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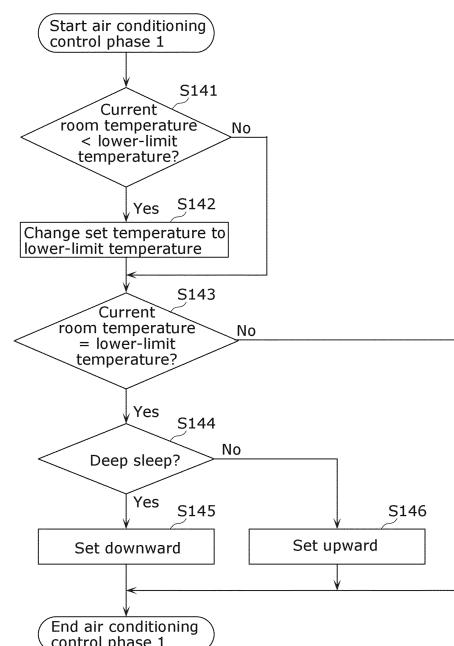
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(54) **CONTROL METHOD, AIR CONDITIONER, AND PROGRAM**

(57) A control method performed by a computer for controlling an air conditioner provided in a room includes: obtaining position information of a user in the room and a sleep depth that is sleep information of the user; controlling an airflow direction of the air conditioner in a first stage of the sleep depth based on the position information, such that the air discharged by the air conditioner avoids the user (S146); and controlling the airflow direction in a second stage of the sleep depth based on the position information, such that the air discharged by the air conditioner hits the user (S145).

FIG. 24



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Description

[Technical Field]

5 **[0001]** The present invention relates to a method of controlling an air conditioner while a user is sleeping.

[Background Art]

10 **[0002]** Patent Literature (PTL) 1 discloses an invention related to a method of operating an air conditioner during sleep.
[0003] PTL 1 discloses an invention related to an air conditioning operation performed by a humidifier during sleep. PTL 1 proposes a method of sensing a sleep state of a user to perform an operation while avoiding discharging air toward a person during light sleep and perform a condensation removing operation during deep sleep.

[Citation List]

15

[Patent Literature]

[0004] [PTL 1] Japanese Unexamined Patent Application Publication No. 2016-176629

20 [Summary of Invention]

[Technical Problem]

25 **[0005]** PTL 1 does not mention a method of improving the thermal comfort of the user during sleep by using the sleep state of the user. The present invention provides a control method for realizing a thermal environment comfortable for a user during sleep.

[Solution to Problem]

30 **[0006]** A control method according to one aspect of the present disclosure is a control method performed by a computer for controlling an air conditioner provided in a room. The control method includes: obtaining position information of a user in the room and a sleep depth which indicates sleep information of the user; controlling an airflow direction of the air conditioner in a first stage of the sleep depth based on the position information, such that an air discharged by the air conditioner avoids the user; and controlling the airflow direction in a second stage of the sleep depth based on the position information, such that the air discharged by the air conditioner hits the user, the second stage being a sleep depth that is deeper than the first stage.

35 **[0007]** A control method according to another aspect of the present disclosure is a control method performed by a computer for controlling an air conditioner provided in a room. The control method includes: obtaining a sleep depth which indicates sleep information of a user in the room; controlling an airflow direction of the air conditioner to be directed upward in the room in a first stage of the sleep depth; and controlling the airflow direction of the air conditioner to be directed downward in the room in a second stage of the sleep depth, the second stage being a sleep depth that is deeper than the first stage.

40 **[0008]** An air conditioner according to another aspect of the present disclosure includes a processor and a memory. The air conditioner is provided in a room. Using the memory, the processor performs: obtaining position information of a user in the room and a sleep depth which indicates sleep information of the user; controlling an airflow direction of the air conditioner in a first stage of the sleep depth based on the position information, such that the air discharged by the air conditioner avoids the user; and controlling the airflow direction of the air conditioner in a second stage of the sleep depth based on the position information, such that the air discharged by the air conditioner hits the user, the second stage being a sleep depth that is deeper than the first stage.

50 **[0009]** General and specific aspects disclosed above may be implemented using a system, an integrated circuit, a computer program, or a non-transitory computer-readable recording medium such as a CD-ROM, or any combination of systems, integrated circuits, computer programs, or non-transitory computer-readable recording media.

[Advantageous Effects of Invention]

55

[0010] A control method according to the present disclosure is capable of controlling an air conditioner according to a sleep state of a user during sleep, and is capable of performing a temperature control comfortable for the user without awakening the user.

[Brief Description of Drawings]

[0011]

5 [FIG. 1]
 FIG. 1 illustrates an overview of a service according to the present embodiment.
 [FIG. 2]
 FIG. 2 illustrates service type 1 (own data center type).
 [FIG. 3]
 10 FIG. 3 illustrates service type 2 (IaaS type).
 [FIG. 4]
 FIG. 4 illustrates service type 3 (PaaS type).
 [FIG. 5]
 FIG. 5 illustrates service type 4 (SaaS type).
 15 [FIG. 6]
 FIG. 6 schematically illustrates an air conditioning control system according to the present embodiment.
 [FIG. 7]
 FIG. 7 is a block diagram illustrating an example of a hardware configuration of an air conditioner according to the present embodiment.
 20 [FIG. 8]
 FIG. 8 is a block diagram illustrating an example of a hardware configuration of a cloud server according to the present embodiment.
 [FIG. 9]
 FIG. 9 is a block diagram illustrating an example of a hardware configuration of a sleep state detector according to the present embodiment.
 25 [FIG. 10]
 FIG. 10 is a block diagram illustrating a configuration of the air conditioning control system according to the present embodiment.
 [FIG. 11]
 30 FIG. 11 illustrates a graph indicating a relationship between peoples' sleep depth or features and elapsed sleep time.
 [FIG. 12]
 FIG. 12 illustrates a table structure of data including air conditioning sensing information and air conditioning control information.
 [FIG. 13]
 35 FIG. 13 illustrates a table structure of data including sleep state information.
 [FIG. 14]
 FIG. 14 illustrates an example of a screen on an application at the time of setting before sleeping.
 [FIG. 15]
 FIG. 15 illustrates examples of screens on the application after awakening.
 40 [FIG. 16]
 FIG. 16 illustrates an example of a structure of a table for managing subjective evaluations on thermal environment.
 [FIG. 17]
 FIG. 17 illustrates an example of a structure of a user table of setting database (DB).
 [FIG. 18]
 45 FIG. 18 illustrates an example of a structure of a schedule table of the setting DB.
 [FIG. 19]
 FIG. 19 illustrates a time-series flow of a method of controlling an air conditioner during sleep of the user.
 [FIG. 20]
 FIG. 20 illustrates a flow of air conditioning data accumulation.
 50 [FIG. 21]
 FIG. 21 illustrates a flow of sleep state data accumulation.
 [FIG. 22]
 FIG. 22 illustrates a flow of air conditioning setting.
 [FIG. 23]
 55 FIG. 23 illustrates a control flow of an initial air conditioning control.
 [FIG. 24]
 FIG. 24 illustrates a control flow of air conditioning control phase 1.
 [FIG. 25]

FIG. 25 illustrates a control flow of air conditioning control phase 2.

[FIG. 26]

FIG. 26 illustrates a relationship between user sleep state and LF/HF.

[FIG. 27]

FIG. 27 illustrates an example of a relationship between LF/HF and airflow direction.

[FIG. 28]

FIG. 28 illustrates another example of the relationship between LF/HF and airflow direction.

[FIG. 29]

FIG. 29 is a graph indicating temporal variations in heart rate, time-averaged heart rate, and estimated heart rate of the user.

[Description of Embodiments]

[0012] A control method according to one aspect of the present disclosure is a control method performed by a computer for controlling an air conditioner provided in a room. The control method includes: obtaining position information of a user in the room and a sleep depth which indicates sleep information of the user; controlling an airflow direction of the air conditioner in a first stage of the sleep depth based on the position information, such that an air discharged by the air conditioner avoids the user; and controlling the airflow direction in a second stage of the sleep depth based on the position information, such that the air discharged by the air conditioner hits the user, the second stage being a sleep depth that is deeper than the first stage.

[0013] With this, the air conditioner can be controlled according to the sleep state of the user during sleep, and a temperature control comfortable for the user can be performed without awakening the user.

[0014] Moreover, it may be that the sleep depth is determined based on an index value obtained by a heart rate variability analysis.

[0015] Moreover, it may be that an end time of the second stage is estimated based on a temporal variation in the index value, and that the controlling of the airflow direction in the second stage includes controlling the airflow direction based on the position information at a predetermined period prior to the estimated end time of the second stage or when the index value becomes a predetermined index value, such that the air discharged by the air conditioner avoids the user.

[0016] Moreover, it may be that the controlling of the airflow direction in the second stage includes controlling the airflow direction based on the position information when a slope in a temporal variation in the index value becomes greater than a predetermined positive slope, such that the air discharged by the air conditioner avoids the user.

[0017] Moreover, it may be that a subjective evaluation made by the user on a room environment during sleep of the user or at an awakening time of the user is obtained, and that a set temperature in an air conditioning operation of the air conditioner during sleep of the user is changed based on the subjective evaluation.

[0018] A control method according to another aspect of the present disclosure is a control method performed by a computer for controlling an air conditioner provided in a room. The control method includes: obtaining a sleep depth which indicates sleep information of a user in the room; controlling an airflow direction of the air conditioner to be directed upward in the room in a first stage of the sleep depth; and controlling the airflow direction of the air conditioner to be directed downward in the room in a second stage of the sleep depth, the second stage being a sleep depth that is deeper than the first stage.

[0019] With this, the air conditioner can be controlled according to the sleep state of the user during sleep, and a temperature control comfortable for the user can be performed without awakening the user.

[0020] An air conditioner according to another aspect of the present disclosure is an air conditioner which includes a processor and a memory. The air conditioner is provided in a room. Using the memory, the processor performs: obtaining position information of a user in the room and a sleep depth which indicates sleep information of the user; controlling an airflow direction of the air conditioner in a first stage of the sleep depth based on the position information, such that the air discharged by the air conditioner avoids the user; and controlling the airflow direction of the air conditioner in a second stage of the sleep depth based on the position information, such that the air discharged by the air conditioner hits the user, the second stage being a sleep depth that is deeper than the first stage.

[0021] With this, the air conditioner can be controlled according to the sleep state of the user during sleep, and a temperature control comfortable for the user can be performed without awakening the user.

[0022] General and specific aspects disclosed above may be implemented using a system, an integrated circuit, a computer program, or a non-transitory computer-readable recording medium such as a CD-ROM, or any combination of systems, integrated circuits, computer programs, or non-transitory computer-readable recording media.

(Overview of Service to be Provided)

[0023] In FIG. 1, (A) illustrates an overview of a service according to the present embodiment.

[0024] Group 100 is, for example, a company, an organization, or a family, and may be of any scale. Group 100 includes device A and device B which are a plurality of devices 101, and home gateway 102. Examples of devices 101 include a device connectable to the Internet (such as a smart phone, personal computer (PC), or television (TV)) and a device that is not connectable to the Internet by itself (such as lighting, washing machine, or refrigerator). The device that is not connectable to the Internet by itself may be connectable to the Internet via home gateway 102. Group 100 includes users 10 who use devices 101.

[0025] Data management company 110 includes cloud server 111. Cloud server 111 is a virtualization server that is linked with various devices via the Internet. Cloud server 111 mainly manages, for example, big data which is difficult to be handled by a general database management tool or the like. Data center management company 110 manages data and cloud server 111, and operates a data center which manages the data and cloud server 111. The services provided by data center management company 110 will be described later in details. Here, data center management company 110 is not limited to a company which is specified in managing data and cloud server 111. For example, in the case where a device manufacture which develops and manufactures one of devices 101 also manages data and cloud server 111, such a device manufacturer corresponds to data center management company 110 ((B) in FIG. 1). Data center management company 110 is not limited to a single company. For example, in the case where a device manufacturer and another management company jointly manage or share managing data and cloud server 111, both or one of the two corresponds to data center management company 110 ((C) in FIG. 1).

[0026] Service provider 120 includes server 121. Here, server 121 may be of any scale. Examples of server 121 include a memory in a PC for personal use. In some cases, service provider 121 does not include server 121.

[0027] Home gateway 102 is not essential in the service described above. For example, in the case where cloud server 111 manages all data, home gateway 102 is not necessary. In addition, as in the case where every device at home is connected to the Internet, a device that is not connectable to the Internet by itself may not be present.

[0028] Next, a flow of log information (control history information and operating history information) of a device in the service described above will be described.

[0029] First, device A or device B in group 100 transmits each item of log information to cloud server 111 of data center management company 110. Cloud server 111 accumulates the log information of device A or device B ((a) in FIG. 1). Here, the log information refers to information indicating an operating state, operating time and date, and the like of each of devices 101. Examples of the log information include TV program viewing history, timer recording information of a recorder, operating time and data and laundry amount of a washing machine, and time and data and count of door opening and closing of a refrigerator. However, the log information is not limited to such examples, and refers to all the information that can be obtained from any types of devices. The log information may be provided directly to cloud server 111 from devices 101 themselves via the Internet. It may also be that the log information is accumulated in home gateway 102 from devices 101, and is provided to cloud server 111 from home gateway 102.

[0030] Next, cloud server 111 of data center management company 110 provides the accumulated log information to service provider 120 in a given unit. Here, the given unit may be a unit which allows the information accumulated by the data center management company to be sorted and provided to service provider 120 or a unit required by service provider 120. The given unit does not have to be a constant unit, but the amount of information provided may vary according to the situation. The log information is stored in server 121 included in service provider 120 as necessary ((b) in FIG. 1). Service provider 120 then sorts the log information into information compatible with the service to be provided to the user, and provides the information to the user. The service may be provided to user 10 of devices 101 or external user 20. The service may be provided to the user, for example, directly from the service provider ((b) and (e) in FIG. 1). The service may be provided to the user, for example, after going through cloud server 111 of data center management company 110 again ((c) and (d) in FIG. 1). It may also be that cloud server 111 of data management company 110 sorts the log information into information compatible with the service to be provided to the user, and provides the information to service provider 120.

[0031] Users 10 and 20 may be identical to each other or different from each other.

(Embodiment)

[0032] FIG. 6 schematically illustrates an air conditioning control system according to the present embodiment.

[0033] Specifically, in FIG. 6, air conditioning control system 1 includes air conditioner 300, cloud server 400, sleep state detector 500, communication network 600, and router 610.

[0034] Air conditioning control system 1 is a system for providing a comfortable air conditioned space, for example, during sleep of user U1 in a room of a building, such as house 601.

[0035] Hereinafter, each device will be specifically described.

[0036] FIG. 7 is a block diagram illustrating an example of a hardware configuration of an air conditioner according to the present embodiment.

[0037] Air conditioner 300 is a device which adjusts the air quality environment in a room, and, for example, adjusts

the temperature in a room by performing a heating or cooling operation. Air conditioner 300 is, for example, a room air conditioner. As illustrated in FIG. 7, air conditioner 300 includes heat source 301, air blower 302, various sensors 303, and control circuit 304.

[0038] Heat source 301 is a heat exchanger included in a refrigerant circuit (not illustrated), and functions as, for example, a condenser. Heat source 301 is not limited to the heat exchanger included in the refrigerant circuit, but may be, for example, an electric heater, a gas heater, or an oil heater.

[0039] Air blower 302 blows air heated by the heat source into the room. Air blower 302 includes, for example, a fan and a motor which rotates the fan. Examples of the fan include a cross flow fan and an axial fan.

[0040] Examples of various sensors 303 include a temperature sensor which detects room temperature, a humidity sensor which detects room humidity, a temperature sensor which detects outside temperature, a humidity sensor which detects outside humidity, a human sensor which detects presence of a person in a room, and a power sensor which detects the amount of power being consumed by air conditioner 300. Examples of various sensors 303 may also include a temperature sensor which detects the temperature of heat source 301, and a temperature sensor which detects the temperature of the air discharged from air conditioner 300.

[0041] Control circuit 304 controls the operations of heat source 301 and air blower 302 according to the room temperature detected by various sensors 303, such that the detected room temperature approaches the preset target temperature. In the case where, for example, the room temperature has not reached the target temperature in the heating operation, that is, the room temperature is lower than the target temperature, control circuit 304 heats the indoor space by driving heat source 301 and air blower 302. In the case where the room temperature has reached the target temperature in the heating operation, that is, the room temperature is higher than or equal to the target temperature, control circuit 304 temporarily stops heat source 301 and air blower 302. Since the outside temperature is often lower than the room temperature in the heating operation, stopping heat source 301 and air blower 302 makes the room temperature approach the outside temperature, leading to a decrease in room temperature. Accordingly, when the room temperature becomes lower than the target temperature, control circuit 304 drives heat source 301 and air blower 302. In such a manner, control circuit 304 controls the operations of heat source 301 and air blower 302 based on the relationship between the room temperature and the target temperature. By doing so, the room temperature can be adjusted so as to be maintained at the target temperature.

[0042] Control circuit 304 includes a communication interface (IF) which establishes communication with communication network 600 via router 610. The communication IF communicates with cloud server 400 via communication network 600. In other words, the communication IF may be a communication interface which can be communicatively connected with communication network 600. Specifically, the communication IF is communicatively connected with communication network 600 via a communication connection with a base station of a mobile communication system or with router 610. The communication IF may be, for example, a wireless local area network (LAN) interface compatible with IEEE 802.11a, b, g, n, ac, ax standard, or a wireless communication interface compatible with a communication standard used in a mobile communication system such as a third generation mobile communication system (3G), a fourth generation mobile communication system (4G), a fifth generation mobile communication system (5G), or a Long-Term Evolution (LTE) (registered trademark).

[0043] The communication IF included in control circuit 304 may be communicatively connected with communication network 600 via a communication connection with another terminal device. In such a case, for example, the communication IF may be a wireless LAN interface or a wireless communication interface compatible with the Bluetooth (registered trademark) standard.

[0044] FIG. 8 is a block diagram illustrating an example of a hardware configuration of a cloud server according to the present embodiment.

[0045] As illustrated in FIG. 8, cloud server 400 includes processor 401, main memory 402, storage 403, and communication IF 404.

[0046] Processor 401 is a processor which executes a control program stored in storage 403 or the like.

[0047] Main memory 402 is a volatile storage area used as a work area when processor 401 executes a control program.

[0048] Storage 403 is a non-volatile storage area for holding control programs and the like.

[0049] Communication IF 404 communicates with devices, such as air conditioner 300, sleep state detector 500, and terminal device 700 via communication network 600. Communication IF 404 is, for example, a wired LAN interface. Communication IF 404 may be a wireless LAN interface. Communication IF 404 is not limited to a LAN interface, but may be any communication interface as long as a communication connection with a communication network can be established.

[0050] FIG. 9 is a block diagram illustrating an example of a hardware configuration of a sleep state detector according to the present embodiment.

[0051] As illustrated in FIG. 9, sleep state detector 500 includes antenna 501 and control circuit 502. Sleep state detector 500 is, for example, a non-contact radio-frequency sensor.

