

DESCRIPTION

Title of Invention

AIR-CONDITIONING DEVICE, CONTROL DEVICE, AIR-CONDITIONING
METHOD, AND PROGRAM

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Technical Field

[0001] The present disclosure relates to an air-conditioning device, a control device, an air-conditioning method, and a program.

Background Art

- 10 [0002] Techniques are known for automatically switching the operation mode of an air conditioner. For example, Patent Literature 1 describes an air conditioner that changes the operation mode between heating, dehumidification, and cooling based on a difference between the set temperature and room temperature while correcting the set temperature in accordance with the calendar and the outside temperature. Patent
- 15 Literature 2 describes an air conditioner that switches between a first dehumidification operation and a second dehumidification operation in accordance with a difference between the humidity in a target space to be air-conditioned and the target humidity.

Citation List

Patent Literature

- 20 [0003] Patent Literature 1: Japanese Patent No. 5194696
- Patent Literature 2: Japanese Patent No. 5799932

Summary of Invention

Technical Problem

- [0004] In such air-conditioning including automatically switching the operation
- 25 mode, switching the operation mode based on either the temperature or the humidity alone may cause the other parameter to fail to achieve the target value although the temperature or the humidity alone reaches its target value to provide comfort, thus failing

to increase comfort in the target space.

[0005] One or more aspects of the present disclosure are directed to an air-conditioning device that increases comfort in a target space.

Solution to Problem

5 [0006] To achieve the above objective, an air-conditioning device according to an aspect of the present disclosure includes air-conditioning means for air-conditioning a target space including a compressor to compress a refrigerant and circulates the refrigerant through a refrigerant pipe, a heat exchanger to cause heat exchange between air in the target space and the refrigerant circulating through the refrigerant pipe, and a
10 blower to feed air in the target space to the heat exchanger, acquiring means for acquiring a temperature and a humidity in the target space, and air-conditioning control means for switching an operation mode, in accordance with the temperature and the humidity acquired by the acquiring means, between a cooling mode in which the air-conditioning means cools the target space, a dehumidification mode in which the air-conditioning
15 means dehumidifies the target space, and an air-blowing mode in which the compressor is stopped without the blower stopping air blowing.

Advantageous Effects of Invention

[0007] The air-conditioning device according to one or more aspects of the present disclosure acquires the temperature and the humidity in the target space, and switches the
20 operation mode based on the acquire temperature and humidity between the cooling mode for cooling the target space, the dehumidification mode for dehumidifying the target space, and the air-blowing mode for stopping the compressor without stopping air blowing of the blower. The air-conditioning device can increase comfort in the target space.

25 Brief Description of Drawings

[0008] FIG. 1 is a schematic diagram of an air-conditioning device according to Embodiment 1 of the present disclosure;

FIG. 2 is a block diagram of an outdoor-unit controller in Embodiment 1 showing the hardware configuration;

FIG. 3 is a diagram showing the relationship between an air-conditioning capacity and an operation mode executed by the air-conditioning device according to Embodiment 1;
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FIG. 4 is a flowchart of control processing in an air-blowing mode executed by the air-conditioning device according to Embodiment 1;

FIG. 5 is a functional block diagram of the outdoor-unit controller in Embodiment 1;

10 FIG. 6 is a diagram showing the relationship between heat load and the operation mode in Embodiment 1;

FIGS. 7(a), 7(b), 7(c), 7(d), 7(e), and 7(f) are graphs showing changes in parameters under high humidity in Embodiment 1: FIG. 7(a), insolation; FIG. 7(b), outside temperature T_o ; FIG. 7(c), outside-air humidity RH_o ; FIG. 7(d), steady sensible heat load Q_s ; FIG. 7(e), steady latent heat load Q_l ; and FIG. 7(f), operation mode;
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FIGS. 8(g), 8(h), 8(i), and 8(j) are graphs showing changes in parameters under high humidity in Embodiment 1: FIG. 8(g), sensible heat capacity; FIG. 8(h), latent heat capacity; FIG. 8(i), room temperature T_i ; and FIG. 8(j), indoor humidity RH_i ;

FIGS. 9(a), 9(b), 9(c), 9(d), 9(e), and 9(f) are graphs showing changes in parameters under low humidity in Embodiment 1: FIG. 9(a), insolation; FIG. 9(b), outside temperature T_o ; FIG. 9(c), outside-air humidity RH_o ; FIG. 9(d), steady sensible heat load Q_s ; FIG. 9(e), steady latent heat load Q_l ; and FIG. 9(f), operation mode;
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FIGS. 10(g), 10(h), 10(i), and 10(j) are graphs showing changes in parameters under low humidity in Embodiment 1: FIG. 10(g), sensible heat capacity; FIG. 10(h), latent heat capacity; FIG. 10(i), room temperature T_i ; and FIG. 10(j), indoor humidity RH_i ;
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FIG. 11 is a diagram illustrating a first example of an indication screen in an

operation mode in Embodiment 1;

FIG. 12 is a diagram illustrating a second example of an indication screen in an operation mode in Embodiment 1;

FIG. 13 is a diagram illustrating a third example of an indication screen in an
5 operation mode in Embodiment 1;

FIG. 14 is a flowchart of control processing in an automatic mode executed by the air-conditioning device according to Embodiment 1;

FIG. 15 is a diagram showing the relationship between temperature, humidity, and the operation mode in Embodiment 2 of the present disclosure;

10 FIG. 16 is a functional block diagram of an outdoor-unit controller in Embodiment 4 of the present disclosure;

FIG. 17 is a table showing example historical information in Embodiment 4;

FIG. 18 is a schematic diagram of heat transfer in an interior space in Embodiment 4;

15 FIGS. 19(a) to 19(c) are graphs each showing an approximate straight line (or lines) representing the relationship between the air-conditioning capacity and the temperature difference between room temperature and outside temperature in Embodiment 4, with FIG. 19(b) showing such lines for different heat insulation efficiencies and FIG. 19(c) showing such lines for different internal heat amounts;

20 FIG. 20 is a graph showing approximate straight lines acquired using typical data points in Embodiment 4;

FIG. 21 is a functional block diagram of an outdoor-unit controller in Embodiment 5 of the present disclosure;

FIG. 22 is a diagram showing the relationship between the first and second
25 sensible heat thresholds and the temperature difference between the room temperature and the outside temperature in Embodiment 5; and

FIG. 23 is a block diagram of an air-conditioning system according to a

modification of the present disclosure showing an overall structure.

Description of Embodiments

[0009] Embodiments of the present disclosure will now be described in detail with reference to the drawings. In the drawings provided below, the size relationship of individual components may differ from the actual size relationship. Throughout the drawings, the same or corresponding components are denoted by the same reference signs.

[0010] Components are described herein by way of example, and not limited to the illustrated examples. The present disclosure is not limited to the embodiments and the drawings. The embodiments and the drawings may naturally be changed within the scope not changing the gist of the present disclosure.

[0011] Steps describing a program for executing operations according to one or more embodiments of the present disclosure may be performed sequentially as specified, but may not be performed sequentially or may include processes that are performed in parallel or individually.

[0012] Embodiments of the present disclosure may be performed either alone or in combination. In either case, these embodiments have advantageous effects described below. The settings and flags described in the embodiments are mere examples, and the present disclosure is not particularly limited to these settings and flags.

[0013] In embodiments of the present disclosure, a system refers to a set of devices or a set of functions.

[0014] Embodiment 1

Structure of Air-Conditioning Device 1

FIG. 1 shows an air-conditioning device 1 according to Embodiment 1 of the present disclosure. The air-conditioning device 1 is equipment for air-conditioning an interior space 71 that is a target space to be air-conditioned. Air-conditioning includes adjusting temperature, humidity, cleanliness, and air currents in the target space, or more

specifically, heating, cooling, dehumidification, humidification, and cleaning of air.

[0015] As shown in FIG. 1, the air-conditioning device 1 is installed in a house 3.

The house 3 is, for example, a typical detached house structure. The air-conditioning device 1 is a heat-pump air conditioner using, for example, carbon dioxide (CO₂) or

5 hydrofluorocarbon (HFC) as a refrigerant. The air-conditioning device 1 includes a vapor-compression refrigeration cycle, and operates with power from, for example, mains electricity, a power generation system, or a power storage system (not shown).

[0016] As shown in FIG. 1, the air-conditioning device 1 includes an outdoor unit 11 installed outside the house 3, an indoor unit 13 installed inside the house 3, and a

10 remote controller 55 that is operated by a user. The outdoor unit 11 and the indoor unit 13 are connected together with a refrigerant pipe 61 through which the refrigerant flows, and a communication line 63 through which various signals are transmitted. The air-conditioning device 1 blows out, from the indoor unit 13, air-conditioned air, for example, cool air to cool the interior space 71, or warm air to heat the interior space 71.

15 [0017] The outdoor unit 11 includes a compressor 21, a four-way valve 22, an outdoor heat exchanger 23, an expansion valve 24, an outdoor fan 31, and an outdoor-unit controller 51. The indoor unit 13 includes an indoor heat exchanger 25, indoor fans 33a and 33b, and an indoor-unit controller 53. The refrigerant pipe 61 annularly connects the compressor 21, the four-way valve 22, the outdoor heat exchanger 23, the expansion valve 24, and the indoor heat exchanger 25 together, thus forming a refrigerating cycle.

[0018] The compressor 21 compresses the refrigerant to circulate the refrigerant through the refrigerant pipe 61. More specifically, the compressor 21 compresses a low-temperature low-pressure refrigerant, and ejects the high-pressure high-temperature
25 refrigerant to the four-way valve 22. The compressor 21 includes an inverter circuit that can change the operating capacity in accordance with the driving frequency. The operating capacity is the rate of the refrigerant fed by the compressor 21 per unit. The

compressor 21 changes the operating capacity in accordance with instructions from the outdoor-unit controller 51.

[0019] The four-way valve 22 is located on the ejection end of the compressor 21. The four-way valve 22 switches the direction in which the refrigerant flows through the refrigerant pipe 61 in accordance with the current operation of the air-conditioning device
5 1 selected from cooling, dehumidification, or heating.

[0020] The outdoor heat exchanger 23 causes the refrigerant flowing through the refrigerant pipe 61 and air in an exterior space 72 (external space) outside the target space to exchange heat with each other. The outdoor fan 31 is located adjacent to the outdoor
10 heat exchanger 23 to feed air in the exterior space 72 to the outdoor heat exchanger 23. The outdoor fan 31 sucks air in the exterior space 72. The sucked air is provided to the outdoor heat exchanger 23, exchanges low or high heat with the refrigerant flowing through the refrigerant pipe 61, and is then blown out to the exterior space 72.

[0021] The expansion valve 24 is located between the outdoor and indoor heat
15 exchangers 23 and 25 to decompress and expand the refrigerant flowing through the refrigerant pipe 61. The expansion valve 24 is an electronic expansion valve with the degree of opening variably controlled. The expansion valve 24 changes the degree of opening in accordance with instructions from the outdoor-unit controller 51 to adjust the pressure of the refrigerant.

[0022] The indoor heat exchanger 25 causes the refrigerant flowing through the refrigerant pipe 61 and air in the interior space 71 to exchange heat with each other. The indoor fans 33a and 33b are located adjacent to the indoor heat exchanger 25 to feed air in the interior space 71 to the indoor heat exchanger 25. The indoor fans 33a and 33b suck air in the interior space 71. The sucked air is provided to the indoor heat exchanger
20 25, exchanges low or high heat with the refrigerant flowing through the refrigerant pipe 61, and is then blown out to the interior space 71. Air undergoing heat exchange in the indoor heat exchanger 25 is provided to the interior space 71 as air-conditioned air.

Thus, the interior space 71 is air-conditioned.

[0023] The indoor heat exchanger 25 includes two heat exchangers 25a and 25b and an expansion valve 26. The first heat exchanger 25a is located upstream from the refrigerant in the cooling refrigerating cycle, and causes the refrigerant and air blown by the indoor fan 33a that is a first blower, to exchange heat with each other. The second heat exchanger 25b is located downstream from the refrigerant in the cooling refrigerating cycle, and causes the refrigerant and air blown by the indoor fan 33b that is a second blower, to exchange heat with each other. The expansion valve 26 is located between the two heat exchangers 25a and 25b to adjust the pressure of the refrigerant flowing between the two heat exchangers 25a and 25b.

[0024] The indoor unit 13 also includes a temperature sensor 41, a humidity sensor 42, and an infrared sensor 43. The temperature sensor 41 is, for example, a resistance thermometer, thermistor, or thermocouple, and detects a room temperature T_i that is the temperature of air in the interior space 71. The humidity sensor 42 is, for example, an electrical resistance or electrical capacitance sensor, and detects an indoor humidity RH_i that is the humidity of air in the interior space 71.

[0025] The temperature and humidity sensors 41 and 42 are located at a suction port of the second heat exchanger 25b of the indoor heat exchanger 25 to detect the temperature and the humidity of air to be sucked into the second heat exchanger 25b by the second indoor fan 33b. The temperature and humidity sensors 41 and 42 at the suction port at which the second indoor fan 33b sucks air can accurately detect the temperature and the humidity of air in the interior space 71.

[0026] The infrared sensor 43 is, for example, a pyroelectric or thermopile sensor, and detects infrared rays radiated from a target object. The infrared sensor 43 is located in the interior space 71 near a window 75 irradiated with sunlight, to detect infrared rays radiated through the window 75 and a window temperature T_w that is the surface temperature of the window 75. The window 75 is irradiated with sunlight during sunny

daytime. Thus, the surface temperature is usable as an index of insolation.

[0027] The infrared sensor 43 also serves as a human sensor. The infrared sensor 43 detects infrared rays radiated from a target, for example, a person or an object in the interior space 71 to specify the existence or position of the target.

5 [0028] Although not shown, the air-conditioning device 1 also includes an outside temperature sensor that detects an outside temperature, an outside-air humidity sensor that detects an outside-air humidity, and an evaporation temperature sensor that detects an evaporation temperature of the refrigerant flowing through the refrigerant pipe 61. The outside temperature sensor and the outside-air humidity sensor are installed in the exterior
10 space 72 to detect an outside temperature To that is the temperature of air in the exterior space 72, and an outside-air humidity RHo that is the humidity of air in the exterior space 72.

[0029] In the example described below, the humidity sensor 42 and the outside-air humidity sensor detect humidity in relative humidity, but may detect humidity in absolute
15 humidity. The relative humidity and the absolute humidity can be converted each other as appropriate using the air temperature at the detected time.

[0030] The evaporation temperature sensor is located at the refrigerant pipe 61 upstream from the indoor heat exchanger 25 during, for example, cooling and dehumidification to detect the temperature of the refrigerant pipe 61. Thus, the
20 evaporation temperature sensor detects an evaporation temperature of the refrigerant that flows into the indoor heat exchanger 25. The evaporation temperature sensor may be located, for example, between the first and second heat exchangers 25a and 25b to detect the refrigerant evaporation temperature in the indoor heat exchanger 25.

[0031] The detection results from each sensor are provided to the indoor-unit
25 controller 53. The indoor-unit controller 53 provides the fed detection results to the outdoor-unit controller 51 through the communication line 63.

[0032] The outdoor-unit controller 51 controls the operation of the outdoor unit 11.

As shown in FIG. 2, the outdoor-unit controller 51 includes a controller 101, a storage 102, a clock 103, and a communication unit 104. These components are connected with each other with a bus.

[0033] The controller 101 includes a central processing unit (CPU), a read-only memory (ROM), and a random-access memory (RAM). The CPU is also referred to as, for example, a processor, a microprocessor, a microcomputer, or a digital signal processor (DSP). The CPU in the controller 101 reads programs and data stored in the ROM and performs centralized control over the outdoor-unit controller 51 using the RAM as a work area.

10 [0034] The storage 102 is a nonvolatile semiconductor memory, such as a flash memory, an erasable programmable ROM (EPROM), or an electrically erasable programmable ROM (EEPROM), and serves as a secondary or auxiliary storage. The storage 102 stores programs and data used by the controller 101 to execute various processes, and data generated and acquired by the controller 101 executing various processes.

[0035] The clock 103 includes a real time clock (RTC) that continues clocking while the air-conditioning device 1 is turned off.

[0036] The communication unit 104 is an interface that allows communication with the indoor-unit controller 53 and the remote controller 55 through the communication line 63. The communication unit 104 receives operation information from a user through the remote controller 55, and transmits indication information for the user to the remote controller 55. The communication unit 104 transmits a command of operating the indoor unit 13 to the indoor-unit controller 53, and receives state information indicating the state of the indoor unit 13 from the indoor-unit controller 53.

25 [0037] Although not shown, the indoor-unit controller 53 includes a CPU, a ROM, a RAM, a communication interface, and a semiconductor nonvolatile memory that is readable and writable. In the indoor-unit controller 53, the CPU executes a control

program stored in the ROM while using the RAM as a work memory to control the operation of the indoor unit 13.

[0038] The outdoor-unit controller 51 is connected to the indoor-unit controller 53 through the communication line 63 that is a wired or wireless medium, or another
 5 communication medium. The outdoor-unit controller 51 transmits or receives various signals to or from the indoor-unit controller 53 through the communication line 63 to operate in cooperation to control the entire air-conditioning device 1. The outdoor-unit controller 51 thus functions as a control device that controls the air-conditioning device 1.

[0039] The outdoor-unit and indoor-unit controllers 51 and 53 control the operation
 10 of the air-conditioning device 1 based on the detection results from each sensor and setting information about the air-conditioning device 1 set by a user. More specifically, the outdoor-unit controller 51 controls the driving frequency of the compressor 21, switching of the four-way valve 22, the rotation rate of the outdoor fan 31, and the degree of opening of the expansion valve 24. The indoor-unit controller 53 controls the
 15 rotation rates of the indoor fans 33a and 33b. In some embodiments, the outdoor-unit controller 51 may control the rotation rates of the indoor fans 33a and 33b, or the indoor-unit controller 53 may control the driving frequency of the compressor 21, switching of the four-way valve 22, the rotation rate of the outdoor fan 31, and the degree of opening of the expansion valve 24. The outdoor-unit and indoor-unit controllers 51
 20 and 53 thus output various operation commands to the individual devices in accordance with the operation commands provided to the air-conditioning device 1.

