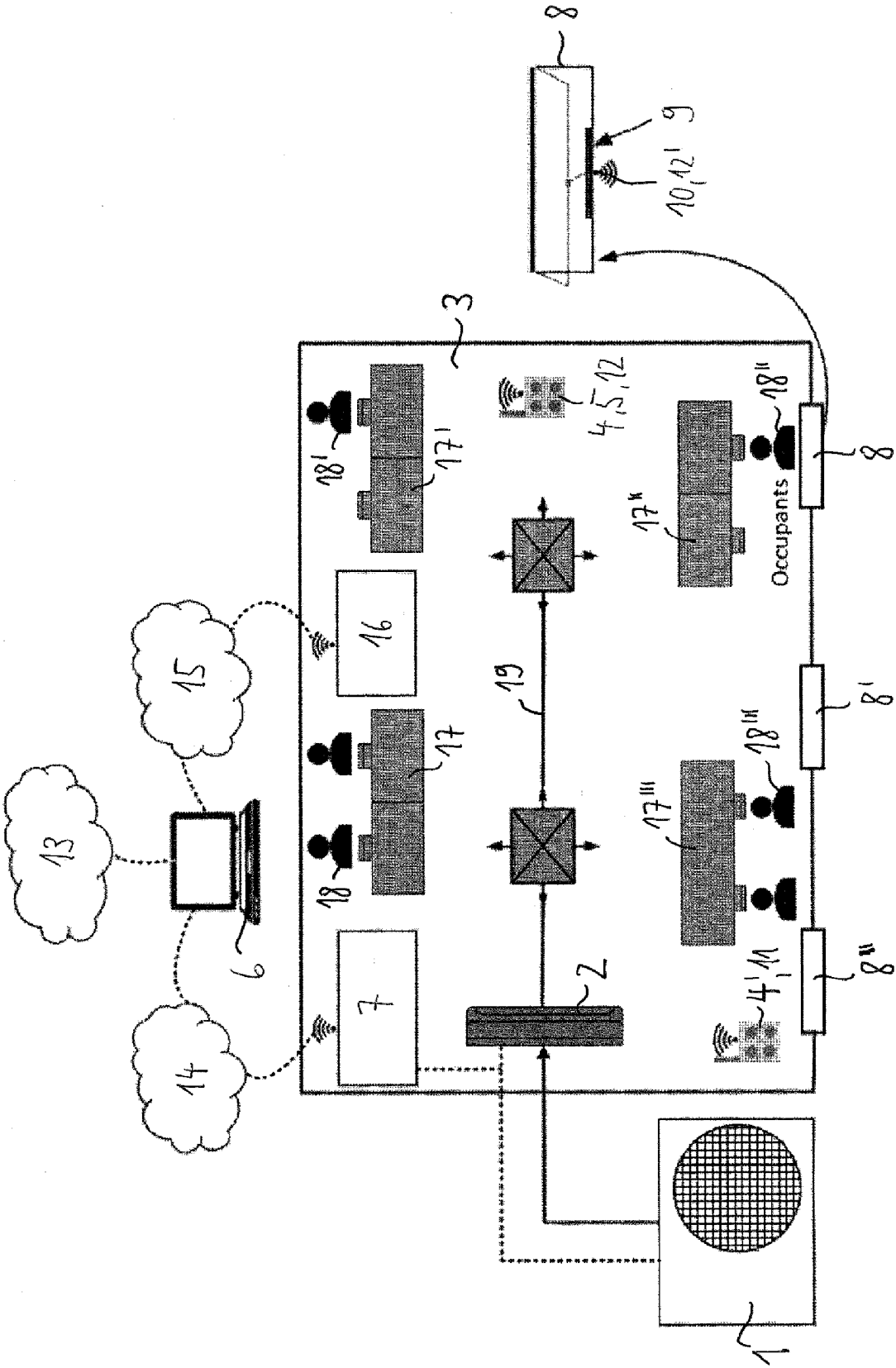


Figure 3

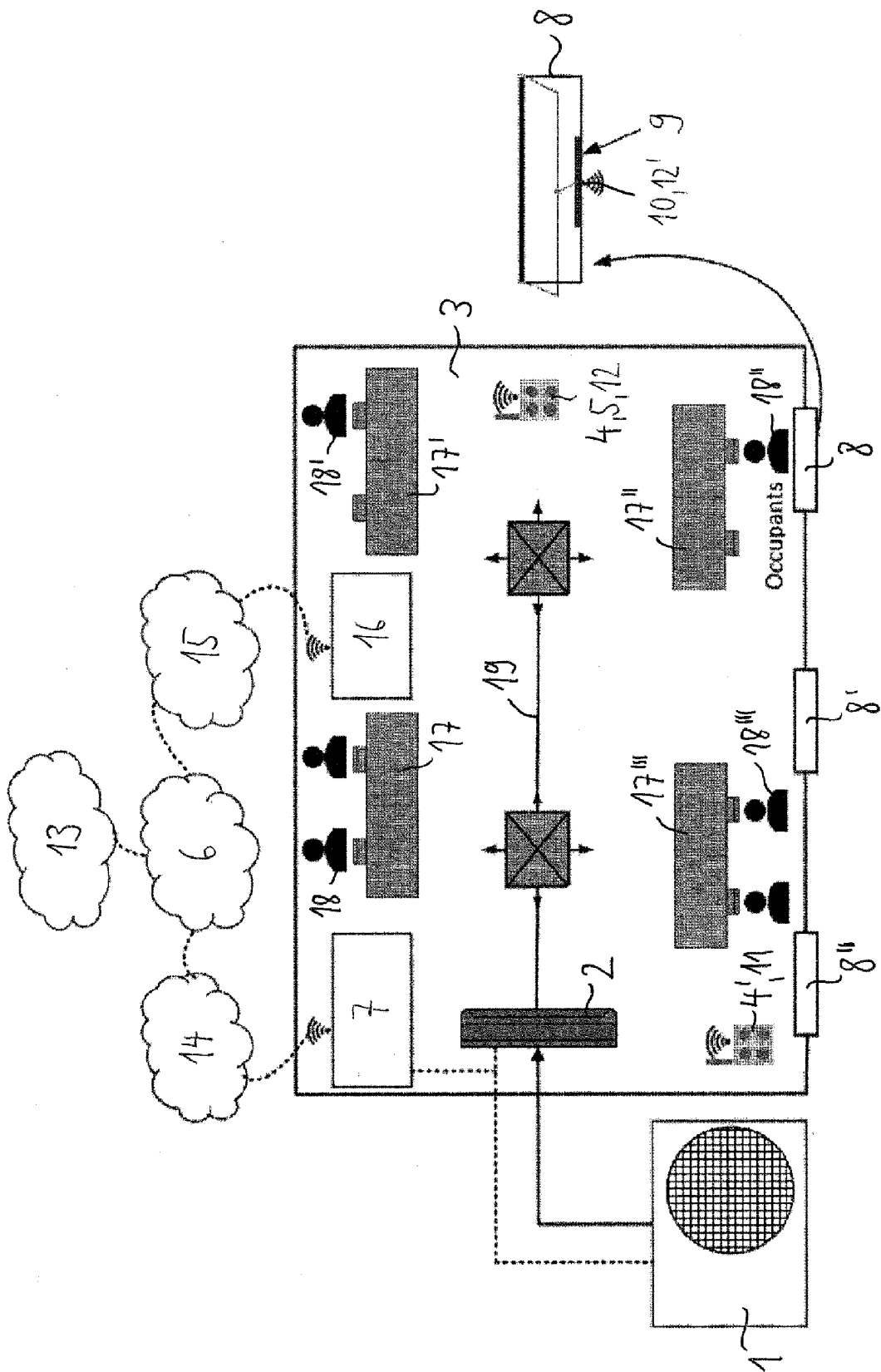