[0052] Antenna 501 includes a transmission antenna for transmitting transmitter pulses (microwaves) of a predeter-

mined frequency and a reception antenna for receiving reflected waves which are the transmitter pulses reflected off an object including a person in a room.

[0053] Control circuit 502 calculates a slight change in distance between antenna 501 and an object to be measured (for example, a living body such as human) based on the Doppler shift of the reflected wave received by antenna 501. Control circuit 502 estimates the movement (body movement), respiratory rate, heart rate and the like of the object to be measured by using the calculated result.

[0054] Control circuit 502 includes a communication IF which establishes communication with communication network 600 via router 610. The communication IF communicates with cloud server 400 via communication network 600. In other words, the communication IF may be a communication IF which is capable of communicatively connected to communication network 600. Specifically, the communication IF is communicatively connected with communication network 600 via a communication connection with a base station of a mobile communication system or with router 610. The communication IF may be, for example, a wireless local area network (LAN) interface compatible with IEEE 802.11a, b, g, n, ac, ax standard, or a wireless communication interface compatible with the communication standard used in a mobile communication system such as a third generation mobile communication system (3G), a fourth generation mobile communication system (4G), a fifth generation mobile communication system (4G), or a LTE (registered trademark).

[0055] The communication IF included in control circuit 502 may be communicatively connected with communication network 600 via a communication connection with another terminal device. In such a case, for example, the communication IF may be a wireless LAN interface or a wireless communication interface compatible with the Bluetooth (registered trademark) standard.

[0056] FIG. 10 is a block diagram illustrating a configuration of an air conditioning control system according to the present embodiment.

[0057] Air conditioning control system 1 includes air conditioner 300, cloud server 400, and sleep state detector 500. Part or all of the blocks in cloud server 400 belong to either cloud server 111 of data center management company 110 or server 121 of service provider 120.

[0058] Air conditioner 300 includes sensor information obtaining unit 311, control information obtaining unit 312, and air conditioning controller 313.

[0059] Air conditioning controller 313 adjusts the temperature, humidity and the like of indoor air by controlling the operations of heat source 301 and air blower 302. Air conditioning controller 313 is specifically an air conditioning function, but is not limited to the function as long as it is a control mechanism which is capable of controlling the room temperature and humidity. Air conditioning controller 313 performs control based on the operating parameter designated by air conditioning setting unit 413. The operating parameter includes parameters indicating "operation", "mode", "set temperature", "air volume", and "airflow direction". The "operation" indicates ON and OFF of the operation, and the "mode" indicates the operating mode of air conditioner 300, such as cooling, heating, or dehumidifying. The "set temperature" indicates the target temperature designated to air conditioner 300, the "air volume" indicates the volume of air discharged by air conditioner 300, and the "airflow direction" indicates the direction of air discharged by the air conditioner. Air conditioning controller 313 is, for example, implemented by control circuit 304.

[0060] Sensor information obtaining unit 311 obtains air conditioning sensing information which is the detection results obtained by various sensors 303 included in air conditioner 300. Examples of the air conditioning sensing information which can be obtained include: temperature/humidity and outside temperature/humidity obtained from a temperature and humidity sensor; "presence/absence information" indicating presence or absence of a person obtained from a human sensor, such as an infrared ray sensor; and "power amount" obtained from a power sensor which calculates the power amount from current flowing at the time of operation of air conditioner 300. Sensor information obtaining unit 311 is implemented by, for example, various sensors 303 and control circuit 304.

[0061] Control information obtaining unit 312 obtains air conditioning control information. The air conditioning control information indicates the details of control performed by air conditioning controller 313 to control the operations of heat source 301 and air blower 302. The air conditioning control information specifically indicates, for example, the operating status (ON/OFF), operating mode (cooling/heating/dehumidifying/automatic), set temperature, airflow direction, air volume, and discharged air temperature, rotating speed of a compressor in a refrigerant circuit (strength of cooling or heating). Control information obtaining unit 312 is implemented by, for example, control circuit 304.

[0062] The configuration of air conditioner 300 has been described above.

[0063] Sleep state detector 500 includes sleep state information obtaining unit 511.

[0064] Sleep state information obtaining unit 511 estimates the sleep state of a person by sensing the person using electromagnetic waves such as microwaves. Sleep state information obtaining unit 511 transmits the sleep state information indicating the estimated sleep state to cloud server 400.

[0065] Peoples' sleep can be classified into some "sleep states" in time series according to the sleep depth or features as illustrated in FIG. 11. As illustrated in FIG. 11, sleep is classified into rapid eye movement (REM) sleep and non-rapid eye movement (NREM) sleep. REM sleep is sleep with rapid eye movement, and is one of the sleep states where the brain is active while the body is resting. People often have dreams during REM sleep.

[0066] NREM sleep is sleep without rapid eye movement, and is classified into four stages from stage 1 to stage 4 depending on the sleep depth. Sleep becomes deeper as the stage number increases, and stage 4 is the deepest sleep level. When the brain waves are measured at this time, low-frequency waves referred to as delta waves from 1 Hz to 4 Hz and high-amplitude waves are frequently measured. Sleep state generally reaches stage 3 and stage 4 of NREM during the period from the sleep onset till an elapse of 45 to 60 minutes, and after an elapse of one or two hours, sleep gradually becomes lighter, turning into REM sleep. Subsequently, NREM sleep and REM sleep alternately appear, and are repeated with a sleep cycle of 90 to 110 minutes.

[0067] The body movement, respiratory rate, and heart rate are correlated with the sleep states illustrated in FIG. 11. For example, it is known that the amount of body movement in deep sleep, such as stage 3 or stage 4 among NREM sleep, decreases compared with light sleep, and that heart rate variability (RRI: R-R interval) decreases. Sleep state information obtaining unit 511 estimates the sleep state of a person in real time by detecting an index value in the index correlated with such sleep states, and transfers the result to cloud server 400 as the sleep state information.

[0068] The sleep state information is information in which a sleep state is associated with the time at which the sleep state was estimated. The sleep state includes awake, REM sleep, and stage 1, stage 2, stage 3, and stage 4 indicating respective depths of NREM sleep. The estimated time indicates the time of measurement of at least one of the body movement, respiratory rate, and heart rate used for estimating the corresponding sleep stage. The sleep state information may further include at least one of the body movement, respiratory rate, and heart rate measured at the estimated time.

[0069] The sleep state may be determined by sleep state detector 500, or by cloud server 400. In such a case, sleep state detector 500 transmits, to cloud server 400, sleep sensing information in which at least one sensing data of the body movement, respiratory rate, and heart rate is associated with the time at which the sensing data was sensed as the sleep state information. Cloud server 400 estimates the sleep state of user U1 by using the sleep sensing information obtained from sleep state detector 500.

[0070] In the above description, sleep state detector 500 is a radio-frequency sensor, but the present disclosure is not limited to such an example. As long as the sleep sensing information for estimating the sleep state can be obtained, the form of sleep state detector 500 is not limited. Examples of the sleep state detector include a wearable terminal to be worn on the arm. In such a case, the sleep state detector includes a heart rate sensor which measures the heart rate and an inertial measurement unit (IMU) which measures the body movement. The IMU includes a three-axis accelerometer and a gyro sensor. The sleep state detector may be positioned under the mat on which a person sleeps, and include a pressure-sensitive sensor which detects the body movement of the person.

[0071] The configuration of sleep state detector 500 has been described above.

[0072] Cloud server 400 includes obtaining unit 411, parameter calculator 412, air conditioning setting unit 413, interface 414, history DB 415, and setting DB 416.

[0073] Obtaining unit 411 obtains air conditioning sensing information from sensor information obtaining unit 311 of air conditioner 300. Obtaining unit 411 stores the obtained air conditioning sensing information in history DB 415. Obtaining unit 411 may obtain air conditioning sensing information from sensor information obtaining unit 311, for example, once per minute, and store the information in history DB 415. Obtaining unit 411 may also obtain air conditioning sensing information uploaded regularly from sensor information obtaining unit 311.

[0074] Obtaining unit 411 also obtains air conditioning control information from control information obtaining unit 312 of air conditioner 300. Obtaining unit 411 stores the obtained air conditioning control information in history DB 415. Obtaining unit 411 may obtain the air conditioning control information from control information obtaining unit 312, for example, once per minute, and store the information in history DB 415. Obtaining unit 411 may also obtain the air conditioning control information regularly uploaded from control information obtaining unit 312. In such a case, upload may be performed not only regularly, but also at the time of occurrence of an event in which control in air conditioner 300 is changed.

[0075] Obtaining unit 411 also obtains sleep state information from sleep state detector 500. Obtaining unit 411 stores the obtained sleep state information in history DB 415. Obtaining unit 411 may obtain the sleep state information from sleep state detector 500, for example, once per minute, and store the information in history DB 415. Obtaining unit 411 may also obtain the sleep state information regularly uploaded from sleep state detector 500.

[0076] Obtaining unit 411 may also obtain weather information of the region where air conditioner 300 is provided. The region where air conditioner 300 is provided may be identified from the global IP address used by air conditioner 300 for communication, from information preset by the user, or from position information obtained by terminal device 700 of the user.

[0077] History DB 415 is a database which stores the air conditioning sensing information, air conditioning control information, and sleep state information obtained by obtaining unit 411. The format of the database may be a relational DB such as SQL, or DB referred to as No SQL in which data is configured by a simple relationship such as Key-Value.

[0078] FIG. 12 and FIG. 13 each illustrate an example of a table structure of the history DB. FIG. 12 illustrates a table structure of data including the air conditioning sensing information and air conditioning control information obtained from air conditioner 300 and accumulated. FIG. 13 illustrates a table structure of data including the sleep state information

obtained from sleep state detector 500 and accumulated.

[0079] In FIG. 12, "ID" indicates a unique ID for identifying each record. The "time" indicates the time when each information was obtained. The "room temperature", "room humidity", "outside temperature", "discharged air temperature", "power amount", and "presence information" are air conditioning sensing information obtained by sensor information obtaining unit 311. The "operating status", "operating mode", "set temperature", "air volume" and "airflow direction" are air conditioning control information obtained by control information obtaining unit 312. The "weather" is regional weather information obtained by obtaining unit 411. In order to facilitate the description, the air conditioning sensing information and the air conditioning control information are included in one table in FIG. 12, but may be managed under different tables. The power amount in FIG. 12 indicates the integrated power amount (wh) from the previous record to the current record.

[0080] In FIG. 13, "ID" indicates a unique ID for identifying each record. The "time" indicates the time when each information was obtained. The "sleep state", "heart rate", "respiratory rate", and "body movement amount" are sleep state information obtained from sleep state detector 500. The sleep state indicates, in stages, the depth of sleep of a person described with reference to FIG. 11. Specifically, the sleep state includes "awake" "REM sleep", "stage 1", "stage 2", "stage 3", and "stage 4". The "heart rate" and the "respiratory rate" respectively indicate the heart rate and the respiratory rate at the corresponding time. In the example of FIG. 13, the "heart rate" and the "respiratory rate" indicate the heart rate and the respiratory rate per minute. The "body movement amount" indicates the amount of body movement at the corresponding time, and indicates, for example, the maximum body movement amount per minute, or the number of times per minute the body movement amount exceeds a threshold for determining the body movement. The "body movement amount" is represented by a normalized value ranging from 0 to 100, for example.

[0081] Interface 414 is an external interface for receiving an input from the user, and is, for example, an external I/F (Web API) which communicates via http/https protocols. Interface 414 stores, for example, setting commands received via an application from terminal device 700 in setting DB 416 or history DB 415. Interface 414 may also transmit information, such as the sleep state information, air conditioning control information, and air conditioning sensing information stored in history DB 415, to terminal device 700 via an application.

[0082] FIG. 14 illustrates an example of a screen of an application at the time of setting before sleeping on a terminal device.

[0083] As illustrated in FIG. 14, in terminal device 700, setting screen 701 of an application before sleeping includes timer lists 702 and 703 for sleep control. Timer lists 702 and 703 indicate that settings for scheduled sleep onset time and scheduled awakening time for each day of the week have been received. In the example of FIG. 14, timer list 702 indicates that the scheduled sleep onset time is 23:00 and the scheduled awakening time is 7:00, and that these scheduled times are enabled on Monday, Tuesday, Wednesday, Thursday, and Friday. Timer list 703 indicates that the scheduled sleep onset time is 23:30 and the scheduled awakening time is 8:00, and that these scheduled times are enabled on Saturday and Sunday. Tapping of timer lists 702 and 703 activates the screen for setting the scheduled sleep onset time, scheduled awakening time, and days of the week when scheduled times are enabled. When timer lists 702 and 703 are set and enabled, terminal device 700 transmits the sleep timer information indicated by timer lists 702 and 703 to cloud server 200.

[0084] FIG. 15 illustrates examples of screens of an application after awakening on the terminal device.

[0085] As illustrated in FIG. 15, when the set scheduled awakening time has come, terminal device 700 displays awakening screen 710 of an application to prompt the user to input "feedback on thermal environment" during sleep and at the awakening time. In the example of FIG. 15, awakening screen 710 includes comments 711 of a character, "how was air conditioning today? press appropriate icon!". Comments 711 prompts the user to input subjective evaluations on the thermal environment of the room during sleep and/or at the awakening time. Awakening screen 710 includes icons 712 and 713 each including five icons "cold" to "hot" for receiving input of feedback (subjective evaluation) on temperature during sleep and/or at the awakening time. Five icons indicate five-step evaluation including "cold", "a little cold", "comfortable", "a little hot", and "hot".

[0086] Upon receiving an input of feedback on the thermal environment during sleep and at the awakening time, terminal device 700 displays feedback received screen 720 including icons 721 and 722 which indicate that feedback input has been received. Terminal device 700 displays feedback received screen 720, and also transmits the evaluation information indicating feedback on the thermal environment to cloud server 200. Terminal device 700 transmits, to cloud server 200, evaluation information indicating one of "cold", "a little cold", "comfortable", "a little hot", and "hot" as feedback during sleep and as feedback at the awakening time. It may be that "1" indicates "cold", "2" indicates "a little cold", "3" indicates "comfortable", "4" indicates "a little hot", and "5" indicates "hot".

[0087] The subjective evaluation on the thermal environment during sleep made by the user as described above is defined as "subjective evaluation on thermal environment during sleep". The subjective evaluation on thermal environment at the awakening time made by the user as described above is defined as "subjective evaluation on thermal environment at awakening time". The thermal environment subjective evaluations may be made based on not only the classification of hot to cold, but may be also based on the detailed classification of temperature perception, humidity

perception, and comfort perception. The time range during sleep to be evaluated may be subdivided into front half, middle, and latter half, or during sleep and the awakening time may be combined. Upon receipt of the evaluation information indicating the thermal environment subjective evaluation from terminal device 700, cloud server 200 stores the information in history DB 415.

[0088] In history DB 415, the subjective evaluations on thermal environment are specifically managed in a table as illustrated in FIG. 16. FIG. 16 illustrates an example of a structure of a table for managing the subjective evaluations on thermal environment in history DB.

[0089] In the table of FIG. 16, the "actual sleep onset time" indicates the time when the user actually started to sleep, and the "actual awakening time" indicates the time when the user actually woke up. In addition, the "subjective evaluation on thermal environment during sleep" and the "subjective evaluation on thermal environment at awakening time" are as described above.

[0090] In the examples of FIG. 14 and FIG. 15, terminal device 700 executes an application to display a screen for receiving an input from the user and receives an input that is based on the displayed screen, but the present disclosure is not limited to such an example. Terminal device 700 may receive an input for setting as described with reference to FIG. 14 and an input for evaluation as described with reference to FIG. 15, by an interactive application which uses virtual personal assistant (VPA). In other words, terminal device 700 may be a device which includes a display device, such as a smart phone, a tablet terminal, and a PC, or a device which includes a microphone and a loudspeaker such as a VPA.

[0091] Setting DB 416 is a database for storing the evaluation information obtained by interface 414. The format of the database may be a relational DB such as SQL, or DB referred to as No SQL in which data is configured by a simple relationship such as Key-Value.

[0092] FIG. 17 illustrates an example of a structure of a user table stored in the setting DB. FIG. 18 illustrates an example of a structure of a schedule table stored in the setting DB.

[0093] Setting DB 416 stores the user table and the schedule table.

[0094] The user table includes columns of "user ID", "username", "awakening time target temperature", and "lower-limit temperature". The "user ID" indicates a unique ID for identifying each record. The "username" indicates the nickname of each user. The "awakening time target temperature" indicates the target room temperature to be reached at the awakening time. The "lower-limit temperature" indicates the lower-limit room temperature during sleep. The "awakening time target temperature" and the "lower-limit temperature" are used in the processing performed by parameter calculator 412. The details thereof will be described later.

[0095] The schedule table includes columns of "schedule ID", "scheduled sleep onset time", "scheduled awakening time", "day of week", and "user ID". The "schedule ID" indicates a unique ID for identifying each record. The "scheduled sleep onset time" indicates the scheduled time of sleep onset. The scheduled awakening time indicates the time at which the user is scheduled to wake up. The "day of week" indicates the days applicable for the scheduled sleep onset time and the scheduled awakening time in the record. The schedule table is generated based on the sleep timer information described with reference to FIG. 14. The "user ID" is an ID for associating with the user table.

[0096] Parameter calculator 412 calculates an operating parameter for commanding control to air conditioner 300, based on the information stored in history DB 415 and/or setting DB 416. Parameter calculator 412 may calculate an operating parameter regularly, or may calculate an operating parameter when a predetermined condition is satisfied.

[0097] Air conditioning setting unit 413 transmits the operating parameter calculated by parameter calculator 412 to air conditioning controller 313 of air conditioner 300. Accordingly, the operation setting of air conditioner 300 is controlled. Air conditioning setting unit 413 transmits the operating parameter calculated by parameter calculator 412 to air conditioner 300 every time parameter calculator 412 calculates the operating parameter.

[0098] FIG. 19 illustrates a time-series flow of a method of controlling an air conditioner during sleep of the user. FIG. 19 is an example where air conditioner 300 performs the heating operation in the environment where the outside temperature is lower than the room temperature.

[0099] In the graph of FIG. 19, the horizontal axis indicates elapsed time during sleep, and the vertical axis indicates temperature. Room temperature 1101 is a line which indicates a temporal change in room temperature. For the room temperature, a detection value obtained from a sensor of air conditioner 300 is used. Set temperature 1102 is a line which indicates a temporal change in set temperature of air conditioner 300 set by parameter calculator 412. The lower-limit temperature indicates the lower-limit temperature of the user set for each user in set DB 416. In the case of FIG. 19, the lower-limit temperature is 19.5°C. The awakening time target temperature indicates the target temperature at the awakening time of the user set for each user in set DB 416. In the case of FIG. 19, the awakening time target temperature is 21.0°C. The diagram of the airflow direction in FIG. 19 indicates the transition of the airflow direction of air conditioner 300 set by parameter calculator 412. Period A indicates a given time period after sleep state detector 500 detects onset of sleep of the user. Time t2 after an elapse of period A indicates the changeover timing of air conditioning control. The details of the changeover of the air conditioning control will be described later.