[0040] The remote controller 55 is located in the interior space 71. The remote controller 55 transmits or receives various signals to or from the indoor-unit controller 53 of the indoor unit 13. The remote controller 55 includes, for example, push buttons, a
 25 touch screen, a liquid crystal display, and a light-emitting diode (LED), and functions as a command receiver that receives various commands from a user and a display that displays various pieces of information to the user. The user operates the remote

controller 55 to input commands to the air-conditioning device 1. Examples of commands include a switching command between operation and stop, and switching commands for, for example, the operation mode, the set temperature, the set humidity, the airflow rate, the airflow direction, and a timer. The air-conditioning device 1
 5 operates in accordance with the input commands. As an example of such a user interface, an information terminal such as a smartphone or a tablet may be included instead of the remote controller 55.

[0041] Operation Modes

The air-conditioning device 1 can operate in any operation mode selected from (A)
 10 cooling, (B) heating, (C) dehumidification, (D) air blowing, and (E) automatic. The air-conditioning device 1 air-conditions the interior space 71 in any of these operation modes.

[0042] (A) Cooling Mode

A cooling operation mode is for cooling air in the interior space 71 to lower the air
 15 temperature. Upon receiving a cooling operation command, the controller 101 switches the channel of the four-way valve 22 to flow the refrigerant ejected from the compressor 21 into the outdoor heat exchanger 23, and opens the expansion valves 24 and 26 as appropriate. The controller 101 then drives the compressor 21, the outdoor fan 31, and the indoor fans 33a and 33b.

20 [0043] When the compressor 21 is driven, the refrigerant ejected from the compressor 21 passes through the four-way valve 22, and flows into the outdoor heat exchanger 23. The refrigerant flowing into the outdoor heat exchanger 23 condenses and liquefies through heat exchange with outdoor air sucked in from the exterior space 72, and flows into the expansion valve 24. The refrigerant flowing into the expansion valve
 25 24 is decompressed by the expansion valve 24, and then flows into the indoor heat exchanger 25. The refrigerant flowing into the indoor heat exchanger 25 evaporates after heat exchange with indoor air sucked from the interior space 71, then passes through

the four-way valve 22, and is sucked again by the compressor 21. As the refrigerant flows in this manner, indoor air sucked from the interior space 71 is cooled by the indoor heat exchanger 25.

[0044] (B) Heating Mode

5 A heating operation mode is for heating air in the interior space 71 to increase the air temperature. Upon receiving a heating operation command, the controller 101 switches the channel of the four-way valve 22 to flow the refrigerant ejected from the compressor 21 into the indoor heat exchanger 25, and opens the expansion valves 24 and 26 as appropriate. The controller 101 drives the compressor 21, the outdoor fan 31, and
10 the indoor fans 33a and 33b.

[0045] When the compressor 21 is driven, the refrigerant ejected from the compressor 21 passes the four-way valve 22, and flows into the indoor heat exchanger 25. The refrigerant flowing into the indoor heat exchanger 25 condenses and liquefies through heat exchange with indoor air sucked from the interior space 71, and flows into
15 the expansion valve 24. The refrigerant flowing into the expansion valve 24 is decompressed by the expansion valve 24, and then flows into the outdoor heat exchanger 23. The refrigerant flowing into the outdoor heat exchanger 23 evaporates after heat exchange with outdoor air sucked in from the exterior space 72, then passes through the four-way valve 22, and is sucked again by the compressor 21. In this manner, the
20 refrigerant flows in the direction opposite to the direction during cooling and dehumidification, and indoor air sucked from the interior space 71 is heated by the indoor heat exchanger 25.

[0046] Operation and Stop of Compressor

In the cooling mode, when the room temperature T_i decreases to a temperature at
25 which the thermostat is to be off (thermostat turning-off temperature) during the operation of the compressor 21, the controller 101 stops operating the compressor 21 to avoid excessive cooling. When the room temperature T_i increases to a temperature at

which the thermostat is to be on (thermostat turning-on temperature) while the compressor 21 is stopped, the controller 101 restarts operating the compressor 21 to avoid excessive heating. Similarly, when the room temperature T_i increases to the thermostat turning-off temperature during the operation of the compressor 21 in the heating mode, the controller 101 stops operating the compressor 21 to avoid excessive heating. When the room temperature T_i decreases to the thermostat turning-on temperature while the compressor 21 is stopped, the controller 101 restarts operating the compressor 21 to avoid excessive cooling. The thermostat turning-off and thermostat turning-on temperatures are each set in advance within a predetermined range from a set temperature T_m that is a target temperature. Through repeated operating and stopping of the compressor 21, the controller 101 maintains the room temperature T_i at the set temperature T_m .

[0047] (C) Dehumidification Mode

A dehumidification operation mode is for decreasing the humidity in the interior space 71. Upon receiving a dehumidification operation command, the controller 101 switches the channel of the four-way valve 22 to flow the refrigerant ejected from the compressor 21 into the outdoor heat exchanger 23, and opens the expansion valves 24 and 26 as appropriate, as in cooling. The controller 101 then drives the compressor 21, the outdoor fan 31, and the indoor fans 33a and 33b. Thus, the refrigerant circulates through the refrigerant pipe 61 in the same direction as in cooling.

[0048] More specifically, the dehumidification operation mode includes six operation modes: (C1) low-cooling dehumidification, (C2) double-fan dehumidification, (C3) dewpoint-temperature dehumidification, (C4) partial-cooling dehumidification, (C5) extensive dehumidification, and (C6) reheating dehumidification. These modes are collectively referred to as the dehumidification mode. In an actual product, the dehumidification mode may be described as part of the cooling mode. Any operation mode in which a sensible heat factor SHF is lower than in cooling is included in the dehumidification mode as described below.

[0049] FIG. 3 shows the relationship between each operation mode and the air-conditioning capacity. The air-conditioning capacity is an index indicating the air-conditioning efficiency of the air-conditioning device 1, and corresponds to the heat exchange effectiveness of the indoor heat exchanger 25 between the refrigerant and the indoor air. As the indoor heat exchanger 25 has higher heat exchange effectiveness between the refrigerant and the air, the air-conditioning capacity of the air-conditioning device 1 increases. The air-conditioning capacity for cooling is referred to as cooling efficiency, and the air-conditioning capacity for heating is referred to as heating efficiency.

10 [0050] In FIG. 3, the horizontal axis represents sensible heat capacity, and the vertical axis represents latent heat capacity. The sensible heat capacity corresponds to the capacity in the air-conditioning capacity associated with the change of air temperature. The latent heat capacity corresponds to the capacity associated with the change of state of moisture in air, or more specifically, the capacity associated with dehumidification and humidification. The sum of the sensible and latent heat capacities is referred to as the total heat capacity. The ratio of the sensible heat capacity to the total heat capacity is referred to as a sensible heat factor (SHF). The sensible heat factor is expressed in the formula (1):

$$\text{sensible heat factor (SHF)} = \text{sensible heat capacity} / \text{total heat capacity} \quad (1).$$

20 [0051] Hereafter, the sensible heat capacity for cooling air is assumed to be positive, and the latent heat capacity for dehumidifying air is assumed to be positive. More specifically, each dehumidification operation mode has higher dehumidification efficiency and higher latent heat capacity, but has lower cooling efficiency and lower sensible heat capacity than in cooling. Each dehumidification operation mode will now be described in detail.

[0052] (C1) Low-Cooling Dehumidification Mode

The low-cooling dehumidification operation mode has lower cooling efficiency

and higher dehumidification efficiency than in cooling. Upon receiving a low-cooling dehumidification operation command, the controller 101 circulates the refrigerant in the same direction as in cooling. The controller 101 then decreases the rotation rates of the indoor fans 33a and 33b further than in cooling. In other words, in low-cooling
 5 dehumidification, the controller 101 lowers the rate of airflow fed to the indoor heat exchanger 25 by the indoor fans 33a and 33b further than in cooling.

[0053] Typically, as the rate of airflow fed by the indoor fans 33a and 33b increases, the refrigerant at the indoor heat exchanger 25 has a higher evaporation temperature, and the refrigerating cycle is performed more highly efficiently. The air-conditioning device
 10 1 operating in cooling at a high airflow rate without causing noise saves energy. In low-cooling dehumidification, the controller 101 lowers the rate of airflow fed by the indoor fans 33a and 33b further than in cooling, and lowers the refrigerant evaporation temperature. The sensible heat capacity of the indoor heat exchanger 25 decreases, and the latent heat capacity increases. The sensible heat factor thus decreases. The room
 15 temperature T_i is less likely to decrease and the indoor humidity RH_i is more likely to decrease in low-cooling dehumidification than in cooling.

[0054] (C2) Double-Fan Dehumidification Mode

In the double-fan dehumidification operation mode, the two indoor fans 33a and 33b are driven at different rotation rates to dehumidify the interior space 71. Upon
 20 receiving a double-fan dehumidification operation command, the controller 101 circulates the refrigerant in the same direction as in cooling. The controller 101 then decreases the rotation rate of the first indoor fan 33a further than the rotation rate of the second indoor fan 33b.

[0055] More specifically, in low-cooling dehumidification, the controller 101 drives
 25 the two indoor fans 33a and 33b at a predetermined rotation rate W_0 , whereas in double-fan dehumidification, the controller 101 drives the first indoor fan 33a, farther from the temperature and humidity sensors 41 and 42, at a first rotation rate W_1 lower

than the predetermined rotation rate W_0 . In double-fan dehumidification, the controller 101 drives the second indoor fan 33b, closer to the temperature and humidity sensors 41 and 42, at a second rotation rate W_2 higher than the first rotation rate W_1 . The second rotation rate W_2 is set to the rotation rate equivalent to the predetermined rotation rate W_0 . Thus, in double-fan dehumidification, the controller 101 lowers the total rate of airflow fed from the first and second indoor fans 33a and 33b further than the total rate of airflow fed from the first and second indoor fans 33a and 33b in low-cooling dehumidification.

[0056] When the rotation rate of the second indoor fan 33b closer to the temperature and humidity sensors 41 and 42 decreases, the amount of sucked air decreases. This lowers the likelihood of acquiring of an accurate temperature of the sucked air, and lowers the likelihood of appropriate air-conditioning control over the target space. However, in double-fan dehumidification, the temperature and the humidity of air fed to the indoor heat exchanger 25 by the second indoor fan 33b can be accurately detected by retaining the rotation rate of the second indoor fan 33b around the same rate as in low-cooling dehumidification.

[0057] When the rotation rate of the first indoor fan 33a farther from the temperature and humidity sensors 41 and 42 decreases further than in low-cooling dehumidification, the total rate of airflow fed by the indoor fans 33a and 33b decreases further than in low-cooling dehumidification. Thus, the refrigerant evaporation temperature at the indoor heat exchanger 25 decreases, and the latent heat capacity increases. The sensible heat capacity decreases, and the sensible heat factor decreases. The room temperature T_i is less likely to decrease, and the indoor humidity R_{Hi} is more likely to decrease in double-fan dehumidification than in low-cooling dehumidification.

[0058] In double-fan dehumidification, the two indoor fans 33a and 33b operate at different rotation rates, and the rate of airflow fed to the indoor heat exchanger 25 can be lowered while the temperature and the humidity in the interior space 71 are accurately

detected. Thus, the interior space 71 can be dehumidified at higher dehumidification efficiency than in low-cooling dehumidification.

[0059] (C3) Dewpoint-Temperature Dehumidification Mode

In the dewpoint-temperature dehumidification operation mode, the refrigerant
 5 evaporation temperature decreases below the air dewpoint temperature to increase dehumidification efficiency. Upon receiving a dewpoint-temperature dehumidification operation command, the controller 101 circulates the refrigerant in the same direction as in cooling. The controller 101 then controls the rotation rate of the compressor 21 to lower the refrigerant evaporation temperature detected by the evaporation temperature
 10 sensor further than the air dewpoint temperature.

[0060] In cooling, low-cooling dehumidification, and double-fan dehumidification, the controller 101 controls the rotation rate of the compressor 21 in accordance with the temperature difference ΔT between the room and set temperatures T_i and T_m , thus the rotation rate of the compressor 21 decreases as the room temperature T_i decreases.
 15 When the rotation rate of the compressor 21 decreases, the refrigerant evaporation temperature at the indoor heat exchanger 25 increases accordingly, and the sensible and latent heat capacities decrease. Thus, the room temperature T_i is stabilized at the set temperature T_m , whereas the indoor humidity RH_i may not decrease and may lower the comfort.

20 [0061] In dewpoint-temperature dehumidification, the controller 101 controls the rotation rate of the compressor 21 to lower the refrigerant evaporation temperature at the indoor heat exchanger 25 below the dewpoint temperature of air sucked into the indoor heat exchanger 25 in accordance with the difference between the evaporation and dewpoint temperatures. Thus, the latent heat capacity can be retained without being
 25 lowered. The indoor humidity RH_i is more likely to decrease in dewpoint-temperature dehumidification than in low-cooling dehumidification.

[0062] (C4) Partial-Cooling Dehumidification Mode

In the partial-cooling dehumidification operation mode, the refrigerant evaporation temperature at the entrance of the indoor heat exchanger 25 decreases below the air dewpoint temperature, and the degree of superheat of the refrigerant at the exit of the indoor heat exchanger 25 increases. Upon receiving a partial-cooling dehumidification operation command, the controller 101 circulates the refrigerant in the same direction as in cooling. The controller 101 then controls the degree of opening of the expansion valve 24 to lower the refrigerant evaporation temperature at the inlet port of the indoor heat exchanger 25 through which the refrigerant flows in below the air dewpoint temperature.

[0063] In cooling, low-cooling dehumidification, and double-fan dehumidification, the controller 101 controls the degree of opening of the expansion valve 24 to form the refrigerant at the refrigerant exit of the indoor heat exchanger 25 into saturated gas, or more specifically, to change the degree of superheat at the refrigerant exit of the indoor heat exchanger 25 to nearly zero. Thus, the total heat capacity of the air-conditioning device 1 is output efficiently. In partial-cooling dehumidification, the controller 101 controls the degree of opening of the expansion valve 24 to lower the refrigerant evaporation temperature around the refrigerant entrance of the indoor heat exchanger 25 below the dewpoint temperature of air sucked into the indoor heat exchanger 25.

[0064] More specifically, in partial-cooling dehumidification, the controller 101 narrows down the degree of opening of the expansion valve 24 further than in cooling and low-cooling dehumidification. Thus, the refrigerant evaporation temperature around the entrance of the indoor heat exchanger 25 decreases, and most of the refrigerant evaporates around the entrance of the indoor heat exchanger 25, thus increasing the degree of superheat around the exit of the indoor heat exchanger 25. Air can thus be dehumidified at a low temperature near the entrance of the indoor heat exchanger 25, and can avoid excessive cooling near the exit of the indoor heat exchanger 25. Thus, the room temperature T_i is less likely to decrease, and the indoor humidity

RHi is more likely to decrease in partial-cooling dehumidification than in low-cooling dehumidification and dewpoint-temperature dehumidification.

[0065] (C5) Extensive Dehumidification Mode

The extensive dehumidification operation mode combines two or three of (C2) double-fan dehumidification, (C3) dewpoint-temperature dehumidification, and (C4) partial-cooling dehumidification. Combining two or three of these three operation modes can continuously and widely adjust the sensible and latent heat capacities. This structure can thus provide comfortable air-conditioning with small changes in room temperature and humidity under various weather conditions, building conditions, and living conditions. The extensive dehumidification increases energy saving further than reheating dehumidification described below.

[0066] (C6) Reheating Dehumidification Mode

In the reheating dehumidification operation mode, the humidity in the interior space 71 decreases while the temperature in the interior space 71 is retained. Upon receiving a reheating dehumidification operation command, the controller 101 circulates the refrigerant in the same direction as in cooling. The controller 101 then closes the expansion valve 26 as appropriate between the two heat exchangers 25a and 25b of the indoor heat exchanger 25.

[0067] By narrowing down the degree of opening of the expansion valve 26, the first heat exchanger 25a located upstream from the expansion valve 26 functions as a condenser that condenses the refrigerant to heat air fed by the second indoor fan 33b. The second heat exchanger 25b located downstream from the expansion valve 26 functions as an evaporator that evaporates the refrigerant to lower the humidity of air fed by the second indoor fan 33b. The humidity decreases while air is heated. Thus, the room temperature T_i is less likely to decrease, and the indoor humidity RHi is more likely to decrease in reheating dehumidification than in other dehumidification modes.

[0068] (D) Air-Blowing Mode

The air-blowing mode in the operation mode will be described. The air-blowing mode is for air-conditioning with air blowing from the indoor fans 33a and 33b while the compressor 21 is stopped. In a cooling period, the operation mode is switched to the air-blowing mode without cooling while the outside temperature T_o is lower than the room temperature T_i . The interior space 71 can thus undergo agitation without large power consumption, providing a cool feeling with wind, without the compressor 21 operating. The air-blowing mode described below includes any mode in which the compressor 21 is stopped without the indoor fans 33a and 33b stopping air blowing, and thus may be such a mode in which the thermostat is off and the compressor 21 is stopped to avoid excessive cooling. A hybrid mode that is a combination of cooling and air blowing, will be described below as an example of the air-blowing mode.

[0069] More specifically, with reference to FIG. 4, the processing in the air-blowing mode will be described. First, when the compressor 21 is in operation, the controller 101 determines whether the room temperature T_i decreases to or below the thermostat turning-off temperature (step S11). When the room temperature T_i is higher than the thermostat turning-on temperature (NO in step S11), the controller 101 maintains the compressor 21 to be on. When the room temperature T_i decreases to or below the thermostat turning-off temperature (YES in step S11), the controller 101 stops operating the compressor 21 (step S12). When stopping operating the compressor 21, the controller 101 increases the rotation rates of the indoor fans 33a and 33b further than the rotation rates immediately before stopping the operation of the compressor 21 (step S13).

[0070] More specifically, in any operation mode other than air blowing, to stop the operation of the compressor 21, the controller 101 decreases the rotation rates of the indoor fans 33a and 33b or stops driving of the indoor fans 33a and 33b without increasing the rotation rates of the indoor fans 33a and 33b. In the air-blowing mode, to stop the operation of the compressor 21, the controller 101 increases the rotation rates of the indoor fans 33a and 33b. This allows a person to have an appropriate cool feeling in

the interior space 71, without suddenly feeling hot.