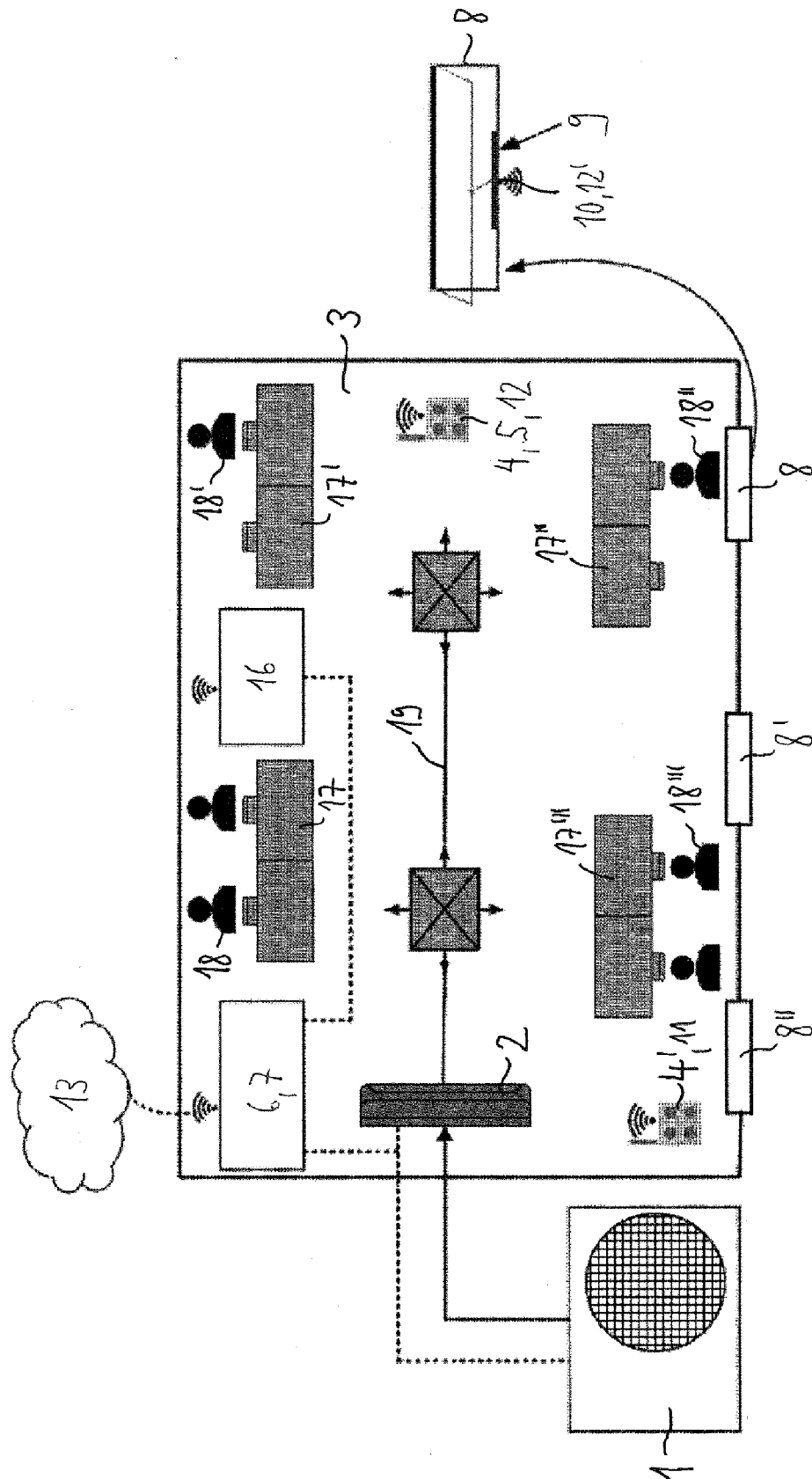


Figure 4





EUROPEAN SEARCH REPORT

Application Number

EP 23 21 0422

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