[0100] The details of the control indicated by the graph will be described below. The diagonally hatched ranges in FIG.

19 indicate the ranges in which the sleep state of the user detected by sleep state detector 500 is deep sleep. Here, the deep sleep refers to, for example, sleep in stage 3 or stage 4 during NRS.

[0101] In FIG. 19, in the period from when the user enters the room till bedtime, air conditioner 300 performs an operation based on the operating parameter set according to the user's preference. Specifically, air conditioner 300 performs an operation with the operating mode, air volume, airflow direction, and temperature setting set by the user via a remote controller or the like of air conditioner 300.

[0102] Next, after bedtime (after the user goes to bed), air conditioner 300 operates based on the operating parameter different from the operating parameter used in the period before the bedtime. Specifically, when the current time is after the scheduled sleep onset time of setting DB 416, parameter calculator 412 determines the onset of sleep of the user, calculates an operating parameter of air conditioner 300, and transmits the calculated operating parameter to air conditioner 300, so that operation control during sleep on air conditioner 300 starts to be performed.

[0103] Parameter calculator 412 determines the set temperature at the bedtime as described below. Parameter calculator 412 refers to history DB 415 to obtain the room temperature obtained from various sensors 303 of air conditioner 300. When the obtained room temperature is higher than the lower-limit temperature, parameter calculator 412 sets the set temperature to the lowest value settable to air conditioner 300 (16°C in the example of FIG. 19) in the heating operation mode. When the room temperature is lower than the lower-limit temperature, parameter calculator 412 sets the set temperature to the lower-limit temperature. In the example of FIG. 19, at bedtime, the room temperature is around 20.5°C, and the lower-limit temperature is 19.5°C. Accordingly, at the bedtime, parameter calculator 412 calculates an operating parameter for setting the set temperature to 16°C which is the lowest value settable to air conditioner 300. Parameter calculator 412 calculates an operating parameter for setting the airflow direction at bedtime upward. By transmitting the calculated operating parameter to air conditioner 300, air conditioning setting unit 413 causes air conditioner 300 to perform the heating operation based on the transmitted operating parameter.

[0104] After the bedtime and till time t2 which is after an elapse of period A from when the sleep onset of the user is detected, parameter calculator 412 determines the set temperature as described below. Here, parameter calculator 412 detects sleep onset of the user based on the sleep state transmitted from sleep state detector 500. Parameter calculator 412 determines "sleep onset" when parameter calculator 412 detects the deep sleep state (stage 3 or stage 4) for the first time after the bedtime.

[0105] Parameter calculator 412 refers to history DB 415 to check the room temperature of air conditioner 300 regularly, such as once per five minutes, and compares the room temperature with the lower-limit temperature. Parameter calculator 412 sets the set temperature to the lower-limit temperature when the room temperature is lower than the lower-limit temperature. In the example of FIG. 19, the room temperature becomes lower than the lower-limit temperature at time t1. Hence, parameter calculator 412 calculates the operating parameter for setting the set temperature of air conditioning to 19.5°C at time t1. After setting the set temperature to the lower-limit temperature, parameter calculator 412 maintains the set temperature even if the room temperature becomes higher than the lower-limit temperature. By setting the set temperature to the lower-limit temperature during the period till the room temperature becomes lower than the lower-limit temperature, the room temperature does not become lower than the set temperature even when air conditioner 300 is performing the heating operation during the period till the room temperature becomes lower than the lower-limit temperature. Accordingly, the operating parameter of air conditioner 300 can be set such that air conditioner 300 does not perform an operation for discharging warm air, and the room temperature can be decreased to the lower-limit temperature. With this, by decreasing the room temperature from when the sleep onset of the user is detected till time t1, decreasing of the deep body temperature is prompted, making an environment suitable for sleeping. In contrast, since the lower-limit temperature is set as the set temperature at time t1, when the room temperature becomes lower than the lower-limit temperature after time t1, air conditioner 300 performs an operation for discharging warm air. Hence, since the room temperature does not become lower than the lower-limit temperature, it is possible to prevent the environment from becoming too cold.

[0106] Here, in order to prompt a decrease in the deep body temperature and decrease the room temperature, it has been described that the set temperature of air conditioner 300 is set to the lowest temperature during the period from the sleep onset till time t1 at which the room temperature becomes lower than the lower-limit temperature. Instead of setting the set temperature of air conditioner 300 to the lowest temperature, power of air conditioner 300 can be turned OFF. In such a case, power of air conditioner 300 is changed from OFF to ON during sleep. Hence, an operating noise of air conditioner 300 is generated at the changeover timing to ON. This might lead to an increased possibility of awakening the user. In addition, in the case where the power of air conditioner 300 is OFF when the user goes to bed and the power of air conditioner 300 is changed from OFF to ON during sleep, the user cannot check that the power of air conditioner 300 is turned ON. This might cause the user to feel anxious in terms of safety. Air conditioner 300 includes a room temperature sensor. Unless the room temperature detected by the room temperature sensor becomes lower than the set temperature, air conditioner 300 does not perform an operation for discharging warm air even during the heating operation. Accordingly, the power of air conditioner 300 at the bedtime is turned ON and the set temperature during the heating operation is set to the lowest temperature.

[0107] After time t_2 , parameter calculator 412 determines the set temperature as described below.

[0108] During the period from time t_2 to the scheduled awakening time, parameter calculator 412 gradually increases the set temperature in steps from the lower-limit temperature to the awakening time target temperature such that the set temperature of air conditioner 300 reaches the awakening time target temperature at the scheduled awakening time.

In other words, during the period from time t_2 to the scheduled awakening time, parameter calculator 412 increases the set temperature of air conditioner 300 in steps. Parameter calculator 412 calculates the set temperature which gradually increases along a line connecting the current set temperature or the room temperature and the awakening time target temperature at every predetermined timing (different timings), in order to avoid rapid temperature change as much as possible, for example. Accordingly, by gradually increasing the room temperature toward the awakening time of the user, an increase in deep body temperature of the user can be prompted, creating an environment in which the user can be wakened with comfort.

[0109] Next, control of the airflow direction will be described.

[0110] Parameter calculator 412 controls the airflow direction after time t_2 based on the sleep state transmitted from sleep state detector 500. Parameter calculator 412 regularly checks the sleep state, for example, once per minute, and sets the airflow direction downward when the sleep state of the user is deep sleep (stage 3 or stage 4), and upward when the sleep state is light sleep (stage 1 or stage 2) or REM sleep. Note that stage 1 or stage 2 in NREM sleep or REM sleep is an example of a first stage in the sleep depth. Stage 3 or stage 4 in NREM sleep is an example of a second stage that is a sleep depth deeper than the first stage in the sleep depth.

[0111] Generally, an indoor unit of a room air conditioner, which is an example of air conditioner 300, is provided at a position higher than the position where the user sleeps. The warm air (heated air) discharged from air conditioner 300 in the heating operation is directed upward due to natural convection. Accordingly, when the airflow direction of air conditioner 300 is set upward, the warm air discharged by air conditioner 300 is unlikely to reach the position where the user is sleeping. In contrast, when the airflow direction of air conditioner 300 is set downward, the user might be wakened by the warm air hitting the user. Hence, the airflow direction is set downward at the time of deep sleep when the senses of the user are blunt for ambient environment and the user is unlikely to waken by the warm air hitting the user, and the airflow direction is set upward at the time of light sleep when the user is likely to waken by the warm air hitting the user. Accordingly, it is possible to make the thermal environment around the user during sleep comfortable without awakening the user during sleep.

[0112] It may be that, after the user wakes up, parameter calculator 412 updates the lower-limit temperature and the awakening time target temperature included in the user table stored in setting DB 416, based on the previous subjective evaluations on thermal environment of the user stored in history DB 415. For example, in the case where air conditioner 300 is controlled with the lower-limit temperature set to 19.5°C, when "cold" was input in the subjective evaluation on thermal environment during sleep, parameter calculator 412 may update the lower-limit temperature to a value in which 1°C is added to the currently set temperature. When "hot" was input, parameter calculator 412 may update the lower-limit temperature to a value in which 1°C is subtracted from the currently set temperature. Moreover, for example, in the case where air conditioner 300 is controlled with the awakening time target temperature set to 21.0°C, when "cold" was input in the subjective evaluation on thermal environment at awakening time, parameter calculator 412 may update the awakening time target temperature to a value in which 1°C is added to the currently set temperature. When "hot" was input, parameter calculator 412 may update the awakening time target temperature to a value in which 1°C is subtracted from the currently set temperature. Accordingly, it is possible to adjust the room environment to a comfortable temperature based on user's subjective view during sleep and at the awakening time.

[0113] The lower-limit temperature and the awakening time target temperature may be determined based on a correlation between thermal environment subjective evaluation and environmental data (air conditioning sensing information) such as room temperature, instead of using the latest data. For example, the lower-limit temperature or the awakening time target temperature may be updated to the average value of the lower-limit temperatures or the awakening time target temperatures evaluated as "comfortable" in the previous thermal environment subjective evaluations. In other words, it may be that parameter calculator 412 sets the average value of the lower-limit temperatures evaluated as "comfortable" in a predetermined period prior to the current time as the lower-limit temperature, and the average value of the awakening time target temperatures evaluated as "comfortable" in the same period as the awakening time target temperature. Accordingly, it is possible to effectively reflect the user preferred temperature compared with the case where the latest result is referred to.

[0114] In the example of FIG. 19, parameter calculator 412 changes the set temperature to the lower-limit temperature at time t_1 when the room temperature becomes lower than the lower-limit temperature. At this timing, parameter calculator 412 may further change the set temperature based on the sleep state of the user. When the sleep state of the user is "light sleep" at the timing when the room temperature becomes lower than the lower-limit temperature, for example, parameter calculator 412 does not have to change the set temperature to the lower-limit temperature. If the set temperature is rapidly increased when the sleep state of the user is "light sleep", air conditioning noise or temperature change occurs due to the operation by air conditioner 300 for discharging warm air. This might awaken the user. Hence, in the case

where the sleep state of the user is "light sleep" even when the room temperature becomes lower than the lower-limit temperature, it may be that the set temperature is not changed and the set temperature is changed to the lower-limit temperature after the sleep state of the user is changed to "deep sleep". Accordingly, it is possible to adjust the room environment to a comfortable temperature while reducing the possibility of awakening the user.

[0115] In the example of FIG. 19, parameter calculator 412 changes the set temperature to the lower-limit temperature at time t1 when the room temperature becomes lower than the lower-limit temperature. At this time, parameter calculator 412 may gradually increase the set temperature so as to reach the lower-limit temperature from the lowest value settable to air conditioner 300 in the heating operating mode, in order to avoid rapid change in temperature setting. Parameter calculator 412 may increase the set temperature, for example, by 0.5°C per 5 minutes. Rapidly increasing the set temperature causes air conditioning noise or temperature change due to the warm air discharging operation of air conditioner 300. This might awaken the user. Accordingly, since the set temperature is gradually increased even at the timing when the room temperature becomes lower than the lower-limit temperature, it is possible to adjust the room environment to a comfortable temperature while reducing the possibility of awakening the user during sleep. When the sleep state is "light sleep", parameter calculator 412 may further gradually increase the set temperature based on the sleep state. When the sleep state is "deep sleep", parameter calculator 412 may increase the set temperature by greater increments than when the sleep state is "light sleep". Accordingly, it is possible to adjust the room environment to a comfortable temperature while more effectively reducing the possibility of awakening the user during sleep.

[0116] It is to be noted that discharging air may also be referred to as outputting air.

[0117] Hereinafter, an operation of air conditioning control system 1 will be described.

[0118] The details of the air conditioning setting flow of parameter calculator 412 will be described with reference to the process flows in FIG. 22 to FIG. 25.

[0119] The system configuration of air conditioning control system 1 according to the present embodiment has been described above.

[0120] Next, the process flow of air conditioning control system 1 according to the present embodiment will be described.

The process flow of air conditioning control system 1 according to the present embodiment is mainly classified into three flows. The three flows are "air conditioning data accumulation flow", "sleep state data accumulation flow", and "air conditioning setting flow".

[0121] FIG. 20 illustrates the "air conditioning data accumulation flow".

[0122] In step S101, sensor information obtaining unit 311 of air conditioner 300 obtains air conditioning sensing information.

[0123] In step S102, control information obtaining unit 312 of air conditioner 300 obtains air conditioning control information of the air conditioner 300.

[0124] In step S103, air conditioner 300 transmits the air conditioning sensing information obtained in step S101 and the air conditioning control information obtained in S102 to cloud server 400. Obtaining unit 411 of cloud server 400 receives the air conditioning sensing information and the air conditioning control information, and stores the information in history DB 415.

[0125] In step S104, air conditioner 300 waits for a predetermined period (for example, one minute), and returns to step S101 after the predetermined period. Air conditioner 300 counts, for example, 60 seconds, and when the counted result has reached 60 seconds, returns to step S101.

[0126] The process of the air conditioning data accumulation flow is always repeatedly performed while the communication path with cloud server 400 is established and power is ON. In such a manner, the air conditioning sensing information and the air conditioning control information are recorded in history DB 415 of cloud server 400. In the air conditioning data accumulation flow illustrated in FIG. 20, step S102 is performed after step S101. However, the processing order may be reversed. In addition, step S101 and step S102 are sequentially performed, but may be performed in parallel. Step S102 in which the air conditioning control information is obtained may be performed when control is changed, that is, when the air conditioning control information is changed, instead of being performed regularly as a routine, and subsequently, the obtained air conditioning information may be transmitted to cloud server 400.

[0127] The "air conditioning data accumulation flow" has been described above.

[0128] FIG. 21 illustrates the "sleep state data accumulation flow".

[0129] In step S111, sleep state detector 500 obtains information such as heart rate/ heart rate variability, respiratory rate, body movement and the like of a person by using sleep state information obtaining unit 511. Sleep state detector 500 also determines the sleep state (awake, REM sleep, stage N (N is any one of 1, 2, 3, and 4) from the obtained information.

[0130] In step S112, sleep state detector 500 transmits the sleep state information obtained in step S111 to cloud server 400.

[0131] In step S113, sleep state detector 500 waits for a predetermined period (for example, one minute), and returns to step S111 after the predetermined period. Sleep state detector 500 counts, for example, 60 seconds, and when the counted result has reached 60 seconds, returns to step S111.

[0132] As described above, the sleep state information does not have to include the estimation result of the sleep state. In other words, sleep state detector 500 may transmit, to cloud server 400, information used for estimating the sleep state including at least one of the body movement, respiratory rate, and heart rate, without estimating the sleep state. In such a case, cloud server 400 may estimate the sleep state based on the information for estimating the sleep state accumulated.

[0133] The "sleep state data accumulation flow" has been described above.

[0134] FIG. 22 illustrates the "air conditioning setting flow".

[0135] In step S121, parameter calculator 412 compares the current time with the scheduled sleep onset time set to setting DB 416, and determines whether or not the current time has passed the scheduled sleep onset time. When the current time has passed the scheduled sleep onset time, parameter calculator 412 performs an initial air conditioning control. When the current time has not passed the scheduled sleep onset time, parameter calculator 412 waits for execution of the initial air conditioning control. When the initial air conditioning control ends, parameter calculator 412 proceeds to step S122. The details of the initial air conditioning control will be described later with reference to FIG. 23.

[0136] In step S122, parameter calculator 412 compares the current time with the scheduled awakening time set to setting DB 416 to determine whether or not the current time has passed the scheduled awakening time. When the current time has passed the scheduled awakening time, that is, when the current time $\geq$ scheduled awakening time (Yes in S122), parameter calculator 412 ends the process of the air conditioning setting flow. When the current time has not passed the scheduled awakening time, that is, when current time $<$ scheduled awakening time (No in S122), parameter calculator 412 proceeds to next step S123.

[0137] In step S123, parameter calculator 412 compares the current time with sleep onset detection + period A to determine whether or not the relation of current time $\geq$ sleep onset detection + period A is satisfied. In other words, parameter calculator 412 determines whether or not period A has passed since the sleep onset of the user is detected. The sleep onset is detected based on the sleep state transmitted from sleep state detector 500. When one or more records in which the sleep state is deep sleep (stage 3 or stage 4) are detected after the scheduled sleep onset time set to setting DB 416, the time of the record is determined as the sleep onset time.

[0138] When determining that period A has not passed since when the sleep onset of the use is detected (No in S123), parameter calculator 412 proceeds to air conditioning control phase 1 in step S124. The details of air conditioning control phase 1 will be described later with reference to FIG. 24. In contrast, when determining that period A has passed since when the sleep onset of the user is detected (Yes in S123), parameter calculator 412 proceeds to air conditioning control phase 2 in step S125. The details of air conditioning control phase 2 will be described later with reference to FIG. 25.

[0139] In step S126, parameter calculator 412 waits for a predetermined period (for example, one minute), and returns to step S122 after the predetermined period. Parameter calculator 412 counts, for example, 60 seconds, and when the counted result has reached 60 seconds, returns to step S122.

[0140] The "air conditioning setting flow" has been described above. The control parameter for controlling air conditioner 300 set by parameter calculator 412 in the air conditioning setting flow may be transmitted to air conditioner 300 by air conditioning setting unit 413 every time a new control parameter is calculated, or may be transmitted to air conditioner 300 regularly by air conditioning setting unit 413.

[0141] FIG. 23 illustrates a control flow of the "initial air conditioning control".

[0142] In step S131, parameter calculator 412 obtains the latest room temperature, that is, the current room temperature from the air conditioning sensing information stored in history DB 415, and compares the current room temperature with the lower-limit temperature. When the current temperature is lower than the lower-limit temperature (Yes in step S131), parameter calculator 412 proceeds to step S132, and when the current room temperature is higher than or equal to the lower-limit temperature (No in step S131), parameter calculator 412 proceeds to step S133.

[0143] In step S132, parameter calculator 412 calculates a control parameter for setting the operating mode of air conditioner 300 to the heating operation. Here, parameter calculator 412 sets the set temperature to the "lower-limit temperature", calculates a control parameter for setting the airflow direction upward, and ends the initial air conditioning control.

[0144] In step S133, parameter calculator 412 calculates a control parameter for setting the operating mode of air conditioner 300 to the heating operation. Here, parameter calculator 412 sets the set temperature to the "lowest set temperature settable to air conditioner", calculates a control parameter for setting the airflow direction upward, and ends the initial air conditioning control.

[0145] The control flow of "initial air conditioning control" has been described above.

[0146] FIG. 24 illustrates a control flow of "air conditioning control phase 1".

[0147] In step S141, parameter calculator 412 obtains the latest room temperature, that is, the current room temperature from the air conditioning sensing information stored in history DB 415, and compares the current room temperature with the lower-limit temperature. When the current room temperature is lower than the lower-limit temperature (Yes in step S141), parameter calculator 412 proceeds to step S142. When the current room temperature is higher than or equal to the lower-limit temperature (No in step S141), parameter calculator 412 proceeds to step S143.

[0148] In step S142, parameter calculator 412 calculates a control parameter for setting the set temperature of air conditioner 300 to the lower-limit temperature, and proceeds to step S143.