[0071] After stopping the operation of the compressor 21, the controller 101 further adjusts the rotation rates of the indoor fans 33a and 33b in accordance with changes in the room temperature T_i (step S14). When, for example, the room temperature T_i increases while the compressor 21 is stopped, the controller 101 gradually increases the rotation rates of the indoor fans 33a and 33b. Thus, the sensible temperature in the interior space 71 decreases.

[0072] While the compressor 21 is stopped, the controller 101 adjusts the direction of airflow blown by the indoor fans 33a and 33b (step S15). More specifically, although not shown, the indoor unit 13 includes a lateral air vent deflector that can laterally change the direction of airflow blown out from the indoor unit 13, and a vertical air vent deflector that can vertically change the direction of airflow blown out from the indoor unit 13.

While the compressor 21 is stopped, the controller 101 swings at least one of the lateral and vertical air vent deflectors to swing air blown by the indoor fans 33a and 33b. Thus, the entire interior space 71 is air-conditioned uniformly.

[0073] In step S15, when the infrared sensor 43 detects a target such as a person or an object in the interior space 71, the controller 101 controls the lateral and vertical air vent deflectors to rotate and direct air blown by the indoor fans 33a and 33b at the detected target position. This increases the cool feeling, thus increasing the comfort.

[0074] Secondly, while the compressor 21 is not operating, the controller 101 determines whether the room temperature T_i increases to or above the thermostat turning-on temperature (step S16). When the room temperature T_i is lower than the thermostat turning-on temperature (NO in step S16), the controller 101 maintains the compressor 21 to be off. When the room temperature T_i increases to or above the thermostat turning-on temperature (YES in step S16), the controller 101 determines that the comfort cannot be retained without the cooling mode, and starts operating the compressor 21 (step S17). When starting to operate the compressor 21, the controller

101 decreases the rotation rates of the indoor fans 33a and 33b to below the rotation rates immediately before starting to operate the compressor 21 (step S18). The thermostat turning-on temperature is set to, for example, the set temperature T_m or a temperature acquired by adding the decrease in the sensible temperature decreased by air blown by
 5 the indoor fans 33a and 33b to the set temperature T_m .

[0075] More specifically, in any operation mode other than air blowing, to start the operation of the compressor 21, the controller 101 increases the rotation rates of the indoor fans 33a and 33b without decreasing the rotation rates of the indoor fans 33a and 33b. In the air-blowing mode, to start the operation of the compressor 21, the controller
 10 101 increases the rotation rates of the indoor fans 33a and 33b. This allows a person to have an appropriate cool feeling in the interior space 71, without suddenly feeling cold.

[0076] After starting the operation of the compressor 21, the controller 101 adjusts the rotation rates of the indoor fans 33a and 33b in accordance with changes in the room temperature T_i (step S19). When, for example, the room temperature T_i decreases
 15 during the operation of the compressor 21, the controller 101 gradually decreases the rotation rates of the indoor fans 33a and 33b. Thus, the sensible temperature in the interior space 71 increases.

[0077] Thereafter, the controller 101 returns the processing to step 11, and repeats the processing from steps S11 to S19. When increasing or decreasing the rotation rates
 20 of the indoor fans 33a and 33b, the controller 101 may gradually change the rotation rates of the indoor fans 33a and 33b to target rotation rates, instead of changing the rates suddenly.

[0078] In the air-blowing operation mode, the controller 101 increases or decreases the rotation rates of the indoor fans 33a and 33b when switching on or off the compressor
 25 21. When the rates of airflow fed by the indoor fans 33a and 33b increase while the compressor 21 is stopped, the sensible temperature of a user is decreased by the airflow. The comfort is thus provided while the compressor 21 is stopped. This structure can

lower the likelihood that a user lowers the set temperature and increase power consumption while the compressor 21 is stopped. Thus, the operation time of the compressor 21 can be reduced to achieve both comfort and energy saving. In particular, the air-blowing operation mode is suitable for air-conditioning with either cooling or
 5 using a fan when the exterior space 72 has a medium temperature and a medium humidity, such as in early or late summer. This structure eliminate a separate fan, and thus improves the design of the interior space 71.

[0079] (E) Automatic Mode

In the automatic operation mode, the operation mode is automatically switched
 10 between (A) cooling, (C1) low-cooling dehumidification, (C2) double-fan dehumidification, (C3) dewpoint-temperature dehumidification, (C4) partial-cooling dehumidification, (C5) extensive dehumidification, (C6) reheating dehumidification, and (D) air blowing. The user can change the operation mode to (E) automatic mode by pressing a single button on the user interface. The indication for (E) automatic mode on
 15 the user interface may have a comprehensive name such as automatic or A.I. In the example described below, the air-conditioning device 1 air-conditions the interior space 71 in (E) automatic operation mode.

[0080] Functions of Air-Conditioning Device 1

The functional components of the air-conditioning device 1 will now be described
 20 with reference to FIG. 5. As shown in FIG. 5, the air-conditioning device 1 includes, as functional units, an acquirer 510, an estimator 520, a determiner 530, an air-conditioning controller 540, and an indicator 550. These functions are implemented by software, firmware, or a combination of software and firmware. Software and firmware are provided as programs, and stored in the ROM or the storage 102. The CPU in the
 25 controller 101 executes the programs stored in the ROM or the storage 102 to implement the functions shown in FIG. 5.

[0081] The acquirer 510 acquires load information on the heat load of the interior

space 71. The heat load refers to the heat quantity used by the air-conditioning device 1 to change the environments of the interior space 71 including the temperature and the humidity to target environments and to retain the environments. The acquirer 510 acquires information such as the temperature and the humidity detected by the sensors including the temperature sensor 41, the humidity sensor 42, and the infrared sensor 43 as the load information.

[0082] More specifically, the acquirer 510 acquires the room temperature T_i detected by the temperature sensor 41 from the temperature sensor 41, the indoor humidity RH_i detected by the humidity sensor 42 from the humidity sensor 42, and the window temperature T_w detected by the infrared sensor 43 and positional information about a target in the interior space 71 from the infrared sensor 43. The acquirer 510 also acquires the outside temperature T_o detected by the outside temperature sensor, the outside-air humidity RH_o detected by the outside-air humidity sensor, and the refrigerant evaporation temperature detected by the evaporation temperature sensor from these sensors.

[0083] Each sensor periodically transmits detected information to the outdoor-unit controller 51 in predetermined cycles. In some embodiments, the acquirer 510 may transmit a request to each sensor as appropriate, and the sensor may transmit detected information in response to this request. The acquirer 510 thus acquires information such as the temperature or humidity detected by each sensor through the indoor-unit controller 53 and the communication line 63. The acquirer 510 is implemented by the controller 101 in cooperation with the communication unit 104. The acquirer 510 functions as acquiring means.

[0084] The estimator 520 estimates the heat load of the interior space 71 based on information such as the temperature or humidity acquired by the acquirer 510. The heat load herein includes sensible heat load caused by sensible heat, and latent heat load caused by latent heat.

[0085] Relationship and Definition of Heat Load and Air-Conditioning Capacity

The sensible heat load is classified into an unsteady sensible heat load P_s expressed in formula (2) below, and a steady sensible heat load Q_s expressed in formula (3) below.

As expressed in formula (4) below, the sum of the unsteady and steady sensible heat

5 loads P_s and Q_s corresponds to sensible heat capacity used by the air-conditioning device 1 to change the room temperature T_i to the set temperature T_m and retain the changed temperature:

unsteady sensible heat load $P_s = \text{sensible heat capacity/unit time} \times (\text{room temperature } T_i - \text{set temperature } T_m)$ (2);

10 steady sensible heat load $Q_s = \alpha(\text{outside temperature } T_o - \text{room temperature } T_i) + \beta(\text{window temperature } T_w - \text{room temperature } T_i) + \text{internal heat amount } Q_n$ (3); and

sensible heat capacity = unsteady sensible heat load P_s + steady sensible heat load Q_s (4).

[0086] In formula (2) above, the sensible heat capacity indicates heat capacity

15 associated with sensible heat of, for example, walls, floor, and furniture of the interior space 71. In formula (3) above, α is a coefficient indicating the heat insulation

efficiency of the interior space 71, β is a coefficient of easiness of sunlight entry, and the internal heat amount Q_n indicates the heat quantity generated by, for example, lighting, home appliances, and people in the interior space 71. These parameters are set in

20 advance to appropriate values and stored in the storage 102.

[0087] As shown in formula (2) above, the unsteady sensible heat load P_s is defined by the temperature difference ΔT between the room and set temperatures T_i and T_m .

The unsteady sensible heat load P_s corresponds to the heat quantity used to change the room temperature T_i to the set temperature T_m , and is a first sensible heat load dominant

25 when the room temperature T_i is apart from the set temperature T_m .

[0088] As shown in formula (3) above, the steady sensible heat load Q_s is defined by the difference between the outside and room temperatures T_o and T_i , the difference

between the window temperature T_w that is a parameter dependent on insolation of the exterior space 72, and the room temperature T_i , and the internal heat amount Q_n . The steady sensible heat load Q_s is mainly caused by the difference between the environments of the interior and exterior spaces 71 and 72. The steady sensible heat load Q_s

5 corresponds to the heat quantity steadily used to maintain the room temperature T_i at the set temperature T_m when the room temperature T_i is equal to the set temperature T_m .

The steady sensible heat load Q_s is a second sensible heat load dominant when the room temperature T_i approximates the set temperature T_m .

[0089] The latent heat load is classified into an unsteady latent heat load Pl

10 expressed in formula (5) below, and a steady latent heat load Ql expressed in formula (6) below. As expressed in formula (7) below, the sum of the unsteady latent heat load Pl and the steady latent heat load Ql corresponds to the latent heat capacity used by the air-conditioning device 1 to change the humidity RHi in the interior space 71 to the set humidity RHm and retain the changed humidity:

15 unsteady latent heat load $Pl = \text{latent heat capacity/unit time} \times (\text{inside absolute humidity} - \text{target absolute humidity})$ (5);

steady latent heat load $Ql = \alpha'(\text{outside absolute humidity} - \text{inside absolute humidity}) + \text{amount of internal evaporation}$ (6); and

latent heat capacity = unsteady latent heat load $Pl + \text{steady latent heat load } Ql$

20 (7).

[0090] In formula (5) above, the latent heat capacity indicates heat capacity associated with the latent heat of, for example, walls, floor, and furniture of the interior space 71. In formula (6) above, α' is a coefficient indicating the likelihood of moisture flowing from the exterior space 72 into the interior space 71. More specifically, the first

25 term in formula (6) above indicates the amount of moisture that enters the interior space 71 from the exterior space 72 through ventilation. The amount of internal evaporation is the amount of moisture evaporated in the interior space 71 from, for example, human

bodies or through activities such as cooking. These parameters are set in advance and stored in the storage 102.

[0091] As shown in formula (5) above, the unsteady latent heat load Pl is defined by the difference between the inside absolute humidity and the target absolute humidity.

- 5 The target absolute humidity is the absolute humidity when the room temperature T_i is equal to the set temperature T_m and the indoor humidity RHi that is the relative humidity in the interior space 71, is equal to the set humidity RHm that is the target humidity. In other words, the unsteady latent heat load Pl corresponds to the heat quantity used to change the indoor humidity RHi to the set humidity RHm when the room temperature T_i is equal to the set temperature T_m . The unsteady latent heat load Pl is a first latent heat load dominant when the inside absolute humidity is apart from the target absolute humidity.

- [0092] As shown in formula (6) above, the steady latent heat load Ql is defined by the difference between the outside and inside absolute humidities and the amount of internal evaporation. The steady latent heat load Ql is mainly caused by the difference between the environments of the interior and exterior spaces 71 and 72, and corresponds to the heat quantity used to maintain the indoor humidity RHi at the set humidity RHm when the inside absolute humidity is equal to the target absolute humidity. The steady latent heat load Ql is a second latent heat load dominant when the inside absolute humidity approximates the target absolute humidity.

- [0093] In accordance with formulas (2) to (7) above, the estimator 520 calculates the unsteady sensible heat load Ps , the steady sensible heat load Qs , the sensible heat capacity, the unsteady latent heat load Pl , the steady latent heat load Ql , and the latent heat capacity from, for example, the temperature and the humidity acquired by the acquirer 510. Thus, the estimator 520 estimates the heat load of the interior space 71. The estimator 520 is implemented by the controller 101 in cooperation with the storage 102. The estimator 520 functions as estimation means.

- [0094] The determiner 530 determines the air-conditioning operation mode based on the heat load estimated by the estimator 520. FIG. 6 shows the relationship between the heat load and the operation mode. As shown in FIG. 6, when the air-conditioning device 1 air-conditions the interior space 71 in (E) automatic operation mode, the operation mode to be executed by the air-conditioning device 1 is determined based on the steady sensible and latent heat loads Q_s and Q_l . Based on the steady sensible and latent heat loads Q_s and Q_l estimated by the estimator 520, the determiner 530 determines the operation mode.
- [0095] Here, switching the operation mode at appropriate timing has some issues. For example, switching from the cooling mode to the air-blowing mode too quickly causes the temperature or humidity to revert in a short period and reduces comfort. Switching from the cooling mode to the dehumidification mode too quickly degrades the efficiency in lowering the room temperature T_i and increases power consumption. In contrast, switching from the cooling mode to the air-blowing mode too slowly causes an increase in power consumption and excessive cooling. Switching from the cooling mode to the dehumidification mode too slowly causes excessive cooling and an increase in humidity. To avoid such issues, the determiner 530 determines the operation mode to automatically switch between the cooling, dehumidification, and air-blowing modes at appropriate timing.
- [0096] Operation Mode Determination Example
- First, the determiner 530 compares the steady latent heat load Q_l estimated by the estimator 520 with a latent heat threshold Q_{l1} or Q_{l2} . The steady latent heat load Q_l being greater than the first latent heat threshold Q_{l1} corresponds to a high-humidity condition in which the outside-air humidity R_{Ho} is relatively high, as in, for example, rainy or cloudy days. The steady latent heat load Q_l being smaller than the second latent heat threshold Q_{l2} corresponds to a low-humidity condition in which the outside-air humidity R_{Ho} is relatively low, as in, for example, dry days.

[0097] When the steady latent heat load Q_l is greater than the first latent heat threshold Q_{l1} , or more specifically, when any high-humidity condition is satisfied, the determiner 530 then compares the steady sensible heat load Q_s with each of sensible heat thresholds Q_{s1} to Q_{s3} . The three sensible heat thresholds Q_{s1} to Q_{s3} are set in advance to satisfy $Q_{s1} > Q_{s2} > Q_{s3}$.

[0098] High-Humidity Condition 1

A high-humidity condition in which the steady sensible heat load Q_s is greater than the first sensible heat threshold Q_{s1} corresponds to when the outside temperature T_o or the window temperature T_w is relatively high. Under this condition, the room temperature T_i is more likely to increase. In this case, maintaining the room temperature T_i at the set temperature T_m mainly uses the cooling efficiency rather than the dehumidification efficiency. The determiner 530 thus determines (A) cooling to be the operation mode to be executed by the air-conditioning device 1.

[0099] High-Humidity Condition 2

A high-humidity condition in which the steady sensible heat load Q_s is smaller than the first sensible heat threshold Q_{s1} and greater than the second sensible heat threshold Q_{s2} involves less cooling efficiency than in the high-humidity condition 1. The determiner 530 thus determines C1 low-cooling dehumidification, serving as a first dehumidification mode, to be the operation mode to be executed by the air-conditioning device 1. In this case, the determiner 530 increases the dehumidification efficiency while lowering the cooling efficiency further than in the high-humidity condition 1.

[0100] High-Humidity Condition 3

A high-humidity condition in which the steady sensible heat load Q_s is smaller than the second sensible heat threshold Q_{s2} and greater than the third sensible heat threshold Q_{s3} involves less cooling efficiency than in the high-humidity condition 2. In this case, the determiner 530 determines the operation mode to be executed by the air-conditioning device 1 as a second dehumidification mode. The second

dehumidification mode is any of (C2) double-fan dehumidification, (C3) dewpoint-temperature dehumidification, (C4) partial-cooling dehumidification, and (C5) extensive dehumidification. In this case, the determiner 530 further lowers the cooling efficiency and increases the dehumidification efficiency further than in the high-humidity condition 2.

[0101] In more detail, when the steady latent heat load Q_l is relatively low under the high-humidity condition 3, the determiner 530 determines (C2) double-fan dehumidification to be the operation mode to be executed by the air-conditioning device 1. When the steady latent heat load Q_l is relatively high and the steady sensible heat load Q_s is relatively high under the high-humidity condition 3, the determiner 530 determines (C3) dewpoint-temperature dehumidification to be the operation mode to be executed by the air-conditioning device 1. When the steady latent heat load Q_l is relatively high and the steady sensible heat load Q_s is relatively low under the high-humidity condition 3, the determiner 530 determines (C4) partial-cooling dehumidification to be the operation mode to be executed by the air-conditioning device 1. At or around a boundary of these three operation modes, the determiner 530 determines (C5) extensive dehumidification, or more specifically, a combination of at least two of these three operation modes, to be the operation mode to be executed by the air-conditioning device 1. Under the high-humidity condition 3, the operation mode is continuously switched in accordance with the steady sensible and latent heat loads Q_s and Q_l .

[0102] High-Humidity Condition 4

Under a high-humidity condition in which the steady sensible heat load Q_s is smaller than the third sensible heat threshold Q_{s3} , cooling the interior space 71 can excessively cool the interior space 71 and reduce comfort. In this case, the determiner 530 thus determines to stop the compressor 21 to stop air-conditioning.

[0103] When the steady latent heat load Q_l is smaller than the second latent heat

threshold Q12, or more specifically, when any low-humidity condition is satisfied, the determiner 530 then compares the steady sensible heat load Q_s with a fourth sensible heat threshold Q_{s4} . The fourth sensible heat threshold Q_{s4} is set to 0 kW or a value acquired by adding the decrease in the sensible temperature acquired in the air-blowing mode and
 5 converted into the heat quantity to 0 kW.

[0104] Low-Humidity Condition 1

Under a low-humidity condition in which the steady sensible heat load Q_s is greater than the fourth sensible heat threshold Q_{s4} , the room temperature T_i is more likely to increase. In this case, maintaining the room temperature T_i at the set
 10 temperature T_m mainly uses the cooling efficiency rather than the dehumidification efficiency. As in the high-humidity condition 1, the determiner 530 determines (A) cooling to be the operation mode to be executed by the air-conditioning device 1.