[0149] In step S143, parameter calculator 412 determines whether or not the current set temperature of air conditioner 300 is equal to the lower-limit temperature. When the current set temperature is equal to the lower-limit temperature (Yes in S143), parameter calculator 412 proceeds to step S144. When the current set temperature is not equal to the lower-limit temperature (No in S143), parameter calculator 412 ends the process of air conditioning control phase 1.

[0150] In Step S144, parameter calculator 412 refers to the latest sleep state, that is, the current sleep state of the user from the user sleep state information stored in history DB 415 to determine whether or not the current sleep state of the user is deep sleep. When the current sleep state of the user is deep sleep (Yes in S144), parameter calculator 412 proceeds to step S145, and when the current sleep state of the user is not deep sleep (No in S144), parameter calculator 412 proceeds to step S146.

[0151] In step S145, parameter calculator 412 calculates a control parameter for setting the airflow direction of air conditioner 300 downward, and ends the process of air conditioning control phase 1.

[0152] In step S146, parameter calculator 412 calculates a control parameter for setting the airflow direction of air conditioner 300 upward, and ends the process of air conditioning control phase 1.

[0153] The control flow of "air conditioning control phase 1" has been described above.

[0154] FIG. 25 illustrates a control flow of "air conditioning control phase 2".

[0155] In step S151, parameter calculator 412 calculates a control parameter for gradually increasing the set temperature from the lower-limit temperature to the awakening time target temperature in steps during the period from time t2 to the scheduled awakening time, such that the set temperature of air conditioner 300 reaches the awakening time target temperature at the scheduled awakening time. Accordingly, parameter calculator 412 regularly calculates the set temperature at the current time, and calculates a control parameter for setting the calculated set temperature to the set temperature of air conditioner 300.

[0156] A rapid temperature change during sleep increases the possibility of awakening the user. Accordingly, it is required to decrease the room temperature as gradually as possible. Hence, the calculation of the set temperature (ST_Target) in step S151 is performed as below, for example.

$$ST_Target = IT_Start + (ST_Wakeup - IT_Start) \times \{(T_Now - T_Start)/(T_Last - T_Start)\}$$

T_Start : start time of air conditioning control phase 2 (=sleep onset detection + period A time)

T_Last : scheduled awakening time

T_Now : current time

IT_Start : room temperature at the time of T_Start

ST_Wakeup : awakening time target temperature

[0157] Since the controllable temperature gradation varies depending on air conditioner 300, parameter calculator 412 calculates the set temperature according to the adjustable temperature gradation of the set temperature of air conditioner 300. Parameter calculator 412 calculates the set temperature by, for example, rounding out ST_Target in increments of 0.5°C, when, for example, the temperature gradation of the settable set temperature is in increments of 0.5°C.

[0158] In addition, it can be assumed that the calculated result is lower than the current set temperature of the air conditioner. In such a case, the set temperature is set to the current set temperature.

[0159] In Step S152, parameter calculator 412 refers to the latest sleep state, that is, the current sleep state of the user from the user sleep state information stored in history DB 415 to determine whether or not the current sleep state of the user is deep sleep. When the current sleep state of the user is deep sleep (Yes in S152), parameter calculator 412 proceeds to step S153, and when the current sleep state of the user is not deep sleep (No in S152), parameter calculator 412 proceeds to step S154.

[0160] In step S153, parameter calculator 412 calculates a control parameter for setting the airflow direction of air conditioner 300 downward, and ends the process of air conditioning control phase 2.

[0161] In step S154, parameter calculator 412 calculates a control parameter for setting the airflow direction of air conditioner 300 upward, and ends the process of air conditioning control phase 2.

[0162] The control flow of "air conditioning control phase 2" has been described above.

[0163] By configuring air conditioning control system 1 as in the present embodiment, it is possible to perform control during the period from when the user goes to bed till when the user wakes up such that the thermal environment in the room where the user is sleeping is made comfortable for the user toward when the user wakes up.

[0164] In the present embodiment, the airflow direction of air conditioner 300 is set downward when the user sleep state measured by the sleep state detector is deep sleep, and is set upward when the user sleep state is light sleep. However, the present embodiment is not limited to such an example. For example, in an air conditioner which is capable of changing the airflow direction to the left or right, the airflow direction may always be set downward, and the airflow direction may be set to inward when the sleep state of the user is deep sleep and set outward to avoid a person when the sleep state is light sleep. By configuring as described above, it is possible to prevent awakening of the user from being induced during light sleep, while blowing warm air downward. It may be that various sensors 303 of air conditioner 300 have a human sensor which detects the position of the user in the indoor space where air conditioner 300 is provided. In such a case, the human sensor outputs position information indicating the position of the user.

[0165] In such a manner, air conditioning control system 1 may control the airflow direction of the air conditioner based on the position information to the direction in which the discharged air hits the user when the sleep state of the user is deep sleep, and may control the airflow direction based on the position information such that the discharged air avoids the user when the sleep state of the user is light sleep.

[0166] In the present embodiment, the airflow direction in which the discharged air avoids the user may be the direction in which the discharged air does not hit the user or the direction directed to a position different from the position of the user. The direction in which the discharged air hits the user is the direction toward the position of the user.

[0167] In the present embodiment, the sleep state of the user is estimated based on the body movement, respiratory rate, and heart rate detected by sleep state detector 500. However, it may be that, for example, the sleep state of the user is estimated based on LF (Low Frequency)/HF (High Frequency) which are the indices obtained from the frequency analysis result of the heart rate variability of the user. The sleep state of the user and LF/HF are correlated with each other as illustrated in FIG. 26. In FIG. 26, (a) indicates a graph of sleep state of a person relative to elapsed sleep time similarly to FIG. 11, and (b) illustrates a graph indicating LF/HF value on the time axis same as (a). In such a manner, when LF/HF is higher than threshold value Th , sleep state detector 500 or cloud server 400 is capable of determining that the user is in a light sleep state. Moreover, in such a case, it is known that during sleep, the sympathetic nerve of the user is more dominant than the parasympathetic nerve. When LF/HF is less than or equal to threshold value Th , sleep state detector 500 or cloud server 400 is capable of determining that the user is in a deep sleep state. In such a case, it is known that during sleep, the parasympathetic nerve of the user is more dominant than the sympathetic nerve.

[0168] As described above, sleep state detector 500 or cloud server 400 may determine the sleep depth based on heart rate variability analysis. Sleep state detector 500 or cloud server 400 may determine the sleep depth of the user based on the value of LF/HF obtained from the heart rate variability analysis.

[0169] In the present embodiment, when the sleep state of the user is deep sleep, the airflow direction is controlled such that the air discharged by air conditioner 300 hits the user. However, the present disclosure is not limited to such an example. For example, as illustrated in FIG. 27, in the airflow direction control of air conditioner 300, at the timing when the slope of the tangent in temporal variation of index value correlated with the sleep depth obtained by the heart rate variability analysis is greater than a predetermined positive slope, the airflow direction of air conditioner 300 may be controlled such that the air discharge by air conditioner 300 avoids the user even in the deep sleep state, based on the position information of the user. In such a case, parameter calculator 412 may control the airflow direction of air conditioner 300 such that the air discharge by air conditioner 300 avoids the user, by calculating a control parameter for setting the airflow direction discharged by air conditioner 300 upward. The timing when the slope of the tangent is greater than a predetermined positive slope refers to the timing when the slope tends to increase and is greater than the predetermined positive slope.

[0170] In the present embodiment, when the sleep depth of the user is a first stage, the airflow direction of air conditioner 300 is controlled based on the position information of the user such that the air discharged by air conditioner 300 avoids the user, and when the sleep depth of the user is a second stage that is a sleep depth deeper than the first stage, airflow direction of air conditioner 300 is controlled based on the position information of the user such that the air discharged by air conditioner 300 hits the user. In other words, the airflow direction control is performed in stages according to the two-stage sleep depth. However, as illustrated in FIG. 28, airflow direction control may be performed in three or more stages according to the sleep depth of three or more stages.

[0171] Specifically, when the index value correlated with the sleep depth obtained from the heart rate variability analysis is within the four ranges divided by three thresholds $Th1$, $Th2$, and $Th3$, parameter calculator 412 may calculate a control parameter for controlling the airflow direction corresponding to the range to which the index value belongs. The four ranges respectively correspond to four airflow directions in a one-to-one correspondence. For example, parameter calculator 412 calculates a control parameter for setting the airflow direction of air conditioner 300 to the lowest downward, when the index value is in the lowest range of the four ranges, that is, when LF/HF is less than or equal to threshold $Th1$. When the index value is in the second lowest range of the four ranges, that is, when LF/HF is greater than threshold $Th1$ and less than or equal to threshold $Th2$, parameter calculator 412 calculates a control parameter for setting the airflow direction of air conditioner 300 to the second lowest downward (airflow direction of second lowest downward). When the index value is in the second highest range (third lowest range) of the four ranges, that is, when LF/HF is

greater than threshold value Th2 and less than or equal to threshold Th3, parameter calculator 412 calculates a control parameter for setting the airflow direction of air conditioner 300 second highest upward (airflow direction of second highest upward). When the index value is in the highest range of the four ranges, that is, when LF/HF is greater than threshold value Th3, parameter calculator 412 calculates a control parameter for setting the airflow direction of air conditioner 300 highest upward. As described above, the calculated control parameter is transmitted to air conditioner 300 by air conditioning setting unit 413 regularly or at the updated timing, and air conditioner 300 changes the operation according to the received control parameter.

[0172] In the present embodiment, parameter calculator 412 updates the lower-limit temperature and the awakening time target temperature included in the user table stored in setting DB 416 based on the previous thermal environment subjective evaluations of the user stored in history DB 415. However, the present disclosure is not limited to the updating based on the thermal environment subjective evaluations. It is known that the heart rate or the heart rate variability value of the user during sleep is influenced by the ambient temperature of the user. Specifically, it is known that the heart rate or heart rate variability value of the user during sleep increases as the ambient temperature of the user increases. Accordingly, it can be said that the more the user feels heat, the more the heart rate or the heart rate variability value increases.

[0173] FIG. 29 is a graph indicating temporal variations in heart rate, time-averaged heart rate, and estimated heart rate of the user.

[0174] In FIG. 29, thin solid line 801 indicates temporal variations in heart rate of the user, bold solid line 802 indicates temporal variations in time-averaged heart rate of the user, and bold dashed line 803 indicates temporal variations in estimated heart rate that is based on the history of heart rates of the user.

[0175] For example, parameter calculator 412 calculates correlation between heart rate or heart rate variability and room temperature obtained previously and stored in history DB 415 and associated with the user. Parameter calculator 412 calculates a predictive value of the future heart rate or heart rate variability of the user based on the calculated correlation. In the calculation of the correlation, a correlation including elapsed sleep time, LF/HF and the like may further be calculated. Parameter calculator 412 may change the lower-limit temperature or the awakening time target temperature to a lower temperature, when the time-averaged heart rate is greater than the predicted value by a predetermined value. For the user heart rate or heart rate variability and room temperature previously obtained and stored in history DB 415 for calculation of the correlation, information obtained during a predetermined period prior to the current time may be used.

[0176] In the present embodiment, "deep sleep" is classified as "stage 3 or stage 4", but may be classified as "only stage 4" or "stage 2, stage 3, or stage 4" depending on the trend of the air conditioning sensing information or sleep state information. Moreover, REM sleep is also considered that the brain is active as in light sleep but the movement of the body itself is restricted and thus the person is unlikely to waken. Hence, REM sleep may be classified as a sleep state where a person is unlikely to waken, in a similar manner to "deep sleep". In other words, in the present embodiment, the airflow direction of air conditioner 300 is controlled according to the sleep depth classified into first and second stages, that is, whether the sleep depth of the user is in the first stage or the second stage. It may be that the airflow direction of air conditioner 300 is controlled according to whether the sleep state of the user is a state where the user is unlikely to waken. When the sleep state of the user is in the stage where the user is unlikely to waken, the airflow direction of air conditioner 300 may be controlled such that the air hits the user. When the sleep state of the user is in the stage where the user is likely to waken, the airflow direction of air conditioner 300 may be controlled such that the air avoids the user. The sleep state where the user is unlikely to waken may be the case where the sleep depth of the user is deep sleep, or REM sleep and deep sleep.

[0177] In air conditioning control system 1, at the initial sleep of the user, the initial value of the lower-limit temperature or the awakening time target temperature may be determined based on the personal subjective evaluation on air conditioning such as "sensitive to heat" or "sensitive to cold". In such a case, cloud server 400 obtains a subjective evaluation of the user from terminal device 700 to determine the lowest limit temperature and the awakening time target temperature according to the obtained subjective evaluation. For example, when the subjective evaluation of the user is "sensitive to heat", cloud server 400 sets the lower-limit temperature to be associated with the user to 18°C, and sets the awakening time target temperature to be associated with the user to 20°C. In contrast, for example, when the subjective evaluation of the user is "sensitive to cold", cloud server 400 sets the lower-limit temperature to be associated with the user to 20°C, and sets the awakening time target temperature to be associated with the user to 22°C. Accordingly, even at the initial use, the operation of air conditioner 300 can be controlled with the preferred set temperature that is in accordance with the subjective evaluation of the user.

[0178] In air conditioning control system 1, at the initial sleep of the user, the initial value of the lower-limit temperature or the awakening time target temperature may be determined according to the state of comforter (bed) being used. In such a case, cloud server 400 obtains the state of comforter the user is using from terminal device 700, and determines the lower-limit temperature and the awakening time target temperature according to the obtained state of comforter. For example, when the state of bed is "comforter + blanket", cloud server 400 sets the lower-limit temperature to 18°C, and sets the awakening time target temperature to 20°C. In contrast, when the state of comforter is "blanket", cloud server

400 sets the lower-limit temperature to 20°C, and sets the awakening time target temperature to 22°C. The state of comforter may be obtained from terminal device 700 by regularly having a questionnaire on terminal device 700. Accordingly, even at the initial use, the operation of air conditioner 300 can be controlled with preferred set temperature that is in accordance with the state of bed being used by the user. In the case where sleep state detector 500 or the like includes a sensor for measuring the temperature inside the comforter, cloud server 400 may obtain the temperature measured by the sensor to estimate the thickness of comforter based on the correlation between the measured temperature and room temperature. Accordingly, cloud server 400 does not require the user to manually set the state of the comforter to terminal device 700, and a change in state of comforter can be reflected automatically.

[0179] In the present embodiment, the airflow direction is set downward when the sleep state measured by the sleep state detector is deep sleep, and the airflow direction is set upward when the sleep state is light sleep. However, it may be that the air volume is increased when the sleep state is deep sleep, and the air volume is decreased or stopped when the sleep state is light sleep. With such a configuration, air conditioning control can be performed more effectively according to the sleep rhythm while preventing the user from being awakened.

[0180] In the present embodiment, the airflow direction is set downward when the sleep state measured by the sleep state detector is deep sleep, and the airflow direction is set upward when the sleep state is light sleep. However, it may be that the set temperature is increased when the sleep state is deep sleep, and the set temperature is decreased or stopped when the sleep state is light sleep. With such a configuration, air conditioning control can be performed more effectively according to the sleep rhythm while preventing the user from being awakened.

[0181] In the present embodiment, the airflow direction of the air conditioner is set downward when the sleep state measured by the sleep state detector is deep sleep, and the airflow direction is set upward when the sleep state is light sleep. However, it may be that the airflow direction is vertically swung when the sleep state is deep sleep. With such a configuration, air in the room is circulated so that air directed upward is brought downward, leading to an increased comfort.

[0182] In the present embodiment, the airflow direction of the air conditioner is set downward when the sleep state measured by the sleep state detector is deep sleep, and the airflow direction is set upward when the sleep state is light sleep. However, "defrosting operation" may be performed when the sleep state is light sleep. When the outside temperature in winter is lower than a predetermined temperature and the outside humidity is higher than a predetermined humidity, frost might be caused on the outdoor unit. The defrosting operation refers to an operation for removing the frost which hinders the heating operation. During the operation, heating is stopped, so that the air of the indoor unit is also stopped. After the defrosting operation, the air conditioner starts to operate to reheat the room which became cold during the defrosting operation. Hence, the defrosting operation is preferably performed during light sleep rather than deep sleep.

[0183] In the present embodiment, the airflow direction of the air conditioner is set downward when the sleep state measured by the sleep state detector is deep sleep, and the airflow direction is set upward when the sleep state is light sleep. However, in the case where the air conditioner includes a humidifying operation function, it may be that the level of the humidifying operation is increased during deep sleep and is decreased or stopped during light sleep. Noise is generated during the humidifying operation. Hence, with the above configuration, the level of humidifying operation is decreased during light sleep, so that the noise of the humidifying operation can be reduced, preventing awakening of the user from being induced.

[0184] In the present embodiment, the airflow direction of the air conditioner is set downward when the sleep stage measured by the sleep state detector is deep sleep, and the airflow direction is set upward when the sleep state is light sleep. However, the setting may be manually operated by the user. The airflow directions and volumes during deep sleep and during light sleep may be preset to the system, so that the system performs control based on the preset setting. With such a configuration, it is possible to perform control in light of user's preference, room layout or the like.

[0185] In the present embodiment, the airflow direction of the air conditioner is set downward when the sleep state measured by the sleep state detector is deep sleep, and the airflow direction is set upward when the sleep state is light sleep. However, the state of the room temperature may also be considered. When the room temperature is sufficiently high, the airflow direction is set upward even during deep sleep, and when the room temperature is too low, the airflow direction is set downward even during light sleep. With such a configuration, more flexible and detailed control can be performed according to the sleep state and the room temperature.

[0186] In the present embodiment, when the sleep state measured by the sleep state detector is deep sleep, the airflow direction of the air conditioner is set downward, and when the sleep state is light sleep, the airflow direction is set upward. However, control may be changed based on the elapsed time of deep sleep. For example, even when the deep sleep is continued after the onset of deep sleep, the airflow direction may be changed upward after 20 minutes from the onset of the deep sleep. Alternatively, it may be that the previous sleep stages, heart rates, and the like are learned, future sleep stages are predicted after turning into deep sleep, and the airflow direction is changed upward before the end of deep sleep. With such a configuration, it is possible to prevent the user from being awakened by the air, when the sleep state shifts from deep sleep to light sleep.

[0187] The state of the room temperature may also be considered. When the room temperature is sufficiently high, the airflow direction is set upward even during deep sleep, and when the room temperature is too low, the airflow direction is set downward even during light sleep. With such a configuration, more flexible and detailed control can be performed according to the sleep state and the room temperature.

[0188] The state of the room humidity may also be considered. When the humidity is too low, the airflow direction is set upward even during deep sleep. With such a configuration, when the humidity is too low, it is possible for the skin from getting dried.

[0189] In the present embodiment, when the sleep state measured by the sleep state detector is deep sleep, the airflow direction of the air conditioner is set downward, and when the sleep state is light sleep, the airflow direction is set upward. However, in the case where the air conditioner includes an air purifying function, it may be that the level of the air purifying function is increased during deep sleep and is decreased or stopped during light sleep. The operation of air purifying function makes noise. Hence, with the above configuration, by decreasing the level of the operation during light sleep, it is possible to prevent awakening of the user from being induced.

[0190] In the present embodiment, when the sleep state measured by the sleep state detector is deep sleep, the airflow direction of the air conditioner is set downward, and when the sleep state is light sleep, the airflow direction is set upward. However, in the case where the air conditioner includes a microparticle ion generating function, such as nanoe (registered trademark), it may be that the level of the microparticle ion generating function is increased during deep sleep and is decreased or stopped during light sleep. The microparticle ion generating function makes noise. With the above configuration, by decreasing the level of operation during light sleep, the noise of the microparticle ion generating function can be reduced, preventing awakening of the user from being induced.

[0191] In the present embodiment, as described with reference to FIG. 18, when the room temperature is higher than the lower-limit temperature at bedtime, the set temperature of the air conditioner is set to the lowest settable temperature. However, cooling or fan operation may be set instead of heating. When the lowest value of the set temperature of the air conditioner is 16°C, the user who sleeps with a thick comforter might want to set the lower-limit temperature to be lower. For example, when the lower-limit temperature is set to 10°C, if the lowest settable temperature of the heating operation is set to 16°C, even if the outside temperature is so low, the room temperature does not become 10°C as the heating operation is performed. In such a case, by setting to cooling operation of 30°C, the lower-limit temperature can be set lower than the lowest temperature of the air conditioner.

[0192] In the present embodiment, as described with reference to FIG. 18, when the room temperature is higher than the lower-limit temperature at the bedtime, the set temperature of the air conditioner is set to the lowest settable temperature. However, instead of heating operation, neutral operation (mode in which no operation is performed) may be set. When the lowest value of the set temperature of the air conditioner is 16°C, the user who sleeps with a thick comforter might want to set the lower-limit temperature to be lower. For example, when the lower-limit temperature is 10°C, if the lowest settable temperature of the heating operation is set to 16°C, even if the outside temperature is so low, the room temperature does not become 10°C as the heating operation is operated. In such a case, by providing a neutral operation mode where the power of the air conditioner is ON but no operation is performed, the lower-limit temperature can be set lower than the lowest temperature of the air conditioner. In addition, the power of the air conditioner is ON at the bedtime, and an anxiety of the user which is caused by the power being turned ON by itself while the user is sleeping can be eliminated.

[0193] In the present embodiment, control of the airflow direction of air conditioner 300 at the time of heating operation has been described. However, control may be performed similarly in the cooling operation as well. In other words, at the time of cooling operation, too, when the sleep depth of the user is the first stage, the airflow direction of the air conditioner may be controlled based on the user position information such that the air discharged by air conditioner 300 avoids the user, and when the sleep depth of the user is the second stage that is deeper than the first stage, the airflow direction may be controlled based on the user position information such that the air discharged by air conditioner 300 hits the user.

[0194] In the present embodiment, it has been described that cloud server 400 obtains the air conditioning sensing information and air conditioning control information from air conditioner 300, and obtains the sleep state information from sleep state detector 500, and a control parameter for controlling air conditioner 300 is calculated based on the obtained information. However, cloud server 400 does not have to calculate the control parameter. In other words, instead of cloud server 400 calculating the control parameter, air conditioner 300 may calculate the control parameter. In such a case, air conditioner 300 includes parameter calculator 412, history DB 415, interface 414, and setting DB 416 among the functional blocks of cloud server 400. Air conditioning controller 313 performs an operation according to the control parameter calculated by parameter calculator 412. In such a case, air conditioner 300 includes an obtaining unit which obtains sleep state information from sleep state detector 500. As described above, cloud server 400 does not have to exist, and air conditioner 300 may calculate the control parameter.

[0195] Air conditioner 300 may further include an airflow direction adjusting mechanism which adjusts the direction of the airflow (airflow direction) discharged by air blower 302 into the room. The airflow direction adjusting mechanism is,

for example, disposed at the outlet of air conditioner 300, and includes a flap for adjusting the direction of the airflow and an actuator (motor) which adjusts the angle of the flap.

[0196] The air conditioning control system according to the present embodiment has been described above.

5 (Service Type 1: Own Data Center Type)

[0197] FIG. 2 illustrates service type 1 (own data center type). In service type 1, service provider 120 obtains information from group 100 to provide a service to the user. In this type, service provider 120 includes functions of a data center management company. In other words, the service provider includes cloud server 111 which manages big data. Accordingly, no data center management company exists.

10 **[0198]** In this type, service provider 120 operates and manages data center (cloud server 111) (203). Service provider 120 also manages an operating system (OS) (202) and an application (201). Service provider 120 provides a service (204) by using the OS (202) and application (201) managed by service provider 120.

15 (Service Type 2: IaaS Type)

[0199] FIG. 3 illustrates service type 2 (IaaS type). Here, the term "IaaS" stands for infrastructure as a service, and is a cloud server providing model which provides the infrastructure itself for constructing and operating a computer system as a service via the Internet.

20 **[0200]** In this type, a data center management company operates and manages data center (cloud server 111) (203). Service provider 120 also manages an OS (202) and an application (201). Service provider 120 provides a service (204) by using the OS (202) and application (201) managed by service provider 120.

(Service Type 3: PaaS Type)

25 **[0201]** FIG. 4 illustrates service type 3 (PaaS type). Here, the term "PaaS" stands for platform as a service, and is a cloud server providing model which provides, as a service via the Internet, a platform for constructing and operating software.

30 **[0202]** In this type, data center management company 110 manages an OS (202), and operates and manages a data center (cloud server 111) (203). Service provider 120 manages an application (201). Service provider 120 provides a service (204) by using the OS (202) managed by the data center management company and the application (201) managed by service provider 120.

(Service Type 4: SaaS Type)

35 **[0203]** FIG. 5 illustrates service type 4 (SaaS type). Here, the term "SaaS" stands for software as a service. For example, SaaS is a cloud server providing model which includes a function that allows a company and an individual (user) which do not own the data center (cloud server) to use the application provided by a platform provider which owns a data center (cloud server) via a network such as the Internet.

40 **[0204]** In this type, data center management company 110 manages an application (201), and an OS (202), operates and manages a data center (cloud server 111) (203). Service provider 120 provides a service (204) by using the OS (202) and application (201) managed by data center management company 110.

45 **[0205]** In any of the types described above, it is considered that service provider 120 provides services. In addition, for example, the service provider or the data center management company may develop OS, applications, database of big data, and the like by themselves, or may outsource a third party to perform the development.

[Industrial Applicability]

50 **[0206]** The air conditioning control system according to one aspect of the present disclosure is capable of providing a comfortable environment at the awakening time by gradually increasing the environmental temperature toward the awakening time by using thermal indices in the control of the air conditioner, leading to an increased comfort during sleep. Accordingly, the air conditioning system according to the present invention has a high usability in home appliance industries.

55 [Reference Signs List]

[0207]

	10, 20	user
	100	group
	101	device
	102	home gateway
5	110	data center management company
	111	cloud server
	120	service provider
	121	server
	201	application
10	202	OS
	203	data center (cloud server)
	204	service provider
	300	air conditioner
	301	heat source
15	302	air blower
	303	various sensors
	304	control circuit
	311	sensor information obtaining unit
	312	control information obtaining unit
20	313	air conditioning controller
	400	cloud server
	401	processor
	402	main memory
	403	storage
25	404	communication IF
	411	obtaining unit
	412	parameter calculator
	413	air conditioning setting unit
	414	interface
30	415	history DB
	416	setting DB
	500	sleep state detector
	501	antenna
	502	control circuit
35	511	sleep state information obtaining unit
	600	communication network
	601	house
	610	router
	700	terminal device
40	701	setting screen
	702, 703	timer list
	710	awakening screen
	711	comments
	712, 713	icon
45	720	feedback received screen
	721, 722	icon
	801	thin solid line
	802	bold solid line
50	803	bold dashed line

Claims

1. A control method performed by a computer for controlling an air conditioner provided in a room, the control method comprising:
- obtaining position information of a user in the room and a sleep depth which indicates sleep information of the user;

controlling an airflow direction of the air conditioner in a first stage of the sleep depth based on the position information, such that an air discharged by the air conditioner avoids the user; and
controlling the airflow direction in a second stage of the sleep depth based on the position information, such that the air discharged by the air conditioner hits the user, the second stage being a sleep depth that is deeper than the first stage.

2. The control method according to claim 1,
wherein the sleep depth is determined based on an index value obtained by a heart rate variability analysis.

3. The control method according to claim 2, further comprising:

estimating an end time of the second stage based on a temporal variation in the index value,
wherein the controlling of the airflow direction in the second stage includes controlling the airflow direction based on the position information at a predetermined period prior to the estimated end time of the second stage or when the index value becomes a predetermined index value, such that the air discharged by the air conditioner avoids the user.

4. The control method according to claim 2,
wherein the controlling of the airflow direction in the second stage includes controlling the airflow direction based on the position information when a slope in a temporal variation in the index value becomes greater than a predetermined positive slope, such that the air discharged by the air conditioner avoids the user.

5. The control method according to any one of claims 1 to 4, further comprising:

obtaining a subjective evaluation made by the user on a room environment during sleep of the user or at an awakening time of the user; and
changing a set temperature in an air conditioning operation of the air conditioner during sleep of the user, based on the subjective evaluation.

6. A control method performed by a computer for controlling an air conditioner provided in a room, the control method comprising:

obtaining a sleep depth which indicates sleep information of a user in the room;
controlling an airflow direction of the air conditioner to be directed upward in the room in a first stage of the sleep depth; and
controlling the airflow direction of the air conditioner to be directed downward in the room in a second stage of the sleep depth, the second stage being a sleep depth that is deeper than the first stage.

7. An air conditioner which includes a processor and a memory, the air conditioner being provided in a room, wherein, using the memory, the processor performs:

obtaining position information of a user in the room and a sleep depth which indicates sleep information of the user;
controlling an airflow direction of the air conditioner in a first stage of the sleep depth based on the position information, such that the air discharged by the air conditioner avoids the user; and
controlling the airflow direction of the air conditioner in a second stage of the sleep depth based on the position information, such that the air discharged by the air conditioner hits the user, the second stage being a sleep depth that is deeper than the first stage.

8. A program for causing a computer to execute a control method of an air conditioner provided in a room, the control method comprising:

obtaining position information of a user in the room and a sleep depth which indicates sleep information of the user;
controlling an airflow direction of the air conditioner in a first stage of the sleep depth based on the position information, such that the air discharged by the air conditioner avoids the user; and
controlling the airflow direction in a second stage of the sleep depth based on the position information, such that the air discharged by the air conditioner hits the user, the second stage being a sleep depth that is deeper than the first stage.

than the first stage.