[0105] Low-Humidity Condition 2

A low-humidity condition in which the steady sensible heat load Q_s is smaller than
 15 the fourth sensible heat threshold Q_{s4} involves neither higher cooling efficiency nor higher dehumidification efficiency than in the low-humidity condition 1. In this case, the determiner 530 thus determines (D) air blowing to be the operation mode to be executed by the air-conditioning device 1 to reduce power consumption.

[0106] The determiner 530 determines the air-conditioning operation mode based
 20 on the steady latent heat load Q_l and the steady sensible heat load Q_s estimated by the estimator 520 as described above. The latent heat thresholds Q_{l1} and Q_{l2} and the sensible heat thresholds Q_{s1} to Q_{s4} are set in advance as appropriate and stored in the storage 102. The determiner 530 is implemented by the controller 101 in cooperation with the storage 102. The determiner 530 functions as determination means.

25 [0107] The first latent heat threshold Q_{l1} is set to be greater than or equal to 0 kW, and greater than the second latent heat threshold Q_{l2} . Thus, the dehumidification mode is executed under high humidity to thoroughly lower the humidity, whereas the cooling

mode is executed under relatively low humidity to increase energy saving. To reduce frequent switching of the operation mode, the first latent heat threshold Q11 may be slightly greater than the second latent heat threshold Q12. For convenience, however, the first latent heat threshold Q11 may be 0 kW when energy can be also saved in the
 5 dehumidification mode. The second latent heat threshold Q12 may be 0 kW or greater than 0 kW by the amount acquired by converting the decrease in the sensible temperature acquired in the air-blowing mode into humidity. The first and second latent heat thresholds Q11 and Q12 may both be 0 kW.

[0108] Referring back to FIG. 5, the air-conditioning controller 540 controls an
 10 air-conditioning unit 110 to air-condition the interior space 71. The air-conditioning unit 110 includes the outdoor unit 11 including the compressor 21, the four-way valve 22, the outdoor heat exchanger 23, the expansion valve 24, and the outdoor fan 31, and the indoor unit 13 including the indoor heat exchanger 25 and the indoor fans 33a and 33b. The air-conditioning unit 110 functions as air-conditioning means for air-conditioning the
 15 interior space 71.

[0109] The air-conditioning controller 540 communicates with the indoor-unit controller 53 through the communication unit 104, and causes the air-conditioning unit 110 to air-condition the interior space 71 in cooperation with the indoor-unit controller 53. More specifically, in accordance with the instructed operation mode, the air-conditioning
 20 controller 540 switches the channel of the four-way valve 22, adjusts the degree of opening of the expansion valve 24, and drives the compressor 21, the outdoor fan 31, and the indoor fans 33a and 33b. As described above in the operation mode, the air-conditioning controller 540 executes the processing of (A) cooling, (B) heating, (C1) low-cooling dehumidification, (C2) double-fan dehumidification, (C3)
 25 dewpoint-temperature dehumidification, (C4) partial-cooling dehumidification, (C5) extensive dehumidification, (C6) reheating dehumidification, or (D) air blowing. The air-conditioning controller 540 is implemented by the controller 101 in cooperation with

the communication unit 104. The air-conditioning controller 540 functions as air-conditioning control means.

[0110] When the operation mode of (E) automatic is designated, the air-conditioning controller 540 causes the air-conditioning unit 110 to air-condition the interior space 71 in the operation mode determined by the determiner 530. More specifically, in accordance with any satisfied one of the high-humidity conditions 1, 2, and 3 and the low-humidity conditions 1 and 2, the air-conditioning controller 540 causes the air-conditioning unit 110 to air-condition the interior space 71 in the operation mode of (A) cooling, (C1) low-cooling dehumidification, (C2) double-fan dehumidification, (C3) dewpoint-temperature dehumidification, (C4) partial-cooling dehumidification, (C5) extensive dehumidification, or (D) air blowing. When the high-humidity condition 4 is satisfied, the air-conditioning controller 540 stops operating the compressor 21.

[0111] When the determiner 530 determines a new operation mode different from the current operation mode based on the load information such as the temperature or humidity acquired by the acquirer 510, the air-conditioning controller 540 switches from the current operation mode to the newly determined operation mode to air-condition the interior space 71.

[0112] More specifically, under any high-humidity condition being satisfied, the air-conditioning controller 540 switches the operation mode to the first dehumidification mode when the steady sensible heat load Q_s decreases below the first sensible heat threshold Q_{s1} during air-conditioning of the air-conditioning unit 110 in the cooling mode. Further, the air-conditioning controller 540 switches the operation mode to the second dehumidification mode when the steady sensible heat load Q_s decreases below the second sensible heat threshold Q_{s2} during air-conditioning of the air-conditioning unit 110 in the first dehumidification mode. The air-conditioning controller 540 stops the compressor 21 when the steady sensible heat load Q_s decreases below the third sensible heat threshold Q_{s3} during air-conditioning of the air-conditioning unit 110 in the

second dehumidification mode. In contrast, the air-conditioning controller 540 switches the operation mode reversely when the steady sensible heat load Q_s exceeds each of the sensible heat thresholds Q_{s1} to Q_{s3} .

[0113] Under any low-humidity condition being satisfied, the air-conditioning controller 540 switches the operation mode to the air-blowing mode when the steady sensible heat load Q_s decreases below the fourth sensible heat threshold Q_{s4} during air-conditioning of the air-conditioning unit 110 in the cooling mode. In contrast, the air-conditioning controller 540 switches the operation mode to the cooling mode when the steady sensible heat load Q_s exceeds the fourth sensible heat threshold Q_{s4} during air-conditioning of the air-conditioning unit 110 in the air-blowing mode.

[0114] Under any low-humidity condition being satisfied, the air-conditioning controller 540 switches the operation mode to the mode corresponding to any of the high-humidity conditions 1 to 4 corresponding to the current steady sensible heat load Q_s when the steady latent heat load Q_l exceeds the first latent heat threshold Q_{l1} during air-conditioning of the air-conditioning unit 110 in the air-blowing mode. Under any high-humidity condition being satisfied, the air-conditioning controller 540 switches the operation mode to the air-blowing mode when the steady latent heat load Q_l decreases below the second latent heat threshold Q_{l2} and the steady sensible heat load Q_s decreases below the fourth sensible heat threshold Q_{s4} .

[0115] Hereafter, air-conditioning of the interior space 71 while the air-conditioning controller 540 is switching the operation mode will be described under any high-humidity condition and any low-humidity condition being satisfied by way of example.

[0116] High-Humidity Conditions

FIGS. 7(a) to 7(f) and FIGS. 8(g) to 8(j) are graphs showing changes in various parameters in a cloudy day satisfying a high-humidity condition in a first example. As shown in FIG. 7(a), although being affected by the amount of cloud, insolation typically

increases substantially between 6 to 12 o'clock, and decreases substantially between 12 to 18 o'clock. Although not shown, the window temperature T_w changes similarly to the increase and decrease in insolation. The outside temperature T_o shown in FIG. 7(b) is increased by insolation, and thus changes to follow changes in insolation and reaches the peak at or around 13 o'clock. The outside-air humidity R_{Ho} shown in FIG. 7(c) changes within a relatively high range under the high-humidity conditions. When the absolute humidity of the outside air has almost no changes without rain, the outside-air humidity R_{Ho} decreases further in the daytime when the outside temperature T_o is high.

[0117] FIG. 7(d) shows changes in the steady sensible heat load Q_s when the room temperature T_i remains at the set temperature T_m . When the room temperature T_i remains at the set temperature T_m , the steady sensible heat load Q_s is estimated by the estimator 520 in accordance with formula (3) above. As shown in FIG. 7(d), the steady sensible heat load Q_s gradually increases from 6 o'clock with the increase in insolation and the outside temperature T_o , reaches the peak at or around noon, and then decreases gradually.

[0118] FIG. 7(e) shows the steady latent heat load Q_l when the room temperature T_i and the indoor humidity R_{Hi} are fixed. The steady latent heat load Q_l is estimated by the estimator 520 in accordance with formula (6) above. When the outside absolute humidity and the amount of ventilation are fixed, and the amount of internal evaporation is also fixed, the steady latent heat load Q_l remains constant as shown in FIG. 7(e).

[0119] FIGS. 7(f) and 8(g) to 8(j) are graphs showing changes in the respective parameters, or in the operation mode, the sensible heat capacity, the latent heat capacity, the room temperature T_i , and the indoor humidity R_{Hi} , when the air-conditioning device 1 starts air-conditioning in the automatic mode at 16 o'clock. The determiner 530 determines the operation mode based on the steady sensible heat load Q_s shown in FIG. 7(d) and the steady latent heat load Q_l shown in FIG. 7(e). The air-conditioning controller 540 executes air-conditioning in the air-conditioning mode determined by the

determiner 530.

[0120] More specifically, at the start of air-conditioning at 16 o'clock, the steady latent heat load Q_l is greater than the first latent heat threshold Q_{l1} , and the steady sensible heat load Q_s is greater than the first sensible heat threshold Q_{s1} . Thus, as shown in FIG. 7(f), the air-conditioning controller 540 starts air-conditioning in the operation mode of cooling. Then, when the outside temperature T_o decreases with time, the steady sensible heat load Q_s decreases. When, for example, the steady sensible heat load Q_s decreases below the first sensible heat threshold Q_{s1} at 17 o'clock, the air-conditioning controller 540 switches the operation mode from cooling to low-cooling dehumidification, serving as a first dehumidification mode. When, for example, the steady sensible heat load Q_s decreases below the second sensible heat threshold Q_{s2} at 23 o'clock, the air-conditioning controller 540 switches the operation mode from low-cooling dehumidification to any of the second dehumidification mode, or more specifically, double-fan dehumidification, dewpoint-temperature dehumidification, partial-cooling dehumidification, or extensive dehumidification.

[0121] The sensible heat capacity shown in FIG. 8(g) is high at 16 o'clock when air-conditioning is started in the cooling mode at the room temperature T_i shown in FIG. 8(i) higher than the set temperature T_m . Thereafter, the sensible heat capacity is controlled by the air-conditioning controller 540 to decrease further as the room temperature T_i approaches the set temperature T_m and to stabilize the room temperature T_i at the set temperature T_m . After the room temperature T_i is stabilized at the set temperature T_m , the outside temperature T_o decreases at nighttime. Thus, the steady sensible heat load Q_s shown in FIG. 7(d) decreases gradually. Accordingly, the sensible heat capacity shown in FIG. 8(g) approximates the steady sensible heat load Q_s , and the room temperature T_i is thus stabilized at or around the set temperature T_m as shown in FIG. 8(i).

[0122] In the cooling mode, the sensible heat capacity is controlled to change the

room temperature T_i to the set temperature T_m , and thus the latent heat capacity shown in FIG. 8(h) changes accordingly. For a certain period after the start of air-conditioning, the latent heat capacity also changes greatly with high sensible heat capacity. Thus, the indoor humidity RH_i shown in FIG. 8(j) decreases. However, when the operation is

5 continued in the cooling mode, the latent heat capacity can decrease as the sensible heat capacity decreases as indicated with a dot-and-dash line in FIG. 8(h). Thus, the amount of dehumidification can decrease, and the indoor humidity RH_i can be shifted to increase, as indicated with a dot-and-dash line in FIG. 8(j).

[0123] To avoid such an increase in the indoor humidity RH_i , the air-conditioning

10 controller 540 sequentially switches the operation mode from the cooling mode to the low-cooling dehumidification mode, and then from the low-cooling dehumidification mode to the extensive dehumidification mode. By switching the operation mode, the latent heat capacity changes around the same level as the steady latent heat load Q_l . Thus, the indoor humidity RH_i is stabilized at around the same level as the set humidity

15 RH_m , as indicated with a solid line in FIG. 8(j).

[0124] Low-Humidity Conditions

FIGS. 9(a) to 9(f) and 10(g) to 10(j) are graphs showing changes in various parameters in a sunny day satisfying a low-humidity condition in a second example. As shown in FIG. 9(a), although being affected by the amount of cloud, insolation increases

20 substantially between 6 to 12 o'clock, and decreases substantially between 12 to 18 o'clock. Although not shown, the window temperature T_w changes similarly to the increase and decrease in insolation. The outside temperature T_o shown in FIG. 9(b) is increased by insolation, and changes following behind insolation and reaches the peak at or around 13 o'clock. The outside-air humidity RH_o shown in FIG. 9(c) changes within

25 a relatively lower range under the low-humidity condition than under the high-humidity condition shown in FIG. 7(c).

[0125] FIG. 9(d) shows changes in the steady sensible heat load Q_s when the room

temperature T_i remains at the set temperature T_m . As shown in FIG. 9(d), the steady sensible heat load Q_s gradually increases from 6 o'clock with the increase in insolation and the outside temperature T_o , reaches the peak at or around noon, and then decreases gradually.

5 [0126] FIG. 9(e) shows the steady latent heat load Q_l when the room temperature T_i and the indoor humidity RH_i are fixed. When the outside absolute humidity and the amount of ventilation are fixed, and the amount of internal evaporation is also fixed, the steady latent heat load Q_l remains constant as shown in FIG. 9(e). Under the low-humidity condition, the steady latent heat load Q_l is lower than under the high-humidity condition shown in FIG. 7(e).

[0127] FIGS. 9(f) and 10(g) to 10(j) are graphs showing changes in the respective parameters, or in the operation mode, the sensible heat capacity, the latent heat capacity, the room temperature T_i , and the indoor humidity RH_i when the air-conditioning device 1 starts air-conditioning in the automatic mode at 16 o'clock.

15 [0128] At the start of air-conditioning at 16 o'clock, the steady latent heat load Q_l is smaller than the second latent heat threshold Q_{l2} , and the steady sensible heat load Q_s is greater than the fourth sensible heat threshold Q_{s4} . Thus, as shown in FIG. 9(f), the air-conditioning controller 540 starts air-conditioning in the cooling operation mode. When the outside temperature T_o decreases with time, the steady sensible heat load Q_s decreases. When, for example, the steady sensible heat load Q_s decreases below the fourth sensible heat threshold Q_{s4} at 17 o'clock, the air-conditioning controller 540 switches the operation mode from cooling to air blowing.

[0129] The sensible heat capacity shown in FIG. 10(g) is high at 16 o'clock when air-conditioning is started in the cooling mode at the room temperature T_i shown in FIG. 10(i) higher than the set temperature T_m . Thereafter, the sensible heat capacity is controlled by the air-conditioning controller 540 to decrease further as the room temperature T_i approaches the set temperature T_m and to stabilize the room temperature

T_i at the set temperature T_m . After the room temperature T_i is stabilized at the set temperature T_m , the outside temperature T_o decreases at nighttime. Thus, the steady sensible heat load Q_s shown in FIG. 9(d) decreases gradually. Accordingly, the sensible heat capacity shown in FIG. 10(g) approximates the steady sensible heat load Q_s , and the
 5 room temperature T_i is stabilized at the set temperature T_m as shown in FIG. 10(i).

[0130] In the cooling mode, the sensible heat capacity is controlled to change the room temperature T_i to the set temperature T_m , and the latent heat capacity shown in FIG. 10(h) changes accordingly. For a certain period after the start of air-conditioning, the latent heat capacity also changes greatly with high sensible heat capacity. Thus, the
 10 indoor humidity R_{Hi} shown in FIG. 10(j) decreases. When the operation is continued in the cooling mode, the latent heat capacity can decrease as the sensible heat capacity decreases. However, the decrease in the latent heat capacity negligibly affects comfort, as the indoor humidity R_{Hi} easily decreases under the low-humidity condition. Thus, the air-conditioning controller 540 switches the operation mode from cooling to air
 15 blowing in accordance with the decrease in the sensible heat capacity.

[0131] The operation mode is switched from cooling to air blowing when satisfying the condition in which the steady sensible heat load Q_s decreases below the fourth sensible heat threshold Q_{s4} . The room temperature T_i is thus less likely to increase above the set temperature T_m when the sensible heat capacity runs short after switching
 20 to air blowing. Under the low-humidity condition, the indoor humidity R_{Hi} is less likely to increase due to, for example, reevaporation of moisture adhering to the indoor heat exchanger 25 through air blowing after switching to air blowing. Thus, switching to air blowing satisfies both comfort and energy saving.

[0132] Although not shown, when the high-humidity and low-humidity conditions
 25 are switched from each other within a day, or when, for example, the outside-air humidity R_{Ho} changes due to sudden rain, each parameter includes a mixture of changes in the high-humidity conditions shown in FIGS. 7(a) to 7(f) and 8(g) to 8(j), and changes in the

low-humidity conditions shown in FIGS. 9(a) to 9(f) and 10(g) to 10(j).

[0133] When, for example, the outside-air humidity RH_o increases to satisfy the high-humidity condition during air-conditioning in air blowing under the low-humidity condition, the air-conditioning controller 540 switches the operation mode to double-fan
 5 dehumidification, dewpoint-temperature dehumidification, partial-cooling dehumidification, or extensive dehumidification. When the outside-air humidity RH_o decreases to satisfy the low-humidity condition during any of double-fan dehumidification, dewpoint-temperature dehumidification, partial-cooling dehumidification, or extensive dehumidification under the high-humidity condition, the
 10 air-conditioning controller 540 switches the operation mode to air blowing. Thus, the operation mode is switched to the dehumidification operation mode under the high-humidity condition to increase the comfort in the interior space 71. When the comfort in the interior space 71 can be retained without dehumidification, the operation mode is switched to air blowing to reduce power consumption.

15 [0134] Indication Function

The indicator 550 provides, to a user through display or sound, first indication information on the environments of the interior space 71 and second indication information on the control of the air-conditioning controller 540 over the air-conditioning unit 110. When the air-conditioning operation mode is switched by the air-conditioning
 20 controller 540, the indicator 550 displays, for example, indication screens shown in FIGS. 11 to 13 on a display 130 of, for example, the remote controller 55, a smartphone, or a tablet personal computer (PC). The indicator 550 is implemented by the controller 101 in cooperation with the communication unit 104. The indicator 550 functions as indication means.

25 [0135] As shown in FIGS. 11 to 13, the indicator 550 provides tendency information 131 indicating the tendency of the temperature or humidity in the interior space 71 as first indication information, and operation mode information 132 indicating

the operation mode as second indication information. The tendency information 131 is first image information showing whether the room temperature T_i or the indoor humidity RH_i acquired by the acquirer 510 is likely to increase, decrease, or remain unchanged.