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FIG. 1

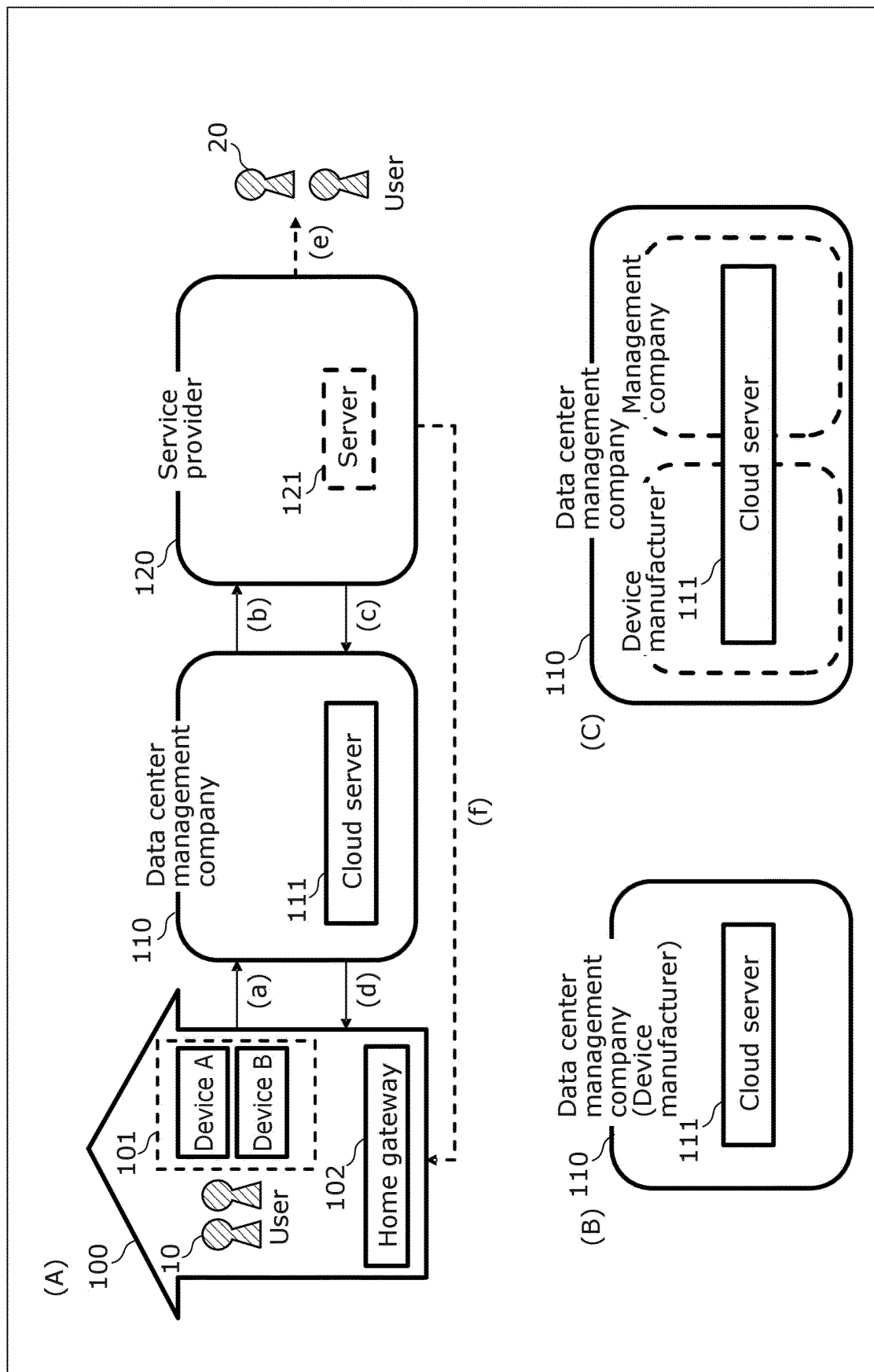


FIG. 2

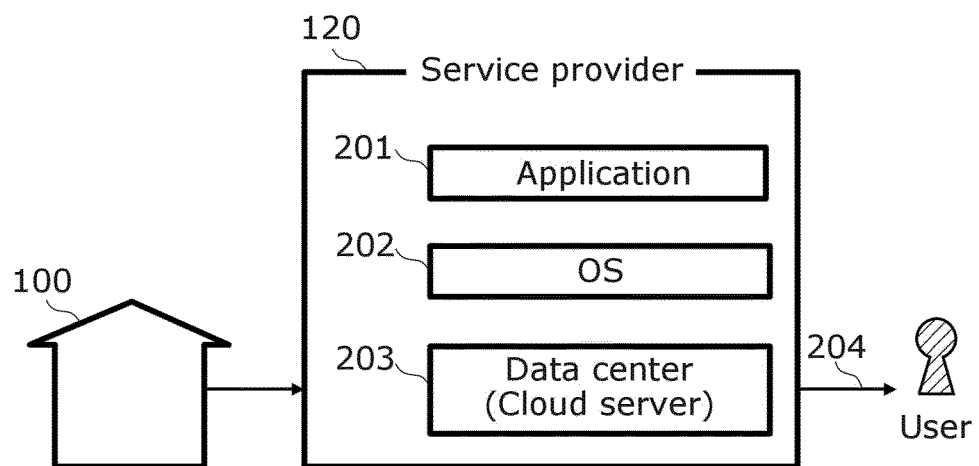


FIG. 3

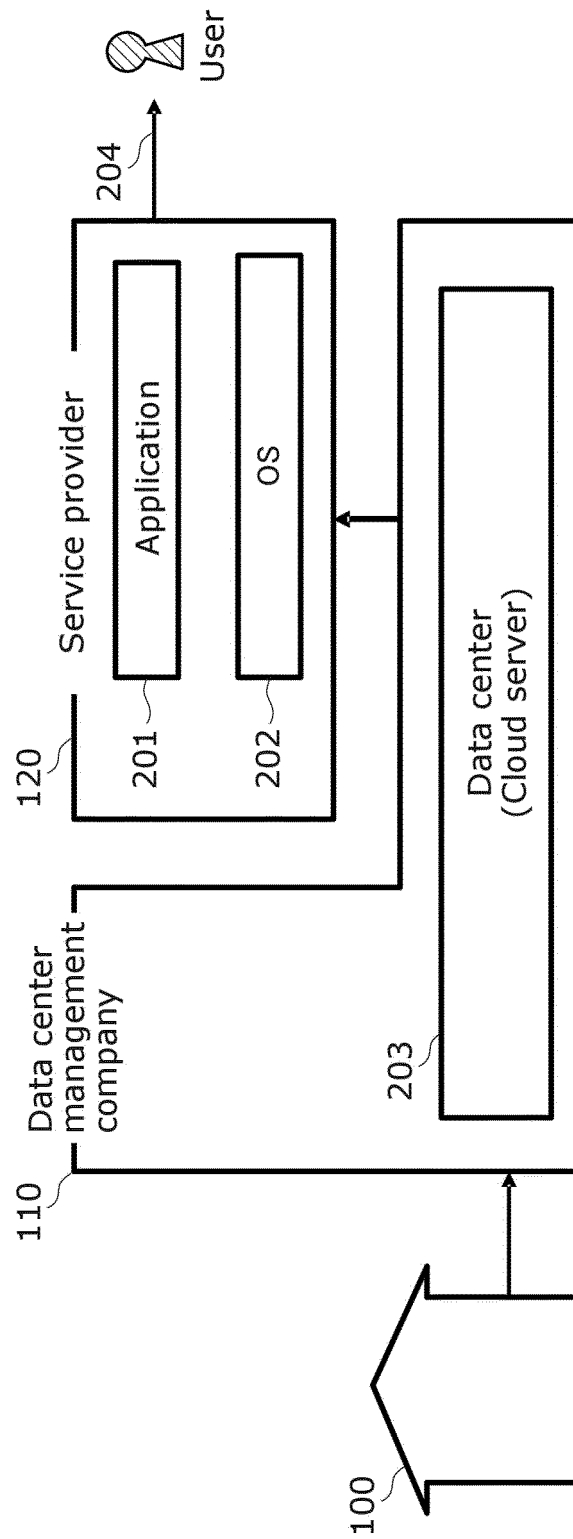


FIG. 4

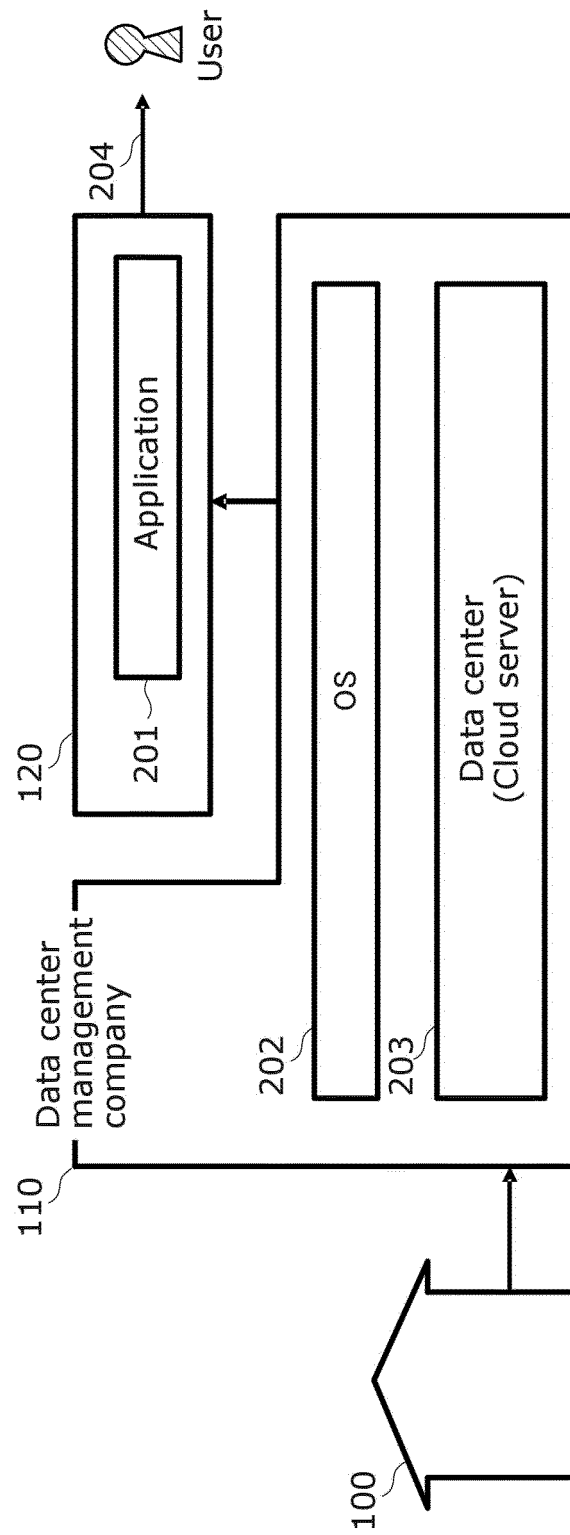


FIG. 5

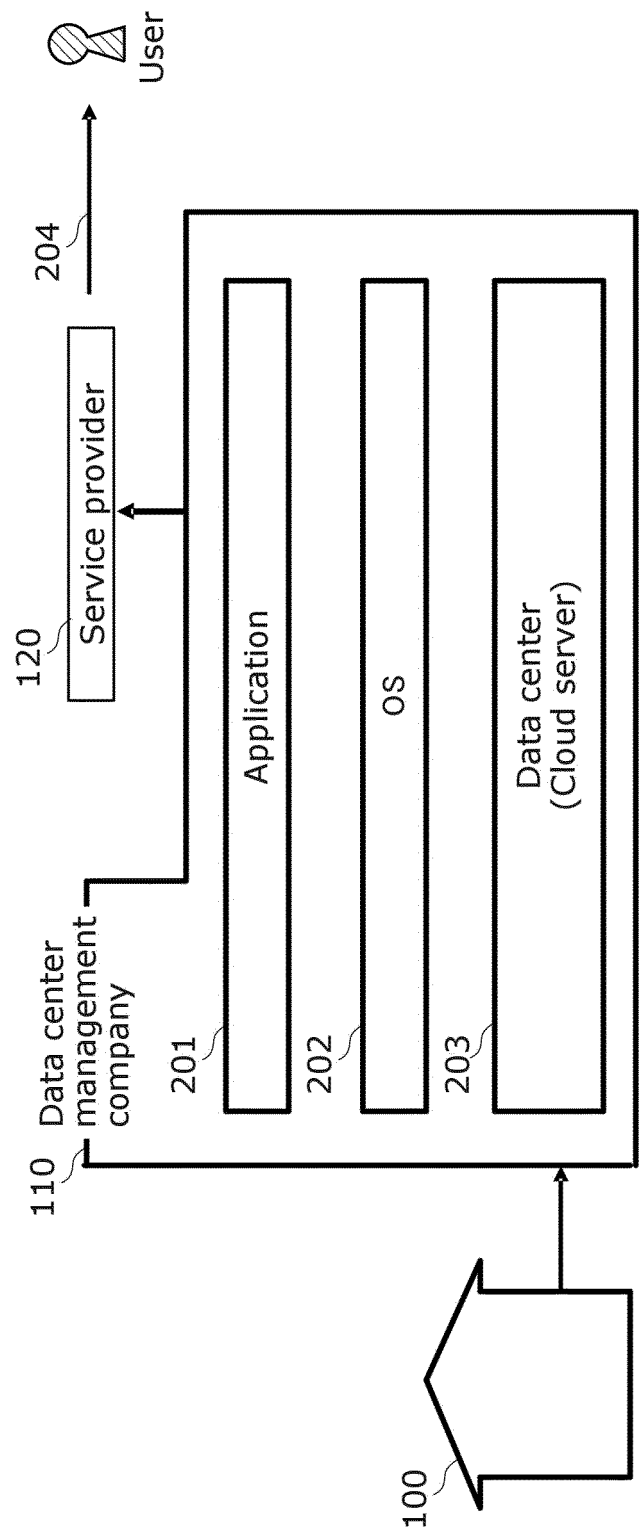


FIG. 6

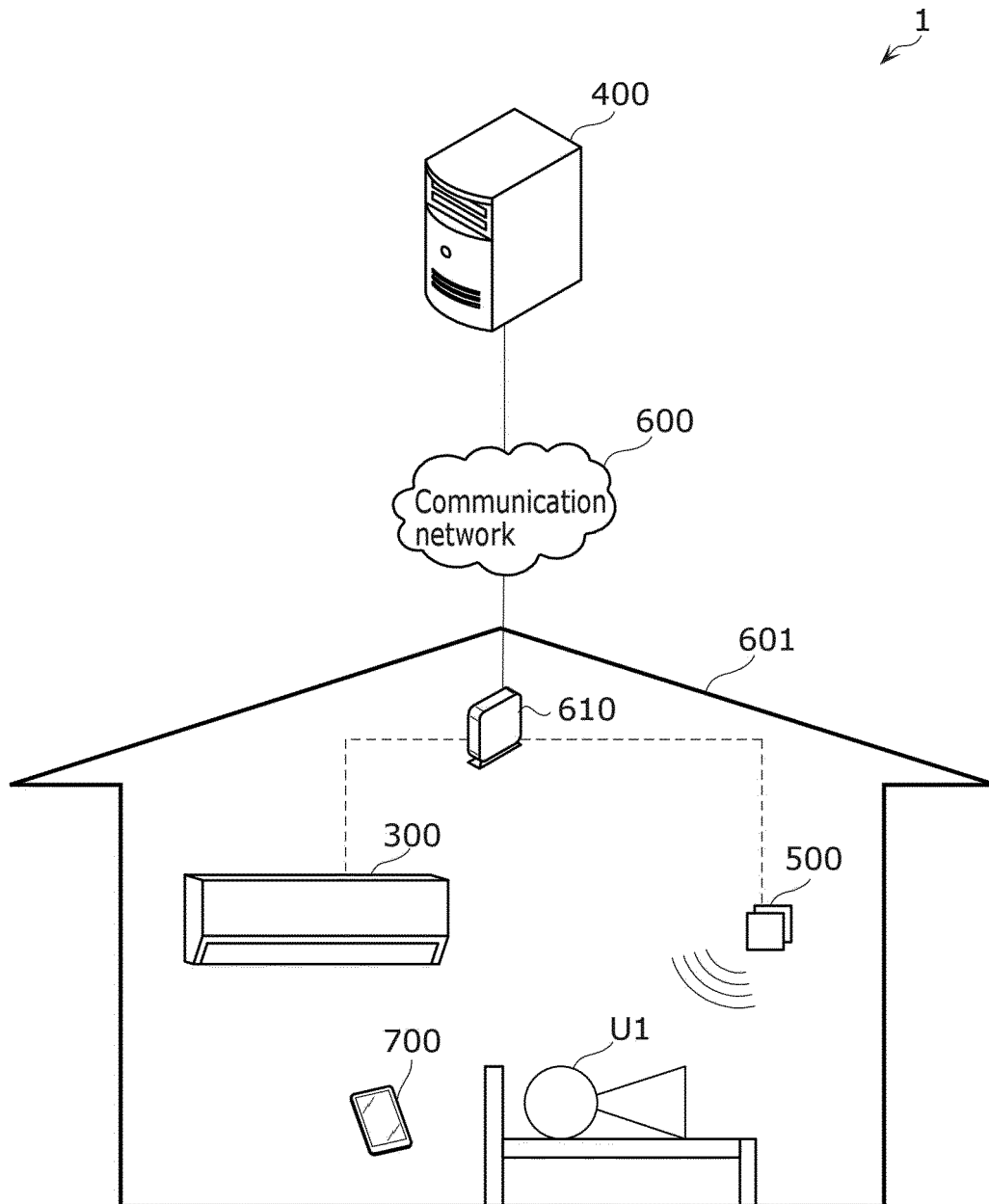


FIG. 7

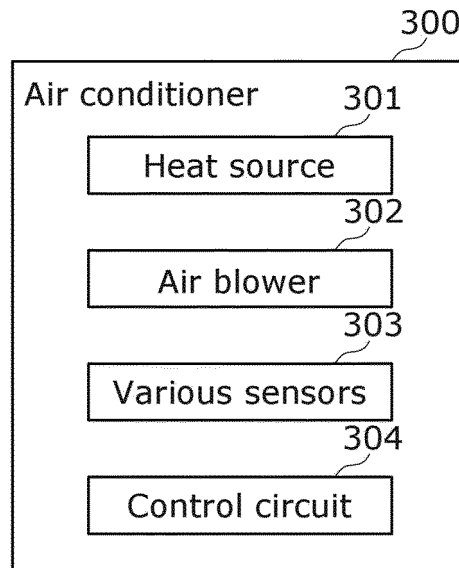


FIG. 8

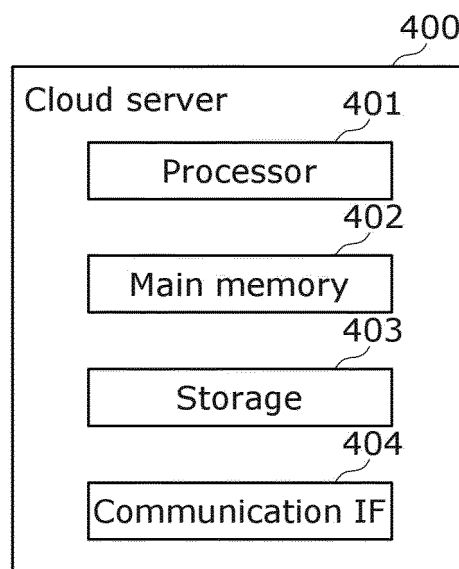


FIG. 9

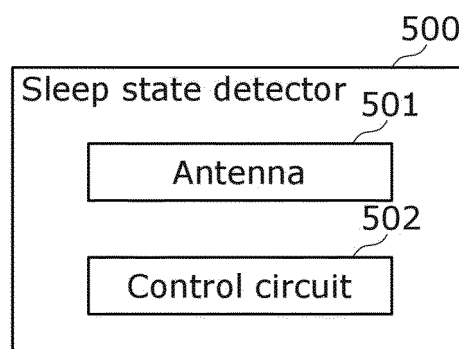


FIG. 10

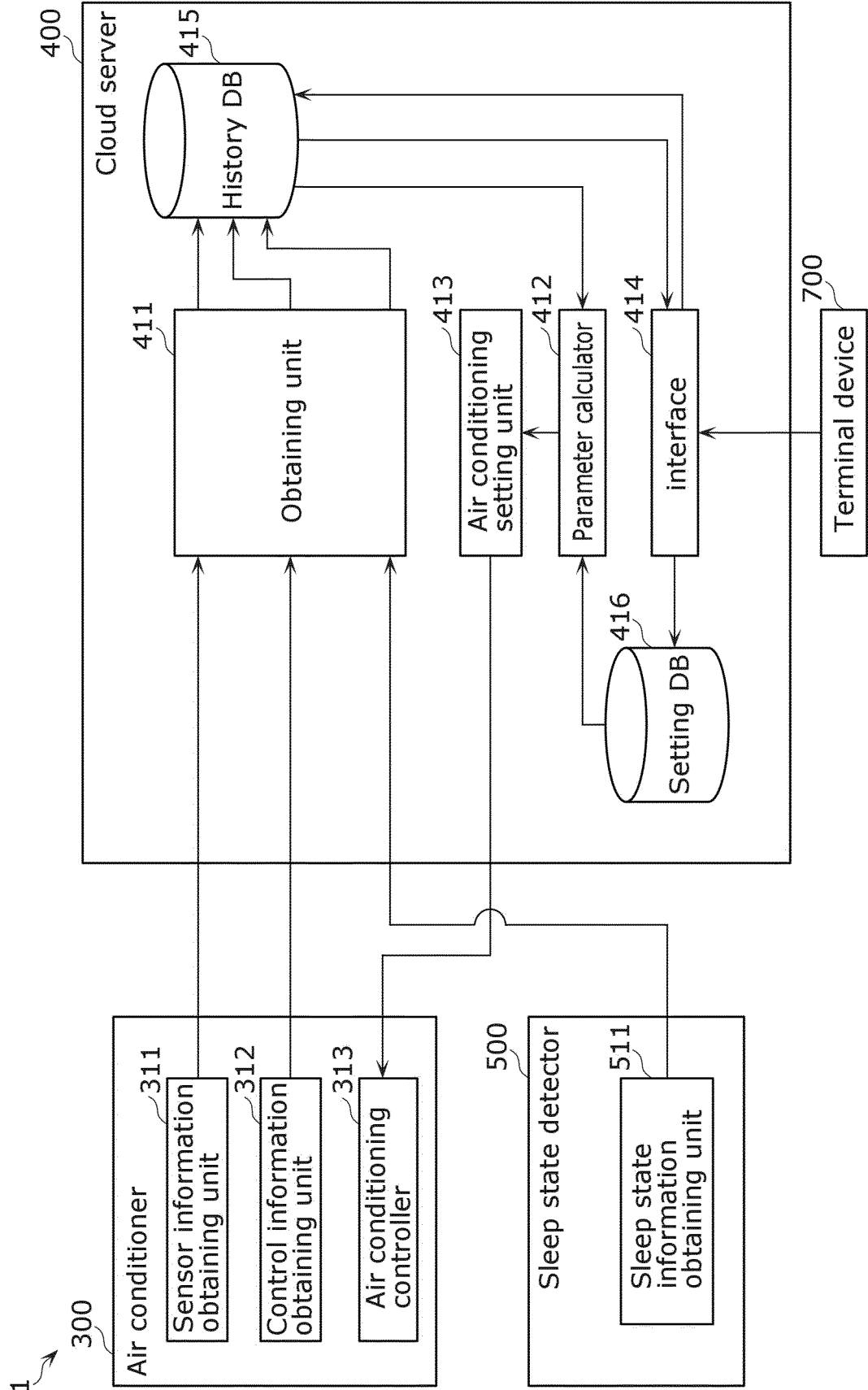


FIG. 11

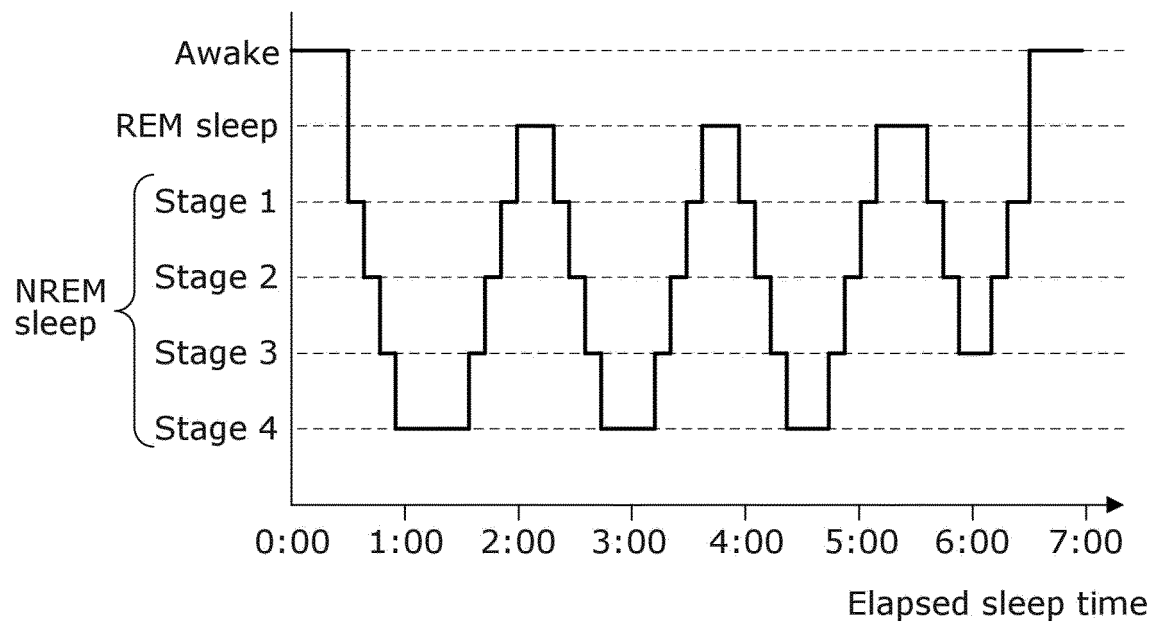


FIG. 12

ID	Time	Air conditioning sensing information						Air conditioning control information					Weather	External device room temperature
		Room temperature (°C)	Room humidity (%)	Outside temperature (°C)	Discharged air temperature (°C)	Power amount (wh)	Presence/absence	Operating status	Operating mode	Set temperature (°C)	Air volume	Airflow direction		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
100	2016/8/14(Sun) 10:00	30.0	50	32.9	-	0	Absence	OFF	-	-	-	-	Fine	30.0
102	2016/8/14(Sun) 10:01	30.1	50	33.0	-	0	Absence	OFF	-	-	-	-	Fine	30.1
103	2016/8/14(Sun) 10:02	30.2	51	33.0	-	0	Presence	OFF	-	-	-	-	Fine	-
104	2016/8/14(Sun) 10:03	30.2	50	32.8	28.0	100	Presence	ON	Cooling	25	Lv5	Dir1	Fine	-
105	2016/8/14(Sun) 10:04	30.0	49	32.7	26.0	60	Presence	ON	Cooling	25	Lv5	Dir1	Fine	-
106	2016/8/14(Sun) 10:05	29.7	49	32.6	24.0	40	Presence	On	Cooling	25	Lv5	Dir1	Fine	-
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

FIG. 13

ID	Time	Sleep state information				
		Sleep state	Heart rate (bpm)	Respiratory rate (brpm)	Body movement amount	...
...	...	...	...	...	...	...
200	2016/8/14(Sun) 23:00	Awake	66.28	13.16	20	...
202	2016/8/14(Sun) 23:01	Awake	64.98	13.68	5	...
203	2016/8/14(Sun) 23:02	Stage 1	67.45	13.2	0	...
204	2016/8/14(Sun) 23:03	Stage 1	66.63	13.2	0	...
205	2016/8/14(Sun) 23:04	Stage 1	65.66	13.31	0	...
206	2016/8/14(Sun) 23:05	Stage 2	65.36	12.3	0	...
...	...	...	...	...	...	...