[0136] For example, as shown in FIG. 11, when the indoor humidity RH_i is likely to increase, the indicator 550 provides a waterdrop picture indicating humidity together with an upward arrow as the tendency information 131. As shown in FIG. 12, when the room temperature T_i and the indoor humidity RH_i are likely to remain unchanged, the indicator 550 provides a waterdrop picture, a thermometer picture indicating the temperature, and a horizontal arrow as the tendency information 131. As shown in FIG. 13, when the room temperature T_i is likely to increase, the indicator 550 provides a thermometer picture together with an upward arrow as the tendency information 131. Such tendencies of the room temperature T_i or the indoor humidity RH_i are determined based on whether the room temperature T_i or the indoor humidity RH_i increases, decreases, or remains within a change tolerance in a latest predetermined period.

[0137] When the air-conditioning controller 540 switches the operation mode, the indicator 550 provides information indicating the tendencies of the room temperature T_i or the indoor humidity RH_i immediately before the operation mode is switched as the tendency information 131. Upon receiving the information immediately before the operation mode is switched, a user can determine the reason for the operation mode switched from, for example, the cooling mode to the dehumidification mode.

[0138] Upon receiving a request from the user, the indicator 550 provides the information indicating the tendencies of the current room temperature T_i or the indoor humidity RH_i as the tendency information 131. With the current information provided upon receiving a request from the user, the user can notice the upcoming tendencies of the temperature and the humidity.

[0139] The operation mode information 132 is second image information indicating the modes from which and to which the air-conditioning controller 540 switches the

operation mode. When the air-conditioning controller 540 switches the operation mode from a first mode to a second mode, the indicator 550 provides, as the operation mode information 132, information indicating the first mode from which the operation mode is switched, and the second mode to which the operation mode is switched.

5 [0140] For example, as shown in FIG. 11, when the operation mode is switched from the cooling mode to the dehumidification mode, the indicator 550 displays, as the operation mode information 132, the dehumidification mode to which the operation mode is switched in a more emphasized manner than the cooling mode from which the operation mode is switched. Similarly, as shown in FIG. 12, when the operation mode
10 is switched from the cooling mode to the air-blowing mode, the indicator 550 displays, as the operation mode information 132, the air-blowing mode to which the operation mode is switched in a more emphasized manner than the cooling mode from which the operation mode is switched.

[0141] Instead of providing information about both the operation modes before and
15 after switching, the indicator 550 may simply provide, as the operation mode information 132, information about the operation mode after switching for convenience. However, upon receiving information about both the operation modes before and after switching, a user can easily notice that the operation mode has been automatically switched.

[0142] With the tendency information 131 and the operation mode information 132
20 displayed in this manner, the user can readily determine the current air-conditioning state. A full-dot display 130 may clearly display an image including pictures and characters with the tendency information 131 and the operation mode information 132 adjacent to each other for the user to more easily notice that the operation mode has been switched and the reason for the switching.

25 [0143] In addition to the tendency information 131 and the operation mode information 132, the indicator 550 also provides determination information 133 indicating the determination of the operation mode, as the first indication information,

and provides control information 134 indicating the details of control of the air-conditioning controller 540 as the second indication information. The determination information 133 is first textual information indicating the determination of the operation mode determined by the determiner 530. As described above, the determiner 530

5 determines whether any of the conditions under which the operation mode is switched is satisfied, and the mode to which the operation mode is to be switched, based on, for example, the room temperature T_i , the indoor humidity RH_i , the steady sensible heat load Q_s , and the steady latent heat load Q_l acquired by the acquirer 510. The determination information 133 is information about the operation mode determined by the determiner

10 530. The control information 134 is second textual information about the details of control when the air-conditioning controller 540 executes air-conditioning or switches the operation mode.

[0144] For example, as shown in FIG. 11, the indicator 550 displays textual information indicating “Temperature is reaching the target, but humidity may remain

15 high, and” as the determination information 133, and displays textual information indicating “Operation mode has been switched to dehumidification mode” as the control information 134. In some embodiments, as shown in FIG. 12, the indicator 550 displays textual information indicating “Temperature and humidity are estimated to remain unraised after switching to air blowing” as the determination information 133, and

20 displays textual information indicating “Operation mode has been switched to air blowing” as the control information 134. Further, as shown in FIG. 13, the indicator 550 displays textual information indicating “Likely be hot with outside air and insolation” as the determination information 133, and displays textual information indicating “Heating has been moderated earlier than planned” as the control information 134.

25 Such information allows a user to determine the details of automatic control. When, for example, the operation mode is switched from the cooling mode to the dehumidification mode, a user can readily determine the reason for the operation mode switching.

[0145] The indicator 550 displays these pieces of textual information in a single sentence. Thus, the user can easily read and recognize the determination information 133 and the control information 134. The single sentence can also save the display space.

5 [0146] As shown in FIGS. 11 to 13, the indicator 550 displays the tendency information 131 and the operation mode information 132 in an upper portion of the screen, and the determination information 133 and the control information 134 in a lower portion of the screen. Simultaneously displaying these pieces of information facilitates understanding of the user. The arrangement of these pieces of information on the screen
10 is not limited to this example.

[0147] The indicator 550 thus allows a user to readily determine the current air-conditioning state. More specifically, in the automatic mode, the user can readily use the cooling mode, the dehumidification mode, and the air-blowing mode without manually controlling air-conditioning. A user may feel unsafe, distrust, or
15 uncomfortable about the automatic mode without understanding the control details, although the mode is convenient. In particular, as automation progresses with the recently widespread artificial intelligence (AI) capabilities, the user may desire to better understand the control details and also to have more interactions with the machine. In Embodiment 1, the indicator 550 allows the user to readily determine the current
20 air-conditioning state, and to more conveniently and safely use air-conditioning in the automatic mode.

[0148] With reference to the flowchart in FIG. 14, the control process in the automatic mode executed by the air-conditioning device 1 will now be described.

[0149] When an operation in the automatic mode is designated, the controller 101
25 functions as the acquirer 510 to acquire sensor information including the room temperature T_i , the outside temperature T_o , the window temperature T_w , the indoor humidity RH_i , and the outside-air humidity RH_o detected by the respective sensors (step

S101). The controller 101 functions as the estimator 520 to estimate the heat load of the interior space 71 (step S102). More specifically, in accordance with formulas (2) to (7) above, the controller 101 calculates the unsteady sensible heat load P_s , the steady sensible heat load Q_s , the sensible heat capacity, the unsteady latent heat load P_l , the steady latent
 5 heat load Q_l , and the latent heat capacity from the acquired sensor information.

[0150] After estimating the heat load, the controller 101 functions as the determiner 530 to determine the air-conditioning operation mode based on the estimated heat load (step S103). Then, the controller 101 functions as the air-conditioning controller 540, and performs air-conditioning in the determined operation mode (step S104). More
 10 specifically, the controller 101 compares the steady sensible heat load Q_s and each of the sensible heat thresholds Q_{s1} to Q_{s4} , and compares the steady latent heat load Q_l and each of the latent heat thresholds Q_{l1} and Q_{l2} . The controller 101 then selects, depending on the criteria shown in FIG. 6, the operation mode to be executed by the air-conditioning device 1 from the multiple operation modes, and causes the air-conditioning unit 110 to
 15 air-condition the interior space 71 in the selected operation mode.

[0151] Further, as shown in, for example, FIG. 11 or 12, the controller 101 provides, as appropriate, information about operation mode switching or information on the operation mode during operation (step S105). For example, the controller 101 functions as the indicator 550 to display any of the indication screens shown in FIGS. 11 to 13 on
 20 the display 130. Thereafter, the controller 101 returns the processing to step S101. The controller 101 repeats the processing from steps S101 to S105 while the automatic mode is being designated.

[0152] As described above, the air-conditioning device 1 according to Embodiment 1 switches the operation mode in accordance with the steady sensible heat load Q_s used
 25 to maintain the room temperature T_i at the set temperature T_m , and the steady latent heat load Q_l used to maintain the indoor humidity RH_i at the set humidity RH_m to air-condition the interior space 71. The air-conditioning device 1 can thus switch the

operation mode based on estimated changes in the room temperature T_i and the indoor humidity RH_i , unlike switching the operation mode simply based on the unsteady heat load caused by the temperature difference ΔT between the room and set temperatures T_i and T_m or the humidity difference ΔRH between the indoor and set humidities RH_i and RH_m . This can avoid reduced comfort due to excessive cooling of the interior space and increase comfort, and thus avoid an increase in power consumption.

[0153] In such determination simply based on the temperature difference ΔT between the room and set temperatures T_i and T_m , the sensible heat load covered in the dehumidification mode may be insufficient after switching from the cooling mode to the dehumidification mode, causing an uncomfortable temperature change due to temperature reversion. In this case, the operation mode is to be switched back to the cooling mode. This also occurs in switching between the multiple dehumidification modes from a first dehumidification mode in which the sensible heat capacity is higher to a second dehumidification mode in which the sensible heat capacity is lower, and switching from the cooling mode to the air-blowing mode. Also, when the operation mode is switched to the air-blowing mode simply based on the determination of the humidity difference ΔRH , humidity reversion may occur under the remaining steady latent heat load Q_l although the current humidity is low. The air-conditioning device 1 according to Embodiment 1 switches the operation mode in accordance with the steady sensible and latent heat loads Q_s and Q_l , and thus can determine, before switching the operation mode, whether the temperature and the humidity increase after the switching. This can discourage a user from frequently switching the operation mode. Thus, the operation mode can be switched accurately without the user selecting one of the three operation modes of the cooling mode, the dehumidification mode, and air-blowing mode by pressing the corresponding button.

[0154] The air-conditioning device 1 according to Embodiment 1 includes the operation modes of double-fan dehumidification, dewpoint-temperature dehumidification,

and partial-cooling dehumidification, in which the air-conditioning device 1 can dehumidify with higher latent heat capacity than in low-cooling dehumidification. In the automatic operation mode, the air-conditioning device 1 according to Embodiment 1 switches between these dehumidification modes in accordance with the steady sensible

5 heat load Q_s to dehumidify the interior space 71. The air-conditioning device 1 can thus continuously output the sensible heat capacity associated with the temperature control and the latent heat capacity associated with the humidity control, and can provide comfortable air-conditioning with small changes in the temperature and the humidity at the mode switching in accordance with various different situations including weather

10 conditions, building conditions, and living conditions. Under the conditions in which the sensible or latent heat capacity overlaps between the multiple operation modes, selecting the operation mode having more energy saving can save power consumption.

[0155] The air-conditioning device 1 according to Embodiment 1 includes an air-blowing operation mode, or a combination of cooling and air blowing. In the

15 automatic operation mode, the air-conditioning device 1 according to Embodiment 1 switches the operation mode to air blowing to air-condition the interior space 71 when any low-humidity condition is satisfied and the steady sensible heat load Q_s is relatively low. The air-conditioning device 1 can thus provide more energy saving while maintaining comfort in the interior space 71.

20 [0156] Embodiment 2

Embodiment 2 of the present disclosure will now be described. In Embodiment 1, the determiner 530 determines the air-conditioning operation mode to be executed by the air-conditioning device 1 based on the steady sensible and latent heat loads Q_s and Q_l . In Embodiment 2, the determiner 530 determines the operation mode based on the

25 temperature difference ΔT between the room and set temperatures T_i and T_m and the humidity difference ΔRH between the indoor and set humidities RH_i and RH_m .

[0157] In Embodiment 2, based on the room temperature T_i acquired by the

acquirer 510, the estimator 520 calculates the temperature difference ΔT between the room and set temperatures T_i and T_m . Based on the indoor humidity RH_i acquired by the acquirer 510, the estimator 520 also calculates the humidity difference ΔRH between the indoor and set humidities RH_i and RH_m . As expressed by formula (2) above, the temperature difference ΔT is an index of the unsteady sensible heat load Ps . In formula (5) above, the humidity difference ΔRH is expressed as a difference between the outside and inside absolute humidities. However, the humidity difference ΔRH can approximately be an index of the unsteady latent heat load Pl .

[0158] FIG. 15 shows the relationship between temperature, humidity, and the operation mode. As shown in FIG. 15, when the air-conditioning device 1 air-conditions the interior space 71 in (E) automatic operation mode, the operation mode to be executed by the air-conditioning device 1 is fixed in accordance with the temperature and humidity differences ΔT and ΔRH . The determiner 530 determines the operation mode based on the temperature and humidity differences ΔT and ΔRH calculated by the estimator 520.

[0159] The operation mode determination performed by the determiner 530 according to Embodiment 2 can be described similarly to the determination in Embodiment 1, in which the unsteady sensible heat load Qs in Embodiment 1 is replaced with the temperature difference ΔT , and the steady latent heat load Ql is replaced with the humidity difference ΔRH .

[0160] More specifically, the determiner 530 first compares the humidity difference ΔRH calculated by the estimator 520 with each of the humidity thresholds $\Delta RH1$ and $\Delta RH2$. The humidity difference ΔRH being greater than the first humidity threshold $\Delta RH1$ corresponds to when any high-humidity condition is satisfied. The humidity difference ΔRH being smaller than the second humidity threshold $\Delta RH2$ corresponds to when any low-humidity condition is satisfied.

[0161] Under any high-humidity condition being satisfied, the determiner 530

- compares the temperature difference ΔT with each of the first to third temperature thresholds $\Delta T1$ to $\Delta T3$. When the temperature difference ΔT is greater than the first temperature threshold $\Delta T1$, the determiner 530 determines (A) cooling to be the operation mode to be executed by the air-conditioning device 1. When the temperature difference ΔT is smaller than the first temperature threshold $\Delta T1$ and greater than the second temperature threshold $\Delta T2$, the determiner 530 determines (C1) low-cooling dehumidification to be the operation mode to be executed by the air-conditioning device 1. When the temperature difference ΔT is smaller than the second temperature threshold $\Delta T2$ and greater than the third temperature threshold $\Delta T3$, the determiner 530 determines (C2) double-fan dehumidification, (C3) dewpoint-temperature dehumidification, or (C4) partial-cooling dehumidification to be the operation mode to be executed by the air-conditioning device 1. When the temperature difference ΔT is smaller than the third temperature threshold $\Delta T3$, the determiner 530 determines to stop the compressor 21.
- 15 [0162] Under any low-humidity condition being satisfied, the determiner 530 compares the temperature difference ΔT with the fourth temperature threshold $\Delta T4$. When the temperature difference ΔT is greater than the fourth temperature threshold $\Delta T4$, the determiner 530 determines (A) cooling to be the operation mode to be executed by the air-conditioning device 1. When the temperature difference ΔT is smaller than the fourth temperature threshold $\Delta T4$, the determiner 530 determines (D) air blowing to be the operation mode to be executed by the air-conditioning device 1. The fourth temperature threshold $\Delta T4$ is set to 0 °C or a temperature acquired by adding, to 0 °C substantially 1 to 2 °C corresponding to the decrease in the sensible temperature acquired in the air-blowing mode.
- 20 [0163] Similarly to Embodiment 1, the air-conditioning controller 540 causes the air-conditioning unit 110 to air-condition the interior space 71 in the operation mode determined by the determiner 530. When the determiner 530 determines a new

operation mode different from the current operation mode based on the load information, such as temperature or humidity, acquired by the acquirer 510, the air-conditioning controller 540 switches from the current operation mode to the newly determined operation mode to air-condition the interior space 71.

- 5 [0164] More specifically, under any high-humidity condition being satisfied, the air-conditioning controller 540 switches the operation mode to the first dehumidification mode when the temperature difference ΔT decreases below the first temperature threshold $\Delta T1$ during air-conditioning of the air-conditioning unit 110 in the cooling mode. Further, the air-conditioning controller 540 switches the operation mode to the
- 10 second dehumidification mode when the temperature difference ΔT decreases below the second temperature threshold $\Delta T2$ during air-conditioning of the air-conditioning unit 110 in the first dehumidification mode. The air-conditioning controller 540 stops the compressor 21 when the temperature difference ΔT decreases below the third
- 15 temperature threshold $\Delta T3$ during air-conditioning of the air-conditioning unit 110 in the second dehumidification mode. In contrast, the air-conditioning controller 540 switches the operation mode reversely when the temperature difference ΔT exceeds each of the temperature thresholds $\Delta T1$ to $\Delta T3$.

- [0165] Under any low-humidity condition being satisfied, the air-conditioning controller 540 switches the operation mode to the air-blowing mode when the
- 20 temperature difference ΔT decreases below the fourth temperature threshold $\Delta T4$ during air-conditioning of the air-conditioning unit 110 in the cooling mode. In contrast, the air-conditioning controller 540 switches the operation mode to the cooling mode when the temperature difference ΔT exceeds the fourth temperature threshold $\Delta T4$ during air-conditioning of the air-conditioning unit 110 in the air-blowing mode.

- 25 [0166] Under any low-humidity condition being satisfied, the air-conditioning controller 540 switches the operation mode to the mode corresponding to any of the high-humidity conditions 1 to 4 corresponding to the current steady sensible heat load Q_s

when the humidity difference ΔRH exceeds the first humidity threshold $\Delta RH1$ during air-conditioning of the air-conditioning unit 110 in the air-blowing mode. Under any high-humidity condition being satisfied, the air-conditioning controller 540 switches the operation mode to the air-blowing mode when the humidity difference ΔRH decreases
 5 below the second humidity threshold $\Delta RH2$ and the temperature difference ΔT decreases below the fourth temperature threshold $\Delta T4$.

[0167] The air-conditioning device 1 according to Embodiment 2 thus switches the operation mode in accordance with the temperature difference ΔT between the room and set temperatures T_i and T_m and the humidity difference ΔRH between the indoor and set
 10 humidities RH_i and RH_m . The determination of the temperature difference ΔT allows determination of switching between the cooling and dehumidification modes but cannot allow determination as to whether the cooling mode is to be switched to the dehumidification or air-blowing mode. The air-conditioning device 1 according to Embodiment 2 can determine whether the cooling mode is to be switched to the
 15 dehumidification or air-blowing mode using the determination of the humidity difference ΔRH , in addition to the determination of the temperature difference ΔT . Thus, the operation mode can be switched to the air-blowing mode after the temperature decreases in the cooling mode while the humidity remains high to avoid reduced comfort. The operation mode can be switched to the dehumidification mode while the humidity
 20 remains low to reduce unintended power consumption. The air-conditioning device 1 can thus easily provide comfort in both the room temperature T_i and the indoor humidity RH_i .

[0168] With the higher heat insulation efficiency and ventilation efficiency of buildings in recent years, humidity is more likely to be trapped, thus causing the room
 25 temperature T_i to decrease quickly but the indoor humidity RH_i to be less likely to decrease. The air-conditioning device 1 according to Embodiment 2 can reduce such humidity trapping by switching the operation mode in accordance with the temperature

and humidity differences ΔT and ΔRH .

[0169] Using the temperature and humidity differences ΔT and ΔRH eliminates the use of information about the outside temperature T_o , the window temperature T_w , and the outside-air humidity RH_o for both determination and switching of the operation mode.

5 Thus, the interior space 71 can be air-conditioned by switching the operation mode with a simpler structure. In particular, when the unsteady sensible heat load P_s and the unsteady latent heat load P_l are dominant over the steady sensible and latent heat loads Q_s and Q_l , the operation mode is determined based on the temperature and humidity differences ΔT and ΔRH . Thus, air-conditioning can be performed by appropriately
10 switching the operation mode.

[0170] The determiner 530 may perform determination based on the steady sensible and latent heat loads Q_s and Q_l shown in FIG. 6 and determination based on the temperature and humidity differences ΔT and ΔRH shown in FIG. 15 in combination using AND or OR conditions. In this case, the air-conditioning controller 540 switches
15 the operation mode between the cooling and dehumidification modes and between the cooling and air-blowing modes based on both the temperature difference ΔT and the steady sensible heat load Q_s , and switches the operation mode between the dehumidification mode and the air-blowing mode based on both the humidity difference ΔRH and the steady latent heat load Q_l . In some embodiments, the determiner 530 may
20 determine the operation mode based on the sensible heat capacity that is the sum of the unsteady and steady sensible heat loads P_s and Q_s , or the latent heat capacity that is the sum of the unsteady latent heat load P_l and the steady latent heat load Q_l . Switching the operation mode by appropriately combining the determination based on the temperature and humidity differences ΔT and ΔRH and determination based on the steady sensible
25 and latent heat loads Q_s and Q_l can reduce the frequency of operation mode switching, changes in the room temperature T_i , and changes in the indoor humidity RH_i . This structure can thus provide both comfort and energy saving.

[0171] Embodiment 3

Embodiment 3 of the present disclosure will now be described. In Embodiment 1, the estimator 520 estimates the steady sensible and latent heat loads Q_s and Q_l based on, for example, the temperature and the humidity currently acquired by the acquirer 510.

- 5 In Embodiment 3, the estimator 520 estimates the heat load a predetermined time after the current time based on the changing tendency of each of the steady sensible and latent heat loads Q_s and Q_l for a predetermined time period before the current time.

[0172] More specifically, the estimator 520 calculates the estimated sensible heat load Q_s' in accordance with formula (8) after the room temperature T_i approximates the
 10 set temperature T_m . The estimator 520 also calculates the estimated latent heat load Q_l' in accordance with formula (9) after the indoor humidity RH_i approximates the set humidity RH_m :

estimated sensible heat load $Q_s' = \text{steady sensible heat load } Q_s + \text{estimated change amount } \Delta Q_s$ (8); and

- 15 estimated latent heat load $Q_l' = \text{steady latent heat load } Q_l + \text{estimated change amount } \Delta Q_l$ (9).

[0173] In formula (8) above, the estimated change amount ΔQ_s is a change amount of the steady sensible heat load Q_s in a latest predetermined time period. When, for example, the current time is 18 o'clock, the steady sensible heat load Q_s has been
 20 decreasing for a long time, and thus the estimator 520 estimates that the steady sensible heat load Q_s is likely to decrease also in the future. When the environments of the exterior space 72 change for a predetermined time after the current time in the same manner as immediately before the current time, the steady sensible heat load Q_s can be estimated by extending the changing tendency of the steady sensible heat load Q_s in the
 25 period immediately before the current time.

[0174] More specifically, the estimator 520 estimates the estimated change amount ΔQ_s by calculating the difference between the steady sensible heat load Q_s at the current

time and the steady sensible heat load Q_s a predetermined time before the current time.

When, for example, the steady sensible heat load Q_s is increased by 10% within one hour before the current time, the estimator 520 estimates that the estimated change amount ΔQ_s can also be 10% one hour after the current time. The estimator 520 then calculates

5 the estimated sensible heat load Q_s' by adding the estimated change amount ΔQ_s to the current steady sensible heat load Q_s . The estimated latent heat load Q_l' shown in formula (9) above is estimated similarly.

[0175] Instead of the steady sensible and latent heat loads Q_s and Q_l in

Embodiment 1, the determiner 530 determines the operation mode based on the estimated
10 sensible and latent heat loads Q_s' and Q_l' a predetermined time after the current time estimated by the estimator 520. The air-conditioning controller 540 air-conditions the interior space 71 in the operation mode determined by the determiner 530.

[0176] The air-conditioning device 1 according to Embodiment 3 estimates the future values of the steady sensible and latent heat loads Q_s and Q_l based on the latest

15 changing tendencies, and switches the operation mode based on the estimated values.

Thus, the expected state of the heat load in the interior space 71 can be more accurately estimated than when simply using the current sensor information, with the estimation less likely to be affected by varying sensor information within a short time.

[0177] With the estimated sensible heat load Q_s' , the air-conditioning device 1 can

20 determine, before switching the operation mode, whether the temperature remains unchanged or increases due to the shortage of the maximum sensible heat capacity in the dehumidification mode after the operation mode is switched from the cooling mode to the dehumidification mode in which the maximum sensible heat capacity is lower than in cooling. The air-conditioning device 1 can also determine, before switching the
25 operation mode, whether the temperature remains unchanged or increases in the air-blowing mode after the operation mode is switched from the cooling mode to the air-blowing mode.

[0178] With the estimated latent heat load Q_l' , the air-conditioning device 1 can determine, before switching the operation mode, whether the latent heat capacity runs short and the humidity increases unless the operation mode is switched from the cooling or air-blowing mode to the dehumidification mode. The air-conditioning device 1 can
 5 determine, before switching the operation mode, whether the humidity remains unchanged or increases in the air-blowing mode after the operation mode is switched from the cooling mode to the air-blowing mode.

[0179] The estimated sensible and latent heat loads Q_s' and Q_l' can be used to acquire, before the temperature approaches the set temperature T_m , the heat load used to
 10 maintain the room temperature T_i and the indoor humidity RH_i after the temperature approaches the set temperature T_m . The air-conditioning device 1 compares the acquired heat load with the sensible and latent heat capacities in the current operation mode to determine whether the operation mode is to be switched. Thus, the room temperature T_i and the indoor humidity RH_i can be more accurately retained at the set
 15 temperature and humidity T_m and RH_m , thus increasing the comfort.

[0180] Embodiment 4

Embodiment 4 of the present disclosure will now be described. In Embodiment 1, when the estimator 520 calculates the steady sensible heat load Q_s in accordance with formula (3) above, α denoting the heat insulation efficiency, β denoting the easiness of
 20 sunlight entry, and the internal heat amount Q_n are known. In contrast, the air-conditioning device 1 according to Embodiment 4 learns α , β , and Q_n based on past information detected by each sensor.

[0181] FIG. 16 is a functional block diagram of an outdoor-unit controller 51a included in the air-conditioning device 1 according to Embodiment 4. The outdoor-unit
 25 controller 51a has a hardware configuration similar to the hardware configuration of Embodiment 1, and will not be described.

[0182] As shown in FIG. 16, the outdoor-unit controller 51a includes, as functional

units, an acquirer 510, an estimator 520, a determiner 530, an air-conditioning controller 540, an indicator 550, an information updater 560, and a learner 570. The functions of the acquirer 510, the estimator 520, the determiner 530, the air-conditioning controller 540, and the indicator 550 are the same as described in Embodiment 1, and thus are not
 5 described.

[0183] The information updater 560 updates historical information 150 stored in the storage 102 with information detected by each sensor and acquired by the acquirer 510. The historical information 150 specifies the histories of, for example, the room temperature T_i , the window temperature T_w , the outside temperature T_o , and the
 10 air-conditioning capacity.

[0184] FIG. 17 shows a specific example of the historical information 150. As shown in FIG. 17, the historical information 150 includes information detected by each sensor stored in chronological order, including the room temperature T_i detected by the temperature sensor 41, the window temperature T_w detected by the infrared sensor 43,
 15 and the outside temperature T_o detected by the outside temperature sensor. The historical information 150 also includes the air-conditioning capacity controlled by the air-conditioning controller 540 stored in chronological order. The historical information 150 also includes the operation mode controlled by the air-conditioning controller 540 stored in chronological order.

20 [0185] The information updater 560 stores information newly detected by each sensor and associated with the air-conditioning capacity at predetermined times in the historical information 150. Thus, the information updater 560 updates the historical information 150. The information updater 560 is implemented by the controller 101 in cooperation with the storage 102. The information updater 560 functions as information
 25 update means.

[0186] The learner 570 learns heat characteristics of the interior space 71. The heat characteristics of the interior space 71 include thermal characteristics of the interior

space 71, for example, the heat insulation efficiency of the interior space 71 and the easiness of sunlight entry into the interior space 71. The learner 570 learns the heat characteristics of the interior space 71 from the past room temperature T_i , the window temperature T_w , the outside temperature T_o , and the air-conditioning capacity recorded in the historical information 150. The learner 570 is implemented by the controller 101. The learner 570 functions as learning means.

[0187] Learning Function

The learning function of the learner 570 will now be described further in detail. As shown in FIG. 18, heat transfers between the interior and exterior spaces 71 and 72 through, for example, walls, windows, gaps, and ventilating facilities of the house 3. The steady sensible heat load Q_s that is the heat quantity used when the air-conditioning device 1 maintains the room temperature T_i at the set temperature T_m , is thus dependent on the properties of the house 3, such as the wall thickness or the window size.

[0188] More specifically, the steady sensible heat load Q_s includes a transmission load, a ventilation load, an internal heat amount, and an insolation load. The transmission load is a heat load transmitted through the outer cover in accordance with the temperature difference ΔT_{io} between the outside and room temperatures T_o and T_i . The outer cover is a wall that insulates the interior space 71 from the exterior space 72. The ventilation load is a heat load from inflow air through ventilation or a draft. The ventilation load is proportional to the temperature difference ΔT_{io} . The internal heat amount Q_n is a heat load in the interior space 71 caused by lighting, furniture, and people. The insolation load is divided into a first insolation load that is a heat load that is transmitted through a window glass to heat the inside, and a second insolation load that is a heat load that heats the outer cover and is transmitted to the interior space 71 from the outer cover.

[0189] The learner 570 learns the heat characteristics of the interior space 71 based on the load information on the heat load of the interior space 71 acquired by the acquirer

510. More specifically, the learner 570 learns, as the heat characteristics of the interior space 71, the relationship between the steady sensible heat load Q_s , the room temperature T_i , the outside temperature T_o , and the window temperature T_w , and estimates α , β , and Q_n in formula (3) above. The estimator 520 estimates the steady sensible heat load Q_s from formula (3) using α , β , and Q_n learned by the learner 570. For ease of understanding, the room temperature T_i is assumed to be equal to the set temperature T_m , and the steady sensible heat load Q_s is assumed to be equivalent to the air-conditioning capacity of the air-conditioning device 1.

[0190] In formula (3) above, α is a coefficient denoting the heat insulation efficiency of the house 3, and is a proportionality coefficient associated with the transmission and ventilation loads, which are heat loads used in proportional to the temperature difference ΔT_{io} between the outside and room temperatures T_o and T_i . Here, the second insulation load is also a heat load transmitted through the outer cover, and may be treated similarly to the transmission load. The learner 570 uses an increase ΔT_o in the outside temperature T_o as a parameter corresponding to the second insulation load, and estimates the heat load Q using an apparent outside temperature T_{o2} ($= T_o + \Delta T_o$) instead of the outside temperature T_o .

[0191] Without the ventilation load being considering, α is estimated in theory by formula (10) described below using an outer-cover average heat transmission rate UA and an outer-cover surface area A . In formula (10), α is expressed in watt per kelvin (W/K), the outer-cover average heat transmission rate UA is expressed in $W/(m^2 \cdot K)$, and the outer-cover surface area A is expressed in m^2 . In addition, 1.000 is a coefficient corresponding to the transmission load, and 0.034 is a coefficient corresponding to the second insulation load. Information on the outer-cover average heat transmission rate UA and the outer-cover surface area A frequently fails to be acquired, and α frequently fails to be accurately acquired from formula (10) below under the ventilation load. In the present embodiment, the learner 570 acquires α using formula (3) above from actual

values of each parameter:

$$\alpha = U_A \times A \times (1.000 + 0.034) \quad (10).$$

[0192] In formula (3) above, the coefficient β denoting the easiness of sunlight entry into the interior space 71 is a proportionality coefficient associated with the first insolation load that is the heat load used in proportional to insolation. The coefficient β is dependent on, for example, the size of the window 75 or the type of glass forming the window 75.

[0193] With reference to the historical information 150 stored in the storage 102, the learner 570 analyzes the relationship between the room temperature T_i , the window temperature T_w , the outside temperature T_o , and the air-conditioning capacity. The learner 570 estimates α , β , and Q_n based on the analysis results.

[0194] A method for learning the coefficient α denoting the heat insulation efficiency of the interior space 71 will be described first. The learner 570 learns the coefficient α based on data on the room temperature T_i , the outside temperature T_o , and the air-conditioning capacity acquired when insolation is sufficiently low. More specifically, when insolation is sufficiently low, the first and second insolation loads are negligible, unlike the transmission and ventilation loads. In formula (3) above, β can be approximated to 0, and ΔT_o can be approximated to 0, or more specifically, T_o can be approximated to T_{o2} . In this case, formula (3) above can be approximated to formula (11) below. The learner 570 learns the coefficient α based on the relationship between the air-conditioning capacity and the temperature difference ΔT_{io} between the room and outside temperatures T_i and T_o expressed in formula (11) described below:

$$Q_s = \alpha(T_o - T_i) + Q_n \quad (11).$$

[0195] FIG. 19(a) shows the relationship between the air-conditioning capacity and the temperature difference ΔT_{io} between the room and outside temperatures T_i and T_o .

FIG. 19(a) shows an example of a coordinate plane including a horizontal axis that is a coordinate axis expressing the temperature difference ΔT_{io} between the room and outside

temperatures T_i and T_o , and a vertical axis that is a coordinate axis expressing the air-conditioning capacity. On the coordinate plane, multiple data points corresponding to the actual values of the temperature difference ΔT_{io} and the air-conditioning capacity are plotted. The transmission and ventilation loads are proportional to the temperature difference ΔT_{io} , and the relationship between the temperature difference ΔT_{io} and the air-conditioning capacity can be expressed in a first order approximation. The learner 570 acquires an approximate straight line L_0 , expressing the relationship between the temperature difference ΔT_{io} and the air-conditioning capacity by applying an appropriate regression analysis, such as the least squares method, to the multiple data points plotted on the coordinate plane. Based on the correspondence between the approximate straight line L_0 and formula (11), the gradient of the approximate straight line L_0 corresponds to the coefficient α denoting the heat insulation efficiency, and an intercept of the approximate straight line L_0 corresponds to the internal heat amount Q_n .

[0196] Here, the transmission load is smaller as the heat insulating material used for the outer cover of the house 3 has a higher performance, or as the outer cover has a smaller area. The ventilation load is smaller as a gap in the outer cover that partitions the interior space 71 from the exterior space 72 is smaller. Thus, the gradient of the approximate straight line is smaller as the transmission load is smaller, or the ventilation load is smaller. More specifically, FIG. 19(b) shows different gradients of the approximate straight lines for different heat insulation efficiencies of the house 3. As shown in FIG. 19(b), the gradient of the approximate straight line L_{11} acquired for the house 3 with low heat insulation efficiency is greater than the gradient of the approximate straight line L_{12} acquired for the house 3 with high heat insulation efficiency. Thus, the learner 570 acquires the heat insulation efficiency of the interior space 71 from the gradient of the approximate straight line.

[0197] The intercept of the approximate straight line is smaller as the internal heat amount Q_n is smaller. More specifically, FIG. 19(c) shows different intercepts of

approximate straight lines according to the internal heat amounts Q_n . As shown in FIG. 19(c), the intercept of the approximate straight line L21 acquired for the house 3 with a large internal heat amount Q_n is greater than the intercept of the approximate straight line L22 acquired for the house 3 with a small internal heat amount Q_n . Thus, the learner

5 570 acquires the internal heat amount Q_n of the interior space 71 from the intercept of the approximate straight line. With reference to the historical information 150 stored in the storage 102, the learner 570 calculates the internal heat amount Q_n and the coefficient α indicating the heat insulation efficiency based on the relationship between the air-conditioning capacity and the temperature difference ΔT_{io} between the room and

10 outside temperatures T_i and T_o .

[0198] To increase the learning accuracy and speed, a large number of pieces of historical information 150 are to be collected within a short period. Thus, when the same temperature difference ΔT_{io} is acquired from different sets of an outside temperature T_o and a room temperature T_i , the learner 570 uses the same air-conditioning

15 capacity for the same temperature difference ΔT_{io} , and thus plots the data points of the same temperature difference ΔT_{io} on the coordinate plane. This structure does not acquire a heat characteristic formula for each outside temperature T_o or each room temperature T_i , and thus can increase the learning accuracy and speed. During the air-conditioning operation, update and learning of the historical information 150 are

20 repeated to acquire the changes in the heat characteristics of the interior space 71, and to increase the control accuracy. The heat characteristics are changed by, for example, increasing the internal heat amount Q_n with the use of an electric carpet in winter, or reducing the transmission load with partitioning of rooms.

[0199] A method for learning the coefficient β indicating the easiness of sunlight

25 entry into the interior space 71 will now be described. The learner 570 learns the coefficient β based on data pieces of room temperature T_i , window temperature T_w , and air-conditioning capacity acquired when the temperature difference ΔT_{io} between the

room and outside temperatures T_i and T_o is the same.