FIG. 14

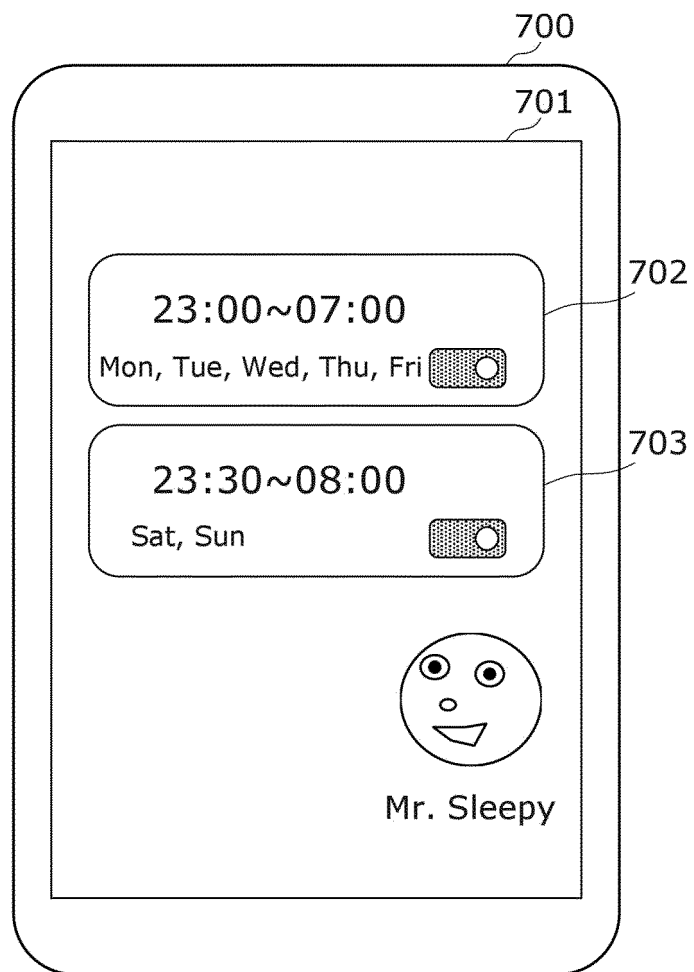


FIG. 15

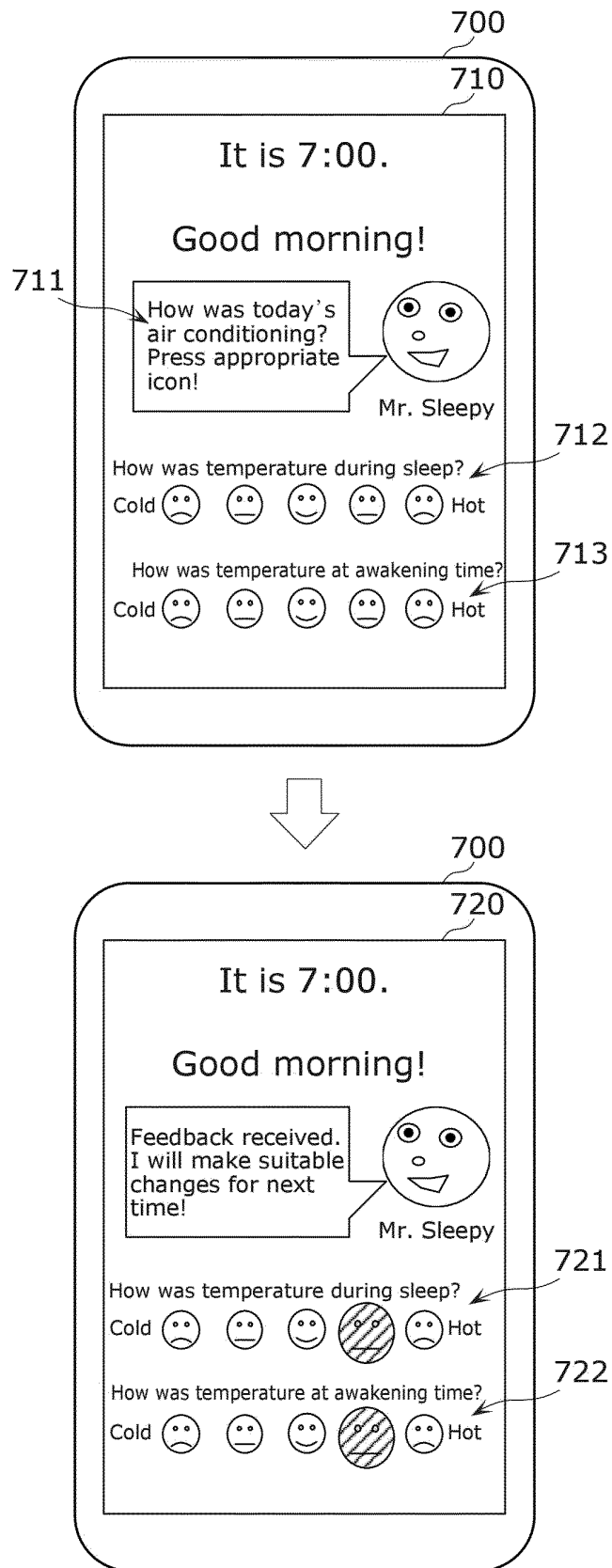


FIG. 16

ID	Actual sleep onset time	Actual awakening time	Subjective evaluation on thermal environment during sleep	Subjective evaluation on thermal environment at awakening time
400	2018/01/16 23:04	2018/01/16 7:00	1 (Cold)	2 (A little cold)
401	2018/01/17 23:20	2018/01/16 7:05	4 (A little hot)	5 (Hot)

FIG. 17

User table

User ID	User name	Awakening time target temperature	Lower-limit temperature	...
100	youkou	25.5	20.0	...
101	ikune	21.5	18.0	...
102	...	...	...	...

FIG. 18

Schedule table

Schedule ID	Scheduled sleep onset time	Scheduled awakening time	Day of week	User ID
300	23:00	07:00	Mon, Tue, Wed, Thu, Fri	100
302	23:30	08:00	Sat, Sun	101