[0200] When the temperature difference ΔT_{io} is the same, the term $\alpha(T_o - T_i)$ in formula (11) above can be treated as a constant. In this case, the learner 570 can estimate the relationship between the air-conditioning capacity and the temperature difference ΔT_{iw} between the room and window temperatures T_i and T_w based on the term $\beta(T_w - T_i)$ in formula (11). More specifically, when multiple data points corresponding to the actual values of the temperature difference ΔT_{iw} and the air-conditioning capacity are plotted on the coordinate plane including a horizontal axis that is a coordinate axis expressing the temperature difference ΔT_{iw} between the room and window temperatures T_i and T_w , and a vertical axis that is a coordinate axis expressing the air-conditioning capacity, the relationship between the temperature difference ΔT_{iw} and the air-conditioning capacity can be expressed in a first order approximation, as in FIG. 19(a).

[0201] Here, the gradient of the approximate straight line is greater as sunlight more easily enters the interior space 71. The gradient of the approximate straight line is smaller as sunlight less easily enters the interior space 71. Thus, FIG. 19(b) can be similarly described by replacing “a house with low heat insulation efficiency” with “a house into which sunlight enters more easily,” and replacing “a house with high heat insulation efficiency” with “a house into which sunlight enters less easily.” The learner 570 acquires an approximate straight line expressing the relationship between the temperature difference ΔT_{iw} and the air-conditioning capacity by applying an appropriate regression analysis, such as the least squares method, to the multiple data points plotted on the coordinate plane. The learner 570 then learns a coefficient β denoting the easiness of sunlight entry into the interior space 71 from the gradient of the approximate straight line.

[0202] Hereafter, a method for increasing the learning accuracy will be described. The learner 570 learns the heat insulation efficiency based on the room temperature T_i ,

the outside temperature T_o , and the air-conditioning capacity when insolation is less than or equal to a threshold. More specifically, multiple data points plotted on the coordinate plane including a horizontal axis that is a coordinate axis expressing the temperature difference ΔT_{io} , and a vertical axis that is a coordinate axis expressing the

5 air-conditioning capacity, are limited to data points acquired when insolation is less than or equal to a threshold. The learner 570 determines whether data on the temperature difference ΔT_{io} and the air-conditioning capacity corresponding to the plotted data points is acquired when insolation decreases to or below a predetermined threshold before the data points corresponding to the temperature difference ΔT_{io} and the air-conditioning

10 capacity are plotted on the coordinate plane. When determining that the data on the temperature difference ΔT_{io} and the air-conditioning capacity corresponding to the plotted data points is acquired when insolation is less than or equal to the threshold, the learner 570 plots these data points on the coordinate plane. When determining that data on the temperature difference ΔT_{io} and the air-conditioning capacity corresponding to the

15 plotted data points is acquired under insolation greater than the threshold, the learner 570 does not plot these data points on the coordinate plane.

[0203] More specifically, among the multiple data points corresponding to the temperature difference ΔT_{io} and the air-conditioning capacity, the learner 570 plots, on the coordinate plane, the data points acquired when insolation is less than or equal to the

20 threshold. For example, the learner 570 determines that insolation is less than or equal to the threshold when the window temperature T_w is lower than the room temperature T_i , and determines that insolation is greater than the threshold when the window temperature T_w is higher than the room temperature T_i .

[0204] When the correlation between the temperature difference ΔT_{io} and the

25 air-conditioning capacity is learned, the relationship between the temperature difference ΔT_{io} and the air-conditioning capacity from data may be acquired when the effect of insolation is small. This structure reduces variations in the data due to the insolation

load. Thus, the coefficient α denoting the heat insulation efficiency expressed by the gradient and the internal heat amount Q_n expressed by the intercept can be acquired accurately. More specifically, the value α can be acquired easily with data acquired when insolation is less than or equal to a threshold using formula (11), instead of formula

- 5 (3). The learner 570 may be any unit that can acquire a gradient and an intercept of an approximate straight line from data on the temperature difference ΔT_{io} and the air-conditioning capacity, and may not actually plot data points on any coordinate plane.

[0205] The learner 570 may learn the heat insulation efficiency based on the room temperature T_i , the outside temperature T_o , and the air-conditioning capacity when the
10 change amount of the room temperature T_i is less than or equal to a reference value. The learner 570 may learn the easiness of sunlight entry based on the room temperature T_i , the window temperature T_w , and the air-conditioning capacity when the change amount of the room temperature T_i is less than or equal to the reference value.

[0206] More specifically, in a transient in which the room temperature T_i is
15 unstable, the exerted air-conditioning capacity is typically unstable. For example, while the room temperature T_i is changing greatly immediately after the activation of air-conditioning, the air-conditioning capacity contains the amount of heat in the room to be handled, and the apparent air-conditioning capacity is high. The learner 570 may thus restrict the multiple data points plotted on the coordinate plane to data points
20 acquired in a predetermined time period in which the change amount of the room temperature T_i is less than or equal to the reference value. The learner 570 can acquire an approximate straight line using data acquired when the room temperature T_i is stable. Thus, the heat insulation efficiency or the easiness of sunlight entry expressed by the gradient of the approximate straight line, and the internal heat amount Q_n expressed by
25 the intercept can be acquired accurately.

[0207] The learner 570 calculates the air-conditioning capacity for the sensible heat with, for example, the effectiveness-number of transfer units (ε -NTU) method. The

total heat capacity, the sensible heat capacity, and the latent heat capacity are expressed by formulas (12) to (14) described below:

total heat capacity = enthalpy efficiency * air density * airflow rate * (suction air enthalpy of the indoor unit 13 – saturated air enthalpy of pipe temperature of the indoor heat exchanger 25) (12),

sensible heat capacity = temperature efficiency * air density * air specific heat * airflow rate * (suction air temperature of the indoor unit 13 – pipe temperature of the indoor heat exchanger 25) (13), and

latent heat capacity = total heat capacity – sensible heat capacity (14).

[0208] With reference to FIG. 20, a data processing method for increasing the learning accuracy will now be described. When the learner 570 actually learns based on the historical information 150, data points may not be plotted uniformly on the coordinate plane. For example, in the example shown in FIG. 20, more data points are distributed in an area having a large temperature difference ΔT_{io} , or more specifically, in an area having a temperature difference ΔT_{io} from T_3 to T_4 . All the data points are plotted with solid circles. When all the data points are used, the gradient and the intercept of an approximate straight line may not be acquired accurately due to the dominant area including many data points. FIG. 20 shows an example of an approximate straight line L31 having a small gradient and a large intercept acquired using all the data points. In this case, a house 3 has high heat insulation efficiency and a large internal heat amount Q_n , causing a large error.

[0209] The learner 570 may acquire an approximate straight line using typical data points indicated with open circles, instead of all the data points indicated with solid circles. FIG. 20 shows an example where the area of the temperature difference ΔT_{io} is classified into multiple sections each having a predetermined temperature range, and one typical data point is acquired for each temperature range. The typical data point is, for example, a data point denoting the average of all the data points belonging to one section.

The average is acquired for each of the temperature difference ΔT_{io} and the air-conditioning capacity. In other words, the learner 570 averages each of actual values of the temperature difference Δ and the air-conditioning capacity in each one of the sections on the coordinate plane to integrate the multiple data points in the section into one typical data point. The learner 570 then acquires an approximate straight line using the integrated typical data points.

[0210] In the example shown in FIG. 20, the gradient of an approximate straight line L32 acquired using the typical data points is greater than the gradient of the approximate straight line L31 acquired using all the data points. The intercept of the approximate straight line L32 is smaller than the intercept of the approximate straight line L31. With the typical data points acquired for the respective sections, the gradient and the intercept of the approximate straight line can be more accurately acquired than using all the data points. This method enables accurate learning also when, for example, the number of data pieces is small or the conditions are unbalanced, as when the air-conditioning device 1 starts being used.

[0211] The air-conditioning device 1 according to Embodiment 4 learns the heat characteristics of the interior space 71, and estimates the steady sensible heat load Q_s based on the learning results. Thus, the steady sensible heat load Q_s used to maintain the room temperature T_i at the set temperature T_m can be accurately estimated. When, for example, the room temperature T_i is 27 °C, a typical air-conditioning device usually air-conditions the room in the cooling mode. However, such an air-conditioning device fails to dehumidify a space in which the steady sensible heat load Q_s is small, such as a house having high heat insulation efficiency, in the cooling mode with the refrigerant in the indoor heat exchanger 25 having its evaporation temperature increasing. In that case, switching to the dehumidification mode increases comfort. The air-conditioning device 1 according to Embodiment 4 estimates the heat characteristics of the interior space 71 by learning. The air-conditioning device 1 can thus provide comfortable air-conditioning

with smaller changes in the room temperature at the mode switching under various weather conditions, building conditions, and living conditions.

[0212] Embodiment 5

Embodiment 5 of the present disclosure will now be described. In the above
 5 embodiments, the sensible heat thresholds Q_{s1} to Q_{s4} or the temperature thresholds ΔT_1 to ΔT_4 are fixed to predetermined values. In Embodiment 5, the air-conditioning device 1 corrects the first and second sensible heat thresholds Q_{s1} and Q_{s2} in accordance with situations.

[0213] FIG. 21 is a functional block diagram of an outdoor-unit controller 51b
 10 included in an air-conditioning device 1 according to Embodiment 5. The outdoor-unit controller 51b has a hardware configuration similar to the hardware configuration of Embodiment 1, and will not be described.

[0214] As shown in FIG. 21, the outdoor-unit controller 51b includes, as functional
 units, an acquirer 510, an estimator 520, a determiner 530, an air-conditioning controller
 15 540, an indicator 550, an information updater 560, and a learner 570. The functions of the acquirer 510, the estimator 520, the determiner 530, the air-conditioning controller 540, and the indicator 550 are the same as the functions in Embodiment 1.

[0215] More specifically, the acquirer 510 acquires load information, such as the
 room temperature T_i , the outside temperature T_o , and the window temperature T_w . The
 20 air-conditioning controller 540 switches the operation mode in accordance with the steady sensible heat load Q_s that is an index based on, for example, the room temperature T_i , the outside temperature T_o , and the window temperature T_w acquired by the acquirer 510, and causes the air-conditioning unit 110 to air-condition the interior space 71.
 More specifically, when the steady sensible heat load Q_s decreases below a threshold
 25 while the air-conditioning unit 110 is air-conditioning the interior space 71 in a first mode, the air-conditioning controller 540 switches the operation mode to a second mode in which the maximum sensible heat capacity of the air-conditioning unit 110 is lower than

in the first mode. Here, when the threshold is the first sensible heat threshold Q_{s1} , the first and second modes correspond to the cooling mode and the first dehumidification mode. When the threshold is the second sensible heat threshold Q_{s2} , the first and second modes correspond to the first and second dehumidification modes.

- 5 [0216] A corrector 580 corrects the first and second sensible heat thresholds Q_{s1} and Q_{s2} in accordance with the room temperature T_i acquired by the acquirer 510. More specifically, the corrector 580 corrects the first and second sensible heat thresholds Q_{s1} and Q_{s2} in accordance with changes in the room temperature T_i after the operation mode is switched by the air-conditioning controller 540. The corrector 580 is
- 10 implemented by the controller 101. The corrector 580 functions as correction means.
- [0217] The room temperature T_i increasing after the operation mode is switched from the cooling mode to the first dehumidification mode corresponds to when the room temperature T_i fails to be retained due to the sensible heat capacity in the first dehumidification mode being smaller than the sensible heat load. In this case, the
- 15 corrector 580 lowers the first sensible heat threshold Q_{s1} to prevent the sensible heat capacity in the first dehumidification mode from decreasing below the sensible heat load. Similarly, when the room temperature T_i increases after the operation mode is switched from the first dehumidification mode to the second dehumidification mode, the corrector 580 lowers the second sensible heat threshold Q_{s2} .
- 20 [0218] In contrast, the room temperature T_i not increasing despite the increase in the outside temperature T_o after the operation mode is switched from the cooling mode to the first dehumidification mode corresponds to when the room temperature T_i is sufficiently retained with the sensible heat capacity in the first dehumidification mode greater than the sensible heat load. In this case, the corrector 580 increases the first
- 25 sensible heat threshold Q_{s1} to expand the range over which the first dehumidification mode covers. Similarly, when the room temperature T_i does not increase despite the increase in the outside temperature T_o after the operation mode is switched from the first

dehumidification mode to the second dehumidification mode, the corrector 580 increases the second sensible heat threshold Q_{s2} .

[0219] The initial value of the first sensible heat threshold Q_{s1} is set to, for example, a maximum sensible heat capacity Q_{s1max} possible with the air-conditioning unit 110 in the first dehumidification mode. The initial value of the second sensible heat threshold Q_{s2} is set to, for example, a maximum sensible heat capacity Q_{s2max} possible with the air-conditioning unit 110 in the second dehumidification mode. The maximum sensible heat capacity is thus set to the initial value of the threshold to allow the air-conditioning unit 110 to have the sensible heat capacity that retains the room temperature T_i after the operation mode switching. When the room temperature T_i increases after the operation mode is switched, the corrector 580 lowers the sensible heat thresholds Q_{s1} and Q_{s2} to correct the maximum sensible heat capacity by reducing the capacity. When the room temperature T_i does not increase despite the increase in the outside temperature T_o after the operation mode is switched, the corrector 580 increases the sensible heat thresholds Q_{s1} and Q_{s2} to correct the maximum sensible heat capacity by increasing the capacity.

[0220] More specifically, when the room temperature T_i either increases or does not increase despite the increase in the outside temperature T_o after the operation mode switching from the cooling mode to the first dehumidification mode, the corrector 580 corrects the first sensible heat threshold Q_{s1} in accordance with the difference between the sensible heat capacity of the air-conditioning unit 110 and the first sensible heat threshold Q_{s1} . When the room temperature T_i increases in the first dehumidification mode after switching, the sensible heat capacity is highly likely below the first sensible heat threshold Q_{s1} . In this case, the corrector 580 lowers the first sensible heat threshold Q_{s1} further as the difference between the sensible heat capacity and the first sensible heat threshold Q_{s1} is larger.

[0221] In the first dehumidification mode after switching, when the room temperature T_i does not increase despite the increase in the outside temperature T_o , the

sufficient large sensible heat capacity is highly likely greater the first sensible heat threshold Q_{s1} . In this case, the corrector 580 increases the first sensible heat threshold Q_{s1} further as the difference between the sensible heat capacity and the first sensible heat threshold Q_{s1} is larger.

5 [0222] The corrector 580 corrects the first sensible heat threshold Q_{s1} in accordance with the number of times the sensible heat capacity and the first sensible heat threshold Q_{s1} deviate from each other. The number of times the sensible heat capacity and the first sensible heat threshold Q_{s1} deviate from each other is the number of times the maximum difference between the sensible heat capacity and the first sensible heat
10 threshold Q_{s1} exceeds a predetermined value when the room temperature T_i either increases or does not increase despite the increase in the outside temperature T_o after the operation mode switching. The corrector 580 stores the number of times in the storage 102, and corrects the first sensible heat threshold Q_{s1} by a greater degree as the number of times of the deviation is greater.

15 [0223] Thus, the corrector 580 corrects the first sensible heat threshold Q_{s1} in accordance with the degree of deviation of the sensible heat capacity from the first sensible heat threshold Q_{s1} and the number of times the sensible heat capacity and the first sensible heat threshold Q_{s1} deviate from each other. The same applies to the second sensible heat threshold Q_{s2} . After the corrector 580 corrects the first or second
20 sensible heat threshold Q_{s1} or Q_{s2} , the air-conditioning controller 540 controls air-conditioning with the corrected first or second sensible heat threshold Q_{s1} or Q_{s2} . More specifically, the air-conditioning controller 540 switches the operation mode in accordance with whether the room temperature T_i is higher than the corrected first or second sensible heat threshold Q_{s1} or Q_{s2} , and causes the air-conditioning unit 110 to
25 air-condition the interior space 71.

[0224] Correcting the sensible heat thresholds Q_{s1} and Q_{s2} in accordance with situations allows the sensible heat thresholds Q_{s1} and Q_{s2} to be acquired appropriate for

the heat characteristics of the house 3 and the environments of the house 3. This structure reduces operation mode switching at excessively early timing or when the comfort decreases, as in the timing when a temperature reversion occurs. This structure can air-condition the interior space 71 by switching the operation mode at appropriate timing to increase comfort, and allows air-conditioning in an appropriate operation mode to provide energy saving.

[0225] Learning of Sensible Heat Threshold

In Embodiment 5, the learner 570 learns the relationship between the temperature difference ΔT_{io} between the room temperature T_i and the outside temperature T_o acquired by the acquirer 510, and the first and second sensible heat thresholds Q_{s1} and Q_{s2} corrected by the corrector 580. More specifically, when the corrector 580 corrects the first or second sensible heat threshold Q_{s1} or Q_{s2} , the information updater 560 stores, in the historical information 150, the corrected sensible heat threshold Q_{s1} or Q_{s2} in association with the current temperature difference ΔT_{io} . The historical information 150 stores the relationship between the first or second sensible heat threshold Q_{s1} or Q_{s2} corrected by the corrector 580 and the current temperature difference ΔT_{io} as a past record. The learner 570 learns the relationship between the temperature difference ΔT_{io} and the first or second sensible heat threshold Q_{s1} or Q_{s2} by referring to the historical information 150. When the maximum frequency of the compressor 21 varies under different environmental conditions, the historical information 150 may store the maximum frequency and the first and second sensible heat thresholds Q_{s1} and Q_{s2} in a manner associated with each other, instead of the temperature difference ΔT_{io} .

[0226] FIG. 22 is a graph showing the first sensible heat threshold Q_{s1} plotted for each temperature difference ΔT_{io} . In FIG. 22, the solid circles denote the initial values of the first sensible heat threshold Q_{s1} , and the open circles denote the first sensible heat thresholds Q_{s1} corrected from the initial values by the corrector 580. With a method such as the least squares method on such plots, the learner 570 approximates the

relationship between the first sensible heat threshold Q_{s1} and the temperature difference ΔT_{io} using, for example, correlation lines drawn with dotted lines in FIG. 22. The learner 570 uses a linear expression as a correlation line for convenience of calculation.

[0227] When the corrector 580 corrects the first sensible heat threshold Q_{s1} , the learner 570 associates the corrected first sensible heat threshold Q_{s1} with the current temperature difference ΔT_{io} to update the plot. The learner 570 then approximates the updated plot with a new correlation line to update the learning results. Thus, the learner 570 learns the relationship between the first sensible heat threshold Q_{s1} and the temperature difference ΔT_{io} corrected by the corrector 580. The learner 570 also learns the relationship between the second sensible heat threshold Q_{s2} and the temperature difference ΔT_{io} , as in the first sensible heat threshold Q_{s1} .

[0228] When the acquirer 510 acquires new room and outside temperatures T_i and T_o , the corrector 580 corrects the sensible heat thresholds Q_{s1} and Q_{s2} based on the relationship learned by the learner 570 and the temperature difference ΔT_{io} between the newly acquired room and outside temperatures T_i and T_o . The air-conditioning controller 540 switches the air-conditioning operation mode using the sensible heat thresholds Q_{s1} and Q_{s2} corrected by the corrector 580. Learning the relationship between the temperature difference ΔT_{io} and the sensible heat thresholds Q_{s1} and Q_{s2} and correcting the sensible heat thresholds Q_{s1} and Q_{s2} in accordance with the current temperature difference ΔT_{io} allow more accurate correction of the sensible heat thresholds Q_{s1} and Q_{s2} in accordance with situations. In particular, this correction is more effective when the second dehumidification mode is a reheating dehumidification mode in which the sensible heat threshold is likely to change more greatly with changes in the temperature difference ΔT_{io} than in other dehumidification modes.

[0229] As in Embodiment 2, the air-conditioning controller 540 may switch the operation mode in accordance with the temperature difference ΔT between the room and set temperatures T_i and T_m . In this case, the corrector 580 corrects the first and second

temperature thresholds $\Delta T1$ and $\Delta T2$ instead of correcting the first and second sensible heat thresholds $Qs1$ and $Qs2$.

[0230] The first sensible heat threshold $Qs1$ used for determining whether the cooling mode is to be switched to the first dehumidification mode may be smaller by about 1γ to 2γ than the first sensible heat threshold $Qs1$ used for determining whether the first dehumidification mode is to be switched to the cooling mode. The same applies to the second to fourth sensible heat thresholds $Qs2$ to $Qs4$. Thus, the operation mode switching having hysteresis can reduce frequent switching of the operation mode within a short period. Here, γ denotes the heat quantity used, for example, to increase the room temperature Ti by $1\text{ }^{\circ}\text{C}$. Here, γ may be acquired through learning. This allows precise operations by 1 to $2\text{ }^{\circ}\text{C}$, thus allowing operation mode switching at appropriate timing while avoiding frequent switching.

[0231] Modifications

Although the embodiments of the present disclosure are described above, various modifications or applications are possible in implementing the present disclosure.

[0232] In the above embodiments, for example, the air-conditioning device 1 air-conditions the interior space 71 in any operation mode of low-cooling dehumidification, double-fan dehumidification, dewpoint-temperature dehumidification, partial-cooling dehumidification, extensive dehumidification, reheating dehumidification, and air blowing. In some embodiments of the present disclosure, the air-conditioning device 1 may eliminate the air-conditioning function in any of these operation modes. When the air-conditioning device 1 eliminates the function of reheating dehumidification, the indoor unit 13 may eliminate the two heat exchangers 25a and 25b and the expansion valve 26, but include one indoor heat exchanger for heat exchange between the air in the interior space 71 and the refrigerant. When the air-conditioning device 1 eliminates the function of double-fan dehumidification, the indoor unit 13 may eliminate the two indoor fans 33a and 33b, but include one indoor fan that blows air toward the indoor heat

exchanger 25.

[0233] In the above embodiments, the first dehumidification mode corresponds to low-cooling dehumidification, and the second dehumidification mode corresponds to double-fan dehumidification, dewpoint-temperature dehumidification, partial-cooling dehumidification, or extensive dehumidification. In some embodiments, the first dehumidification mode and the second dehumidification mode may be any operation mode, but the maximum sensible heat capacity is higher in the first dehumidification mode than in the second dehumidification mode. For example, the first dehumidification mode may be low-cooling dehumidification, double-fan dehumidification, dewpoint-temperature dehumidification, partial-cooling dehumidification, or extensive dehumidification, and the second dehumidification mode may be reheating dehumidification. Either of the first or second dehumidification mode may be a controllable dehumidification mode.

[0234] The automatic mode may include a heating mode. The operation mode is switchable between the heating and cooling modes based on the outside temperature T_o or the set temperature T_m . For example, the air-conditioning controller 540 switches the operation mode to the heating mode when the outside temperature T_o or the set temperature T_m is lower than a predetermined value, and switches the operation mode to the cooling mode when the outside temperature T_o or the set temperature T_m is higher than a predetermined value.

[0235] In the above embodiments, the acquirer 510 acquires the window temperature T_w detected by the infrared sensor 43 as an index indicating insolation. In some embodiments of the present disclosure, the acquirer 510 may acquire any information that directly or indirectly indicates insolation as an index of insolation instead of the window temperature T_w . For example, the acquirer 510 may acquire light intensity in the interior space 71 detected by a light intensity sensor or an image of the interior space 71 captured by a camera, and estimate insolation in the interior space 71

based on the light intensity or the image. The acquirer 510 may acquire information about the power generation capacity of a solar power generation system through an external communication network, or information indicating the weather data including insolation information through an external communication network.

5 [0236] In the above embodiments, the outdoor-unit controller 51 has the functions of the components shown in FIG. 5, 16, or 21, and functions as a control device that controls the air-conditioning device 1. In some embodiments of the present disclosure, the indoor-unit controller 53 or a device external to the air-conditioning device 1 may include part or all of these functions.

10 [0237] For example, as shown in FIG. 23, in an air-conditioning system S including the air-conditioning device 1 and a control device 100, the control device 100 connected to the air-conditioning device 1 through a communication network N may include the functions of the components shown in FIG. 5, 16, or 21. For example, the communication network N may be a home network conformance to ECHONET Lite, and
15 the control device 100 may be a controller for a home energy management system (HEMS) that manages power in the house 3. In some embodiments, the communication network N may be a wide area network such as the Internet, and the control device 100 may be a server that controls the air-conditioning device 1 from outside the house 3.

[0238] When the control device 100 has each of the above functions, the
20 air-conditioning system S may include multiple air-conditioning devices 1 controlled by the control device 100. In this case, the number of air-conditioning devices 1 is not limited. The control device 100 may control any device that includes a refrigerating cycle such as the air-conditioning device 1, and may have any structure in detail.

[0239] In the above embodiments, the house 3 is described as an example where the
25 air-conditioning device 1 is installed. In some embodiments of the present disclosure, a target space in which the air-conditioning device 1 is to be installed may be, for example, an apartment house, an office building, a facility, or a factory. Instead of a room in the

house 3, the target space may be any space to be air-conditioned by the air-conditioning device 1. The air-conditioning device 1 may not include one outdoor unit 11 and one indoor unit 13 but may include one outdoor unit 11 and multiple indoor units 13, or may include multiple indoor units 13 including an indoor unit 13 for cooling and an indoor unit 13 for heating.

[0240] In the above embodiments, a user operates the remote controller 55 to input the set temperature and humidity T_m and RH_m . In some embodiments, a user may designate a high, medium, or low level in cooling or dehumidification through the remote controller 55 to determine the corresponding set temperature or humidity T_m or RH_m .

10 In some embodiments, a user interface other than the remote controller 55 may receive a user input, or output indication information from the indicator 550.

[0241] In the above embodiments, the CPU in the controller 101 executes a program stored in the ROM or the storage 102 to function as each component shown in FIG. 5, 16, or 21. In some embodiments of the present disclosure, the controller 101 may be dedicated hardware. Examples of dedicated hardware include a single circuit, a complex circuit, a programmed processor, an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA), and a combination of two or more of these. When the controller 101 is dedicated hardware, the functions of the respective components may be implemented by separate pieces of hardware or by a single piece of hardware.

[0242] The functions of the respective components may be partly implemented by dedicated hardware and partly by software or firmware. The controller 101 can thus implement the above functions using hardware, software, and firmware either alone or in combination.

25 [0243] When a program defining the operation of the controller 101 according to the present disclosure is applied to an existing computer such as a PC or an information terminal, the computer may be function as the air-conditioning device 1 or the control

device 100 according to the present disclosure.

[0244] Such a program may be distributed in any manner, and may be, for example, stored in a computer readable recording medium such as a compact disc ROM (CD-ROM), a digital versatile disc (DVD), a magneto-optical (MO) disc, or a memory card, or may be distributed through a communication network such as the Internet.

[0245] The foregoing describes some example embodiments for explanatory purposes. Although the foregoing discussion has presented specific embodiments, persons skilled in the art will recognize that changes may be made in form and detail without departing from the broader spirit and scope of the invention. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense. This detailed description, therefore, is not to be taken in a limiting sense, and the scope of the invention is defined only by the included claims, along with the full range of equivalents to which such claims are entitled.

Industrial Applicability

[0246] The present disclosure is applicable to an air-conditioning device.

Reference Signs List

[0247]

- 1 Air-conditioning device
- 3 House
- 20 11 Outdoor unit
- 13 Indoor unit
- 21 Compressor
- 22 Four-way valve
- 23 Outdoor heat exchanger
- 25 24, 26 Expansion valve
- 25 Indoor heat exchanger
- 25a, 25b Heat exchanger

	31	Outdoor fan
	33a, 33b	Indoor fan
	41	Temperature sensor
	42	Humidity sensor
5	43	Infrared sensor
	51, 51a, 51b	Outdoor-unit controller
	53	Indoor-unit controller
	55	Remote controller
	61	Refrigerant pipe
10	63	Communication line
	71	Interior space
	72	Exterior space
	75	Window
	100	Control device
15	101	Controller
	102	Storage
	103	Clock
	104	Communication unit
	110	Air-conditioning unit
20	130	Display
	131	Tendency information
	132	Operation mode information
	133	Determination information
	134	Control information
25	150	Historical information
	510	Acquirer
	520	Estimator

CLAIMS

1. An air-conditioning device, comprising:

air-conditioning means for air-conditioning a target space, the air-conditioning means including

a compressor to compress a refrigerant and circulate the refrigerant through a refrigerant pipe,

a heat exchanger to cause heat exchange between air in the target space and the refrigerant circulating through the refrigerant pipe, and a blower to feed air in the target space to the heat exchanger;

acquiring means for acquiring a temperature and a humidity in the target space; and

air-conditioning control means for switching an operation mode, in accordance with the temperature and the humidity acquired by the acquiring means, between a cooling mode in which the air-conditioning means cools the target space, a dehumidification mode in which the air-conditioning means dehumidifies the target space, and an air-blowing mode in which the compressor is stopped without the blower stopping air blowing,

wherein

in a case in which a humidity difference between the humidity acquired by the acquiring means and a set humidity in the target space is greater than a first humidity threshold, the air-conditioning control means switches the operation mode to the dehumidification mode when a temperature difference between the temperature acquired by the acquiring means and a set temperature in the target space decreases below a first temperature threshold during air-conditioning of the target space performed by the air-conditioning means in the cooling mode,

in a case in which the humidity difference is smaller than a second humidity threshold, the air-conditioning control means switches the operation mode to the air-blowing mode when the temperature difference decreases below a fourth temperature threshold during air-conditioning of the target space performed by the

air-conditioning means in the cooling mode,

in a case in which the temperature difference is smaller than the first temperature threshold, the air-conditioning control means switches the operation mode to the dehumidification mode when the humidity difference exceeds the first humidity threshold during air-conditioning of the target space performed by the air-conditioning means in the air-blowing mode,

in a case in which the temperature difference is smaller than the fourth temperature threshold, the air-conditioning control means switches the operation mode to the air-blowing mode when the humidity difference decreases below the second humidity threshold during air-conditioning of the target space performed by the air-conditioning means in the dehumidification mode,

the first humidity threshold is greater than the second humidity threshold, and
the first temperature threshold is greater than the fourth temperature threshold.

2. The air-conditioning device according to claim 1, wherein

in the case in which the humidity difference is greater than the first humidity threshold, the air-conditioning control means switches the operation mode to a second dehumidification mode in which a sensible heat capacity is smaller than in the dehumidification mode when the temperature difference decreases below a second temperature threshold that is smaller than the first temperature threshold during air-conditioning of the target space performed by the air-conditioning means in the dehumidification mode.

3. The air-conditioning device according to claim 2, wherein

in the case in which the humidity difference is greater than the first humidity threshold, the air-conditioning control means stops the compressor when the temperature difference decreases below a third temperature threshold that is smaller than the second temperature threshold during air-conditioning of the target space performed by the air-conditioning means in the second dehumidification mode.

4. The air-conditioning device according to any one of claims 1 to 3, wherein the acquiring means further acquires a temperature in an external space external to the target space, and

the air-conditioning control means switches the operation mode between the cooling mode and the dehumidification mode in accordance with the temperature difference and a sensible heat load of the target space defined by the temperature in the external space acquired by the acquiring means.

5. The air-conditioning device according to any one of claims 1 to 4, wherein the acquiring means further acquires a humidity in an external space external to the target space, and

the air-conditioning control means switches the operation mode between the dehumidification mode and the air-blowing mode in accordance with the humidity difference and a latent heat load of the target space defined by the humidity in the external space acquired by the acquiring means.

6. A control device for controlling an air-conditioning device to air-condition a target space, the air-conditioning device including a compressor to compress a refrigerant and circulate the refrigerant through a refrigerant pipe, a heat exchanger to cause heat exchange between air in the target space and the refrigerant circulating through the refrigerant pipe, and a blower to feed air in the target space to the heat exchanger, the control device comprising:

acquiring means for acquiring a temperature and a humidity in the target space; and

air-conditioning control means for switching an operation mode, in accordance with the temperature and the humidity acquired by the acquiring means, between a cooling mode in which the air-conditioning device cools the target space, a dehumidification mode in which the air-conditioning device dehumidifies the target space, and an air-blowing mode in which the compressor is stopped without the blower

stopping air blowing,

wherein

in a case in which a humidity difference between the humidity acquired by the acquiring means and a set humidity in the target space is greater than a first humidity threshold, the air-conditioning control means switches the operation mode to the dehumidification mode when a temperature difference between the temperature acquired by the acquiring means and a set temperature in the target space decreases below a first temperature threshold during air-conditioning of the target space performed by the air-conditioning device in the cooling mode,

in a case in which the humidity difference is smaller than a second humidity threshold, the air-conditioning control means switches the operation mode to the air-blowing mode when the temperature difference decreases below a fourth temperature threshold during air-conditioning of the target space performed by the air-conditioning device in the cooling mode,

in a case in which the temperature difference is smaller than the first temperature threshold, the air-conditioning control means switches the operation mode to the dehumidification mode when the humidity difference exceeds the first humidity threshold during air-conditioning of the target space performed by the air-conditioning device in the air-blowing mode,

in a case in which the temperature difference is smaller than the fourth temperature threshold, the air-conditioning control means switches the operation mode to the air-blowing mode when the humidity difference decreases below the second humidity threshold during air-conditioning of the target space performed by the air-conditioning device in the dehumidification mode,

the first humidity threshold is greater than the second humidity threshold, and
the first temperature threshold is greater than the fourth temperature threshold.

7. An air-conditioning method for air-conditioning a target space with a compressor to compress a refrigerant and circulate the refrigerant through a refrigerant

pipe, a heat exchanger to cause heat exchange between air in the target space and the refrigerant circulating through the refrigerant pipe, and a blower to feed air in the target space to the heat exchanger, the method comprising:

acquiring a temperature and a humidity in the target space;

switching an operation mode, in accordance with the acquired temperature and the acquired humidity, between a cooling mode for cooling the target space, a dehumidification mode for dehumidifying the target space, and an air-blowing mode for stopping the compressor without stopping air blowing of the blower;

in a case in which a humidity difference between the humidity and a set humidity in the target space is greater than a first humidity threshold, switching the operation mode to the dehumidification mode when a temperature difference between the temperature and a set temperature in the target space decreases below a first temperature threshold during air-conditioning of the target space in the cooling mode;

in a case in which the humidity difference is smaller than a second humidity threshold, switching the operation mode to the air-blowing mode when the temperature difference decreases below a fourth temperature threshold during air-conditioning of the target space in the cooling mode;

in a case in which the temperature difference is smaller than the first temperature threshold, switching the operation mode to the dehumidification mode when the humidity difference exceeds the first humidity threshold during air-conditioning of the target space in the air-blowing mode; and

in a case in which the temperature difference is smaller than the fourth temperature threshold, switching the operation mode to the air-blowing mode when the humidity difference decreases below the second humidity threshold during air-conditioning of the target space in the dehumidification mode,

wherein

the first humidity threshold is greater than the second humidity threshold, and

the first temperature threshold is greater than the fourth temperature threshold.

8. A program causing a computer to function as acquiring means and air-conditioning control means, the computer being to control an air-conditioning device to air-condition a target space, the air-conditioning device including a compressor to compress a refrigerant and circulate the refrigerant through a refrigerant pipe, a heat exchanger to cause heat exchange between air in the target space and the refrigerant circulating through the refrigerant pipe, and a blower to feed air in the target space to the heat exchanger, wherein

the acquiring means acquires a temperature and a humidity in the target space,

the air-conditioning control means switches an operation mode, in accordance with the temperature and the humidity acquired by the acquiring means, between a cooling mode in which the air-conditioning device cools the target space, a dehumidification mode in which the air-conditioning device dehumidifies the target space, and an air-blowing mode in which the compressor is stopped without the blower stopping air blowing,

in a case in which a humidity difference between the humidity acquired by the acquiring means and a set humidity in the target space is greater than a first humidity threshold, the air-conditioning control means switches the operation mode to the dehumidification mode when a temperature difference between the temperature acquired by the acquiring means and a set temperature in the target space decreases below a first temperature threshold during air-conditioning of the target space performed by the air-conditioning device in the cooling mode,

in a case in which the humidity difference is smaller than a second humidity threshold, the air-conditioning control means switches the operation mode to the air-blowing mode when the temperature difference decreases below a fourth temperature threshold during air-conditioning of the target space performed by the air-conditioning device in the cooling mode,

in a case in which the temperature difference is smaller than the first temperature threshold, the air-conditioning control means switches the operation mode to the dehumidification mode when the humidity difference exceeds the first humidity

threshold during air-conditioning of the target space performed by the air-conditioning device in the air-blowing mode,

in a case in which the temperature difference is smaller than the fourth temperature threshold, the air-conditioning control means switches the operation mode to the air-blowing mode when the humidity difference decreases below the second humidity threshold during air-conditioning of the target space performed by the air-conditioning device in the dehumidification mode,

the first humidity threshold is greater than the second humidity threshold, and the first temperature threshold is greater than the fourth temperature threshold.