FIG. 19

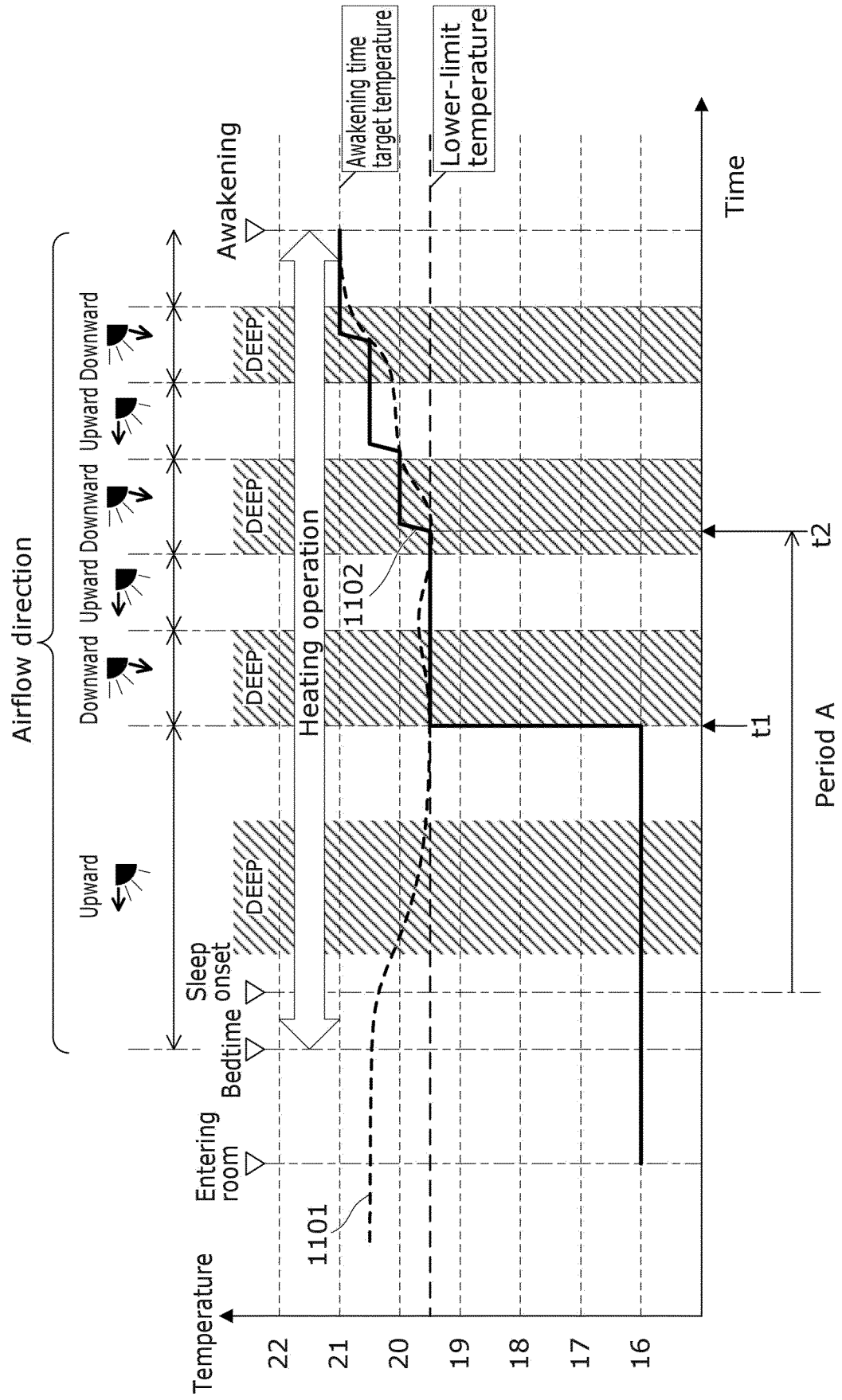


FIG. 20

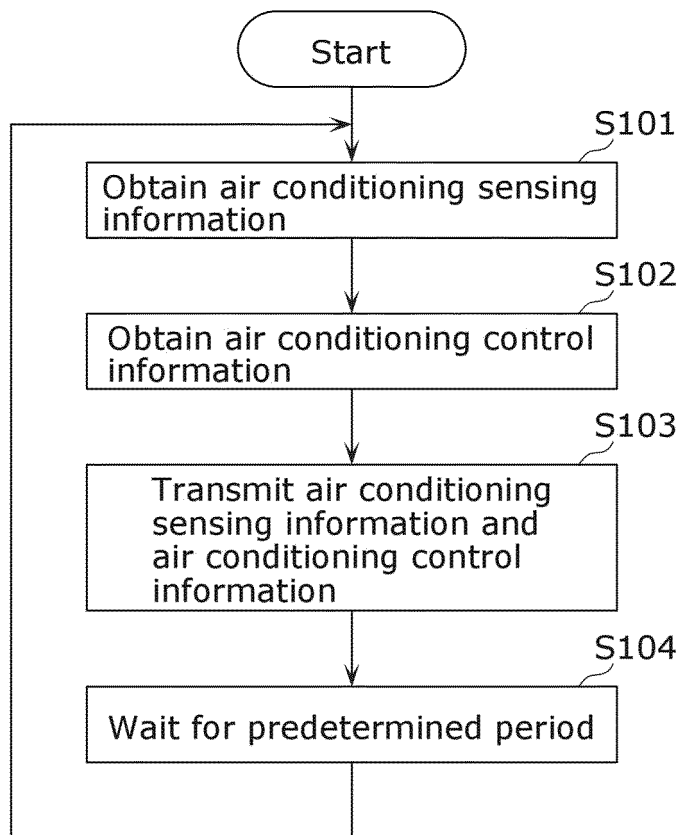


FIG. 21

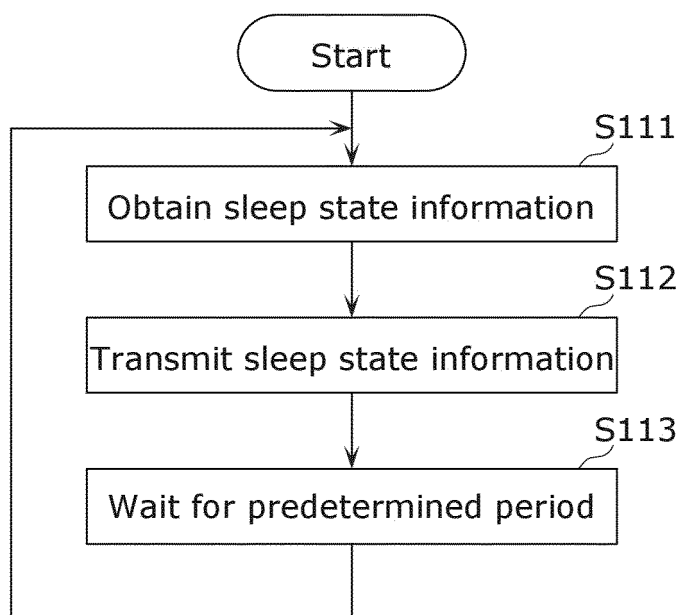


FIG. 22

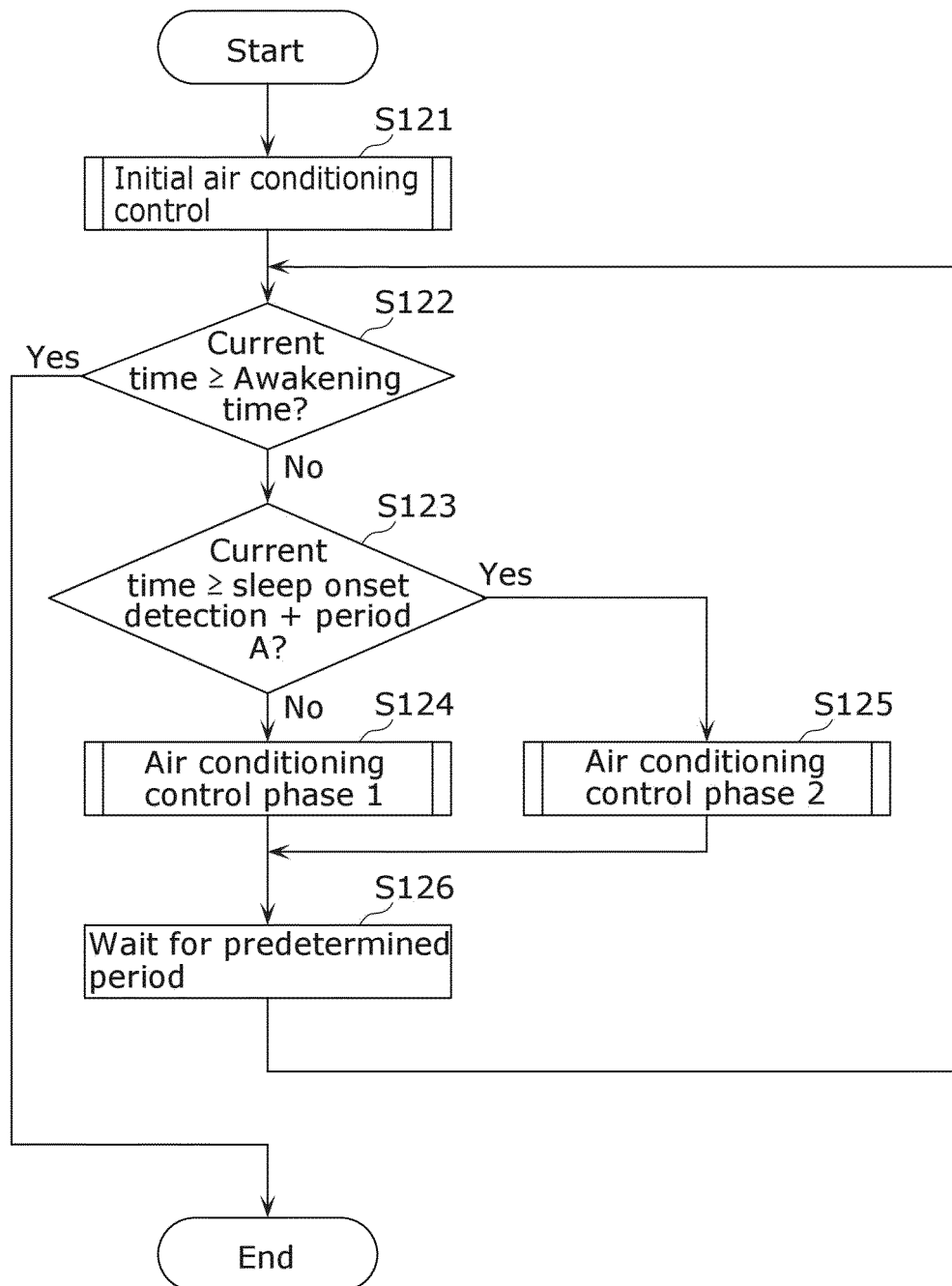


FIG. 23

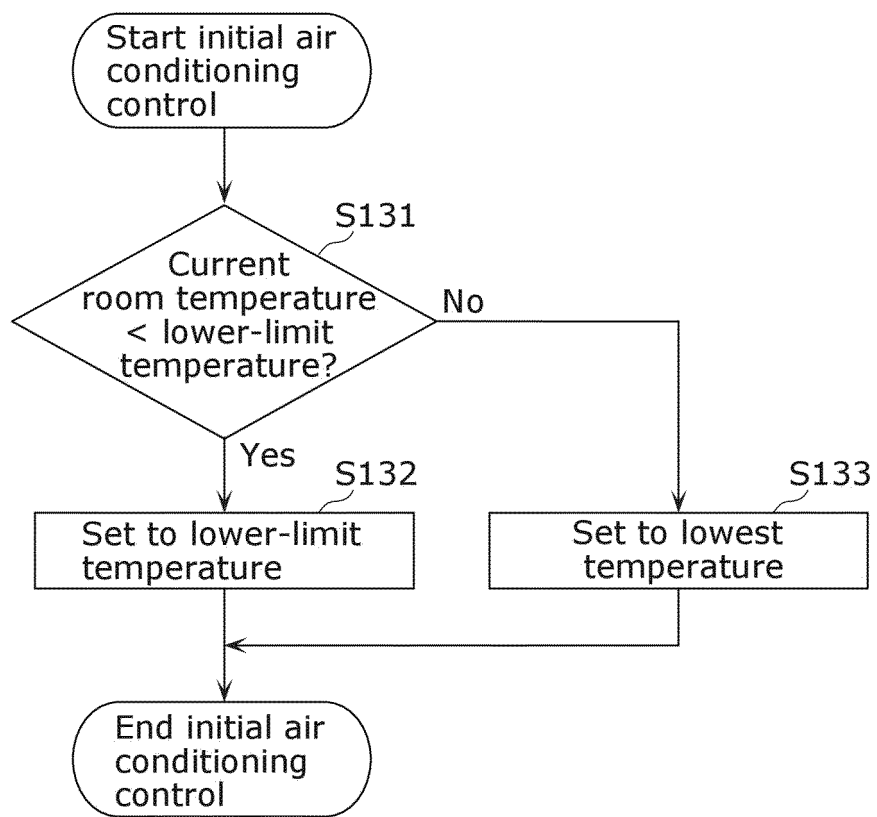


FIG. 24

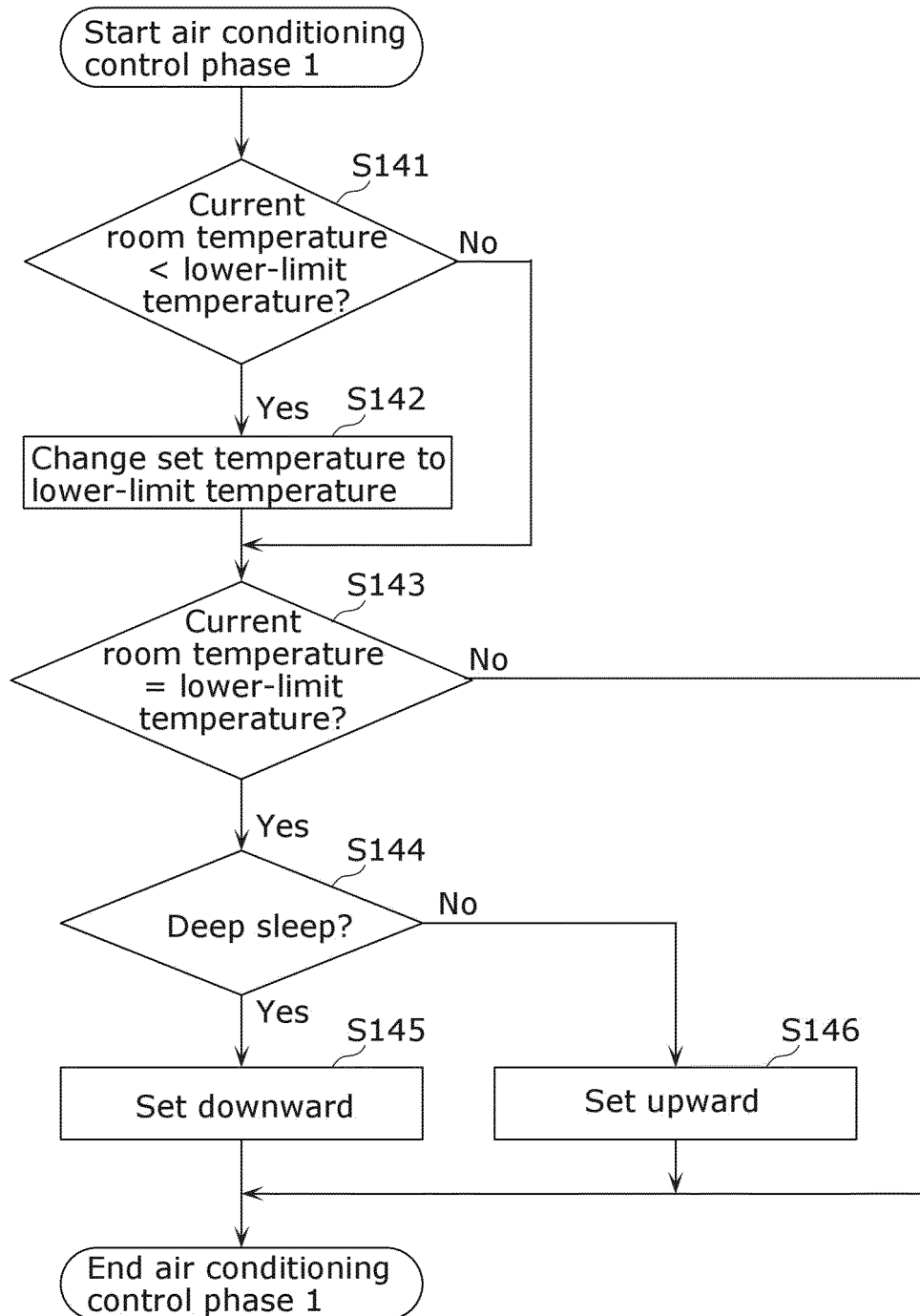


FIG. 25

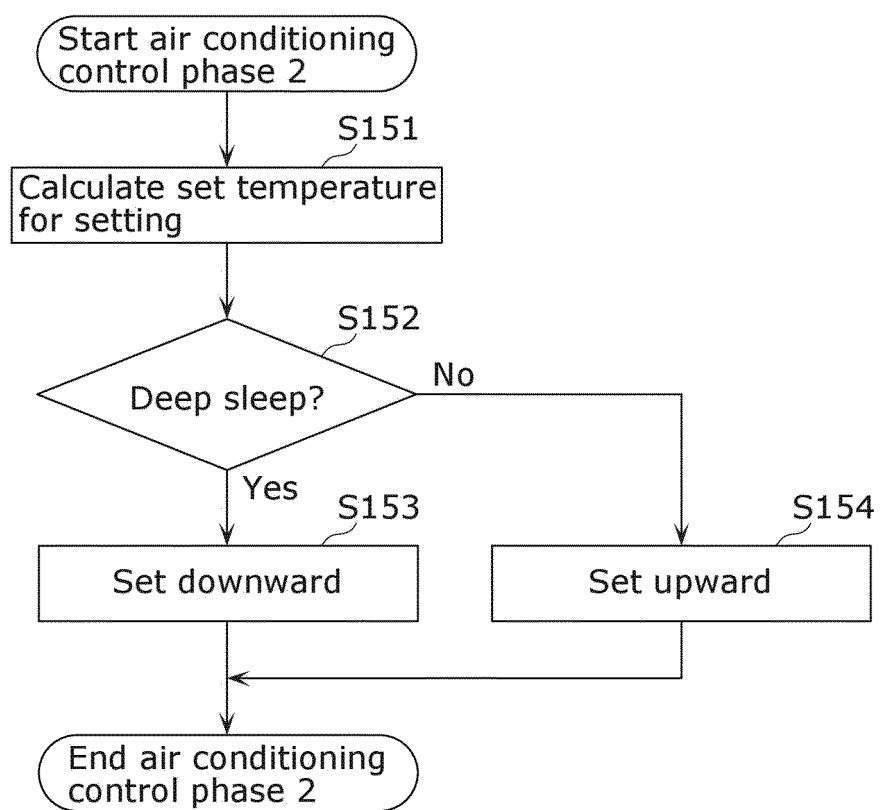


FIG. 26

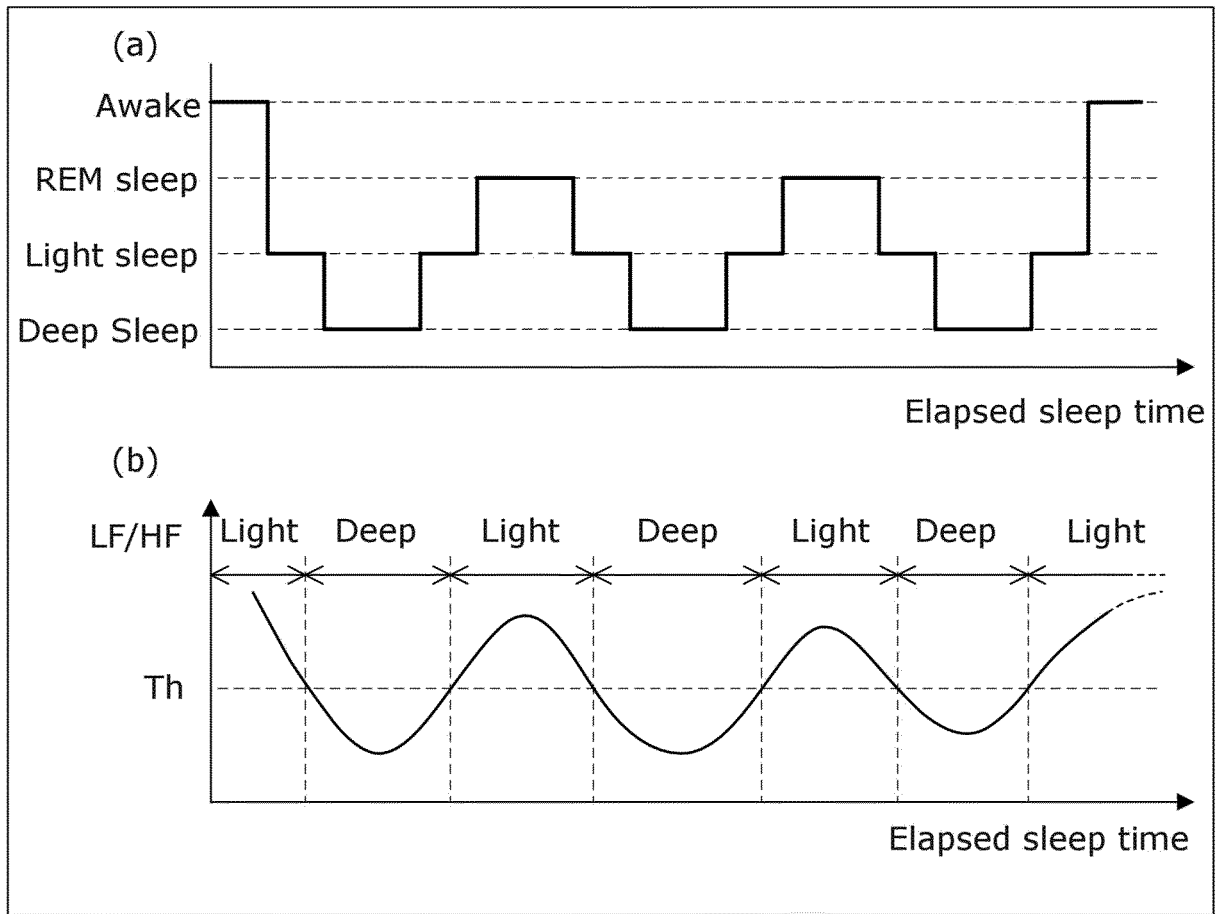


FIG. 27

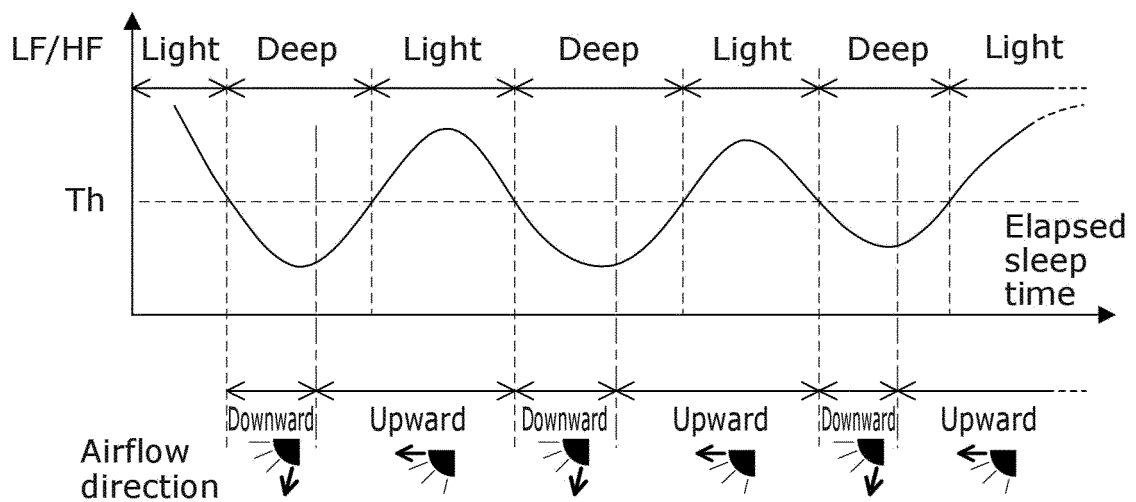


FIG. 28

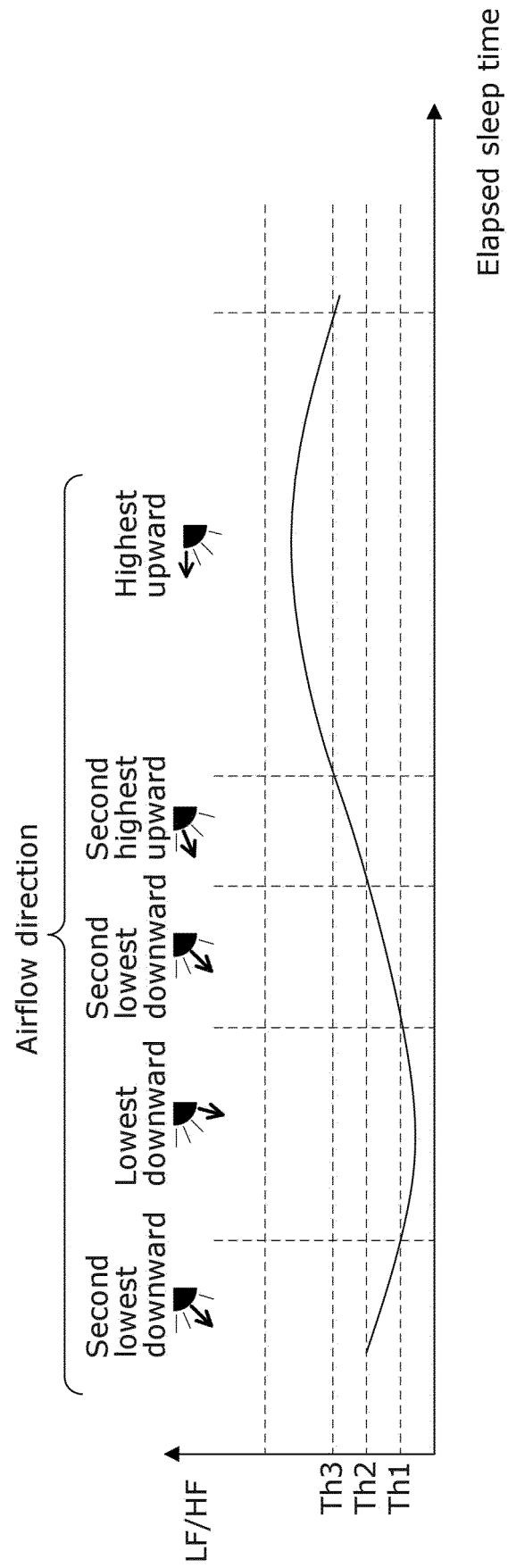
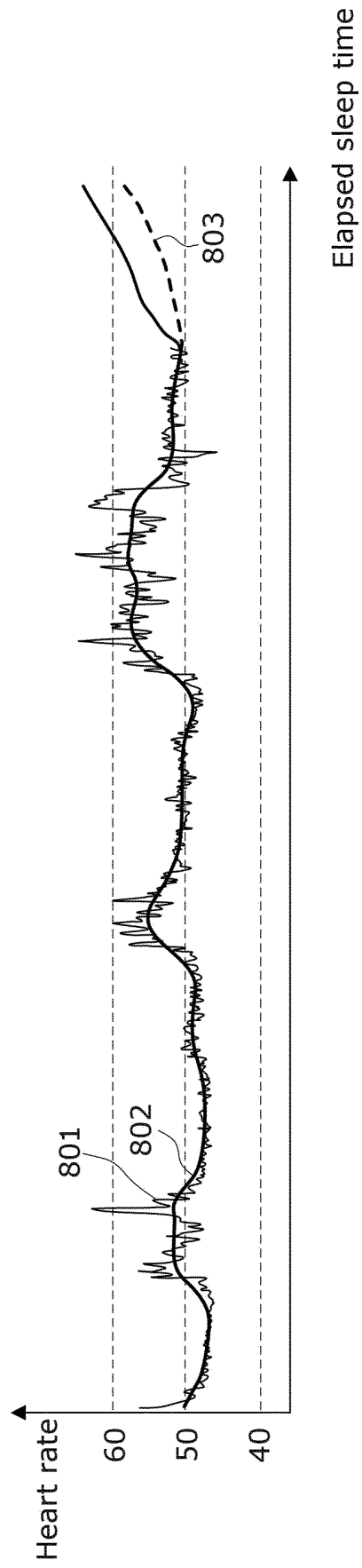


FIG. 29



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2020/008084

A. CLASSIFICATION OF SUBJECT MATTER

F24F 11/63 (2018.01) i; F24F 11/79 (2018.01) i; F24F 11/80 (2018.01) i; F24F 120/12 (2018.01) n

FI: F24F11/79; F24F11/80; F24F11/63; F24F120:12

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F24F11/63; F24F11/79; F24F11/80; F24F120/12

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

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2020

Registered utility model specifications of Japan 1996-2020

Published registered utility model applications of Japan 1994-2020

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2010-133692 A (MITSUBISHI ELECTRIC CORP.)	1, 6-8
Y	17.06.2010 (2010-06-17) paragraphs [0012]-[0036], fig. 1-3	2-5
Y	JP 2009-18091 A (TOYOTA MOTOR CORP.) 29.01.2009 (2009-01-29) paragraphs [0024]-[0063], fig. 1-2	2-5
Y	JP 2019-100621 A (PANASONIC IP MANAGEMENT CO., LTD.) 24.06.2019 (2019-06-24) paragraphs [0039]- [0040]	2-5
Y	JP 2017-215131 A (MITSUBISHI ELECTRIC CORP.) 07.12.2017 (2017-12-07) paragraphs [0047]-[0053], fig. 5-7	5



Further documents are listed in the continuation of Box C.



See patent family annex.

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document member of the same patent family

Date of the actual completion of the international search
25 March 2020 (25.03.2020)Date of mailing of the international search report
07 April 2020 (07.04.2020)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2020/008084

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2013-213642 A (MITSUBISHI ELECTRIC CORP.) 17.10.2013 (2013-10-17) paragraphs [0014]-[0016], [0025]-[0026], fig. 1-2	1-8

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/JP2020/008084

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
JP 2010-133692 A	17 Jun. 2010	(Family: none)	
JP 2009-18091 A	29 Jan. 2009	(Family: none)	
JP 2019-100621 A	24 Jun. 2019	(Family: none)	
JP 2017-215131 A	07 Dec. 2017	(Family: none)	
JP 2013-213642 A	17 Oct. 2013	(Family: none)	

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Patent documents cited in the description

- JP 2016176629 A [0004]