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(54) **AIR CONDITIONER, CONTROL DEVICE,
AIR CONDITIONING SYSTEM, AND AIR
CONDITIONING METHOD**

(52) **U.S. Cl.**
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(2018.01); *F24F 2110/12* (2018.01)

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(57) **ABSTRACT**

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An air conditioner acquires an arrival required amount of time that is an amount of time required for a user to arrive at a building, calculates a time constant from when air conditioning of a room of the building is started until a temperature of the room reaches a target in-progress temperature that is a temperature reached prior to reaching a target temperature, the target in-progress temperature being determined based on a setting temperature of the room, calculates, based on the time constant, an air conditioning required amount of time from when the air conditioning of the room is started until the temperature of the room reaches the target temperature, and starts an air-conditioning operation when the acquired arrival required amount of time is equal to or shorter than the air conditioning required amount of time.

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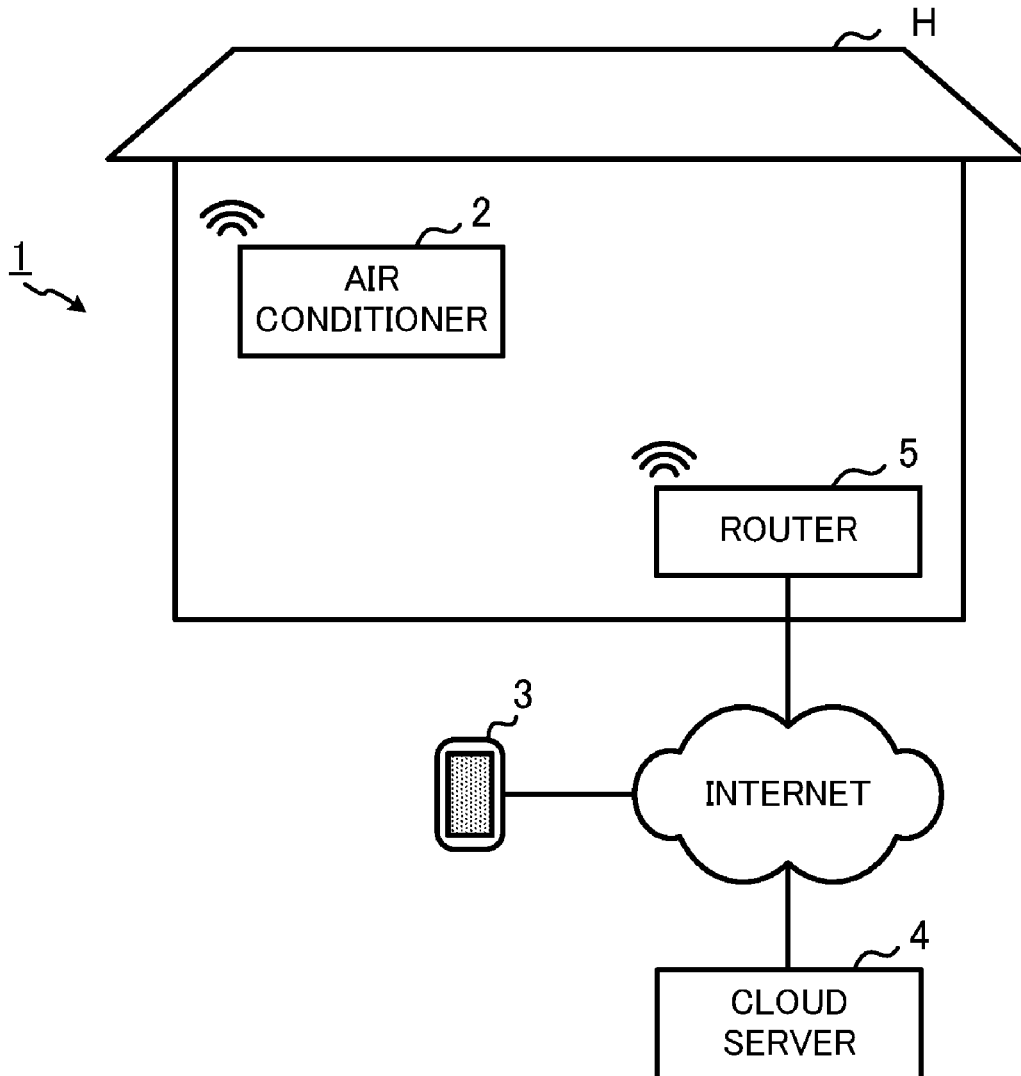


FIG. 1

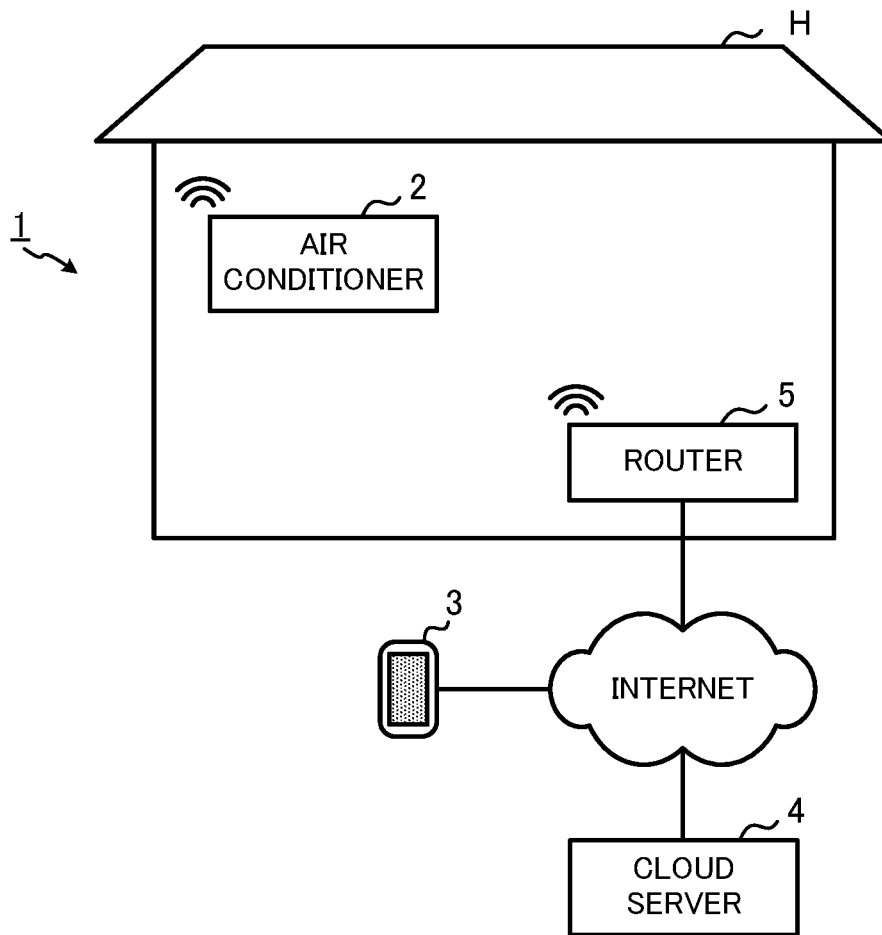


FIG. 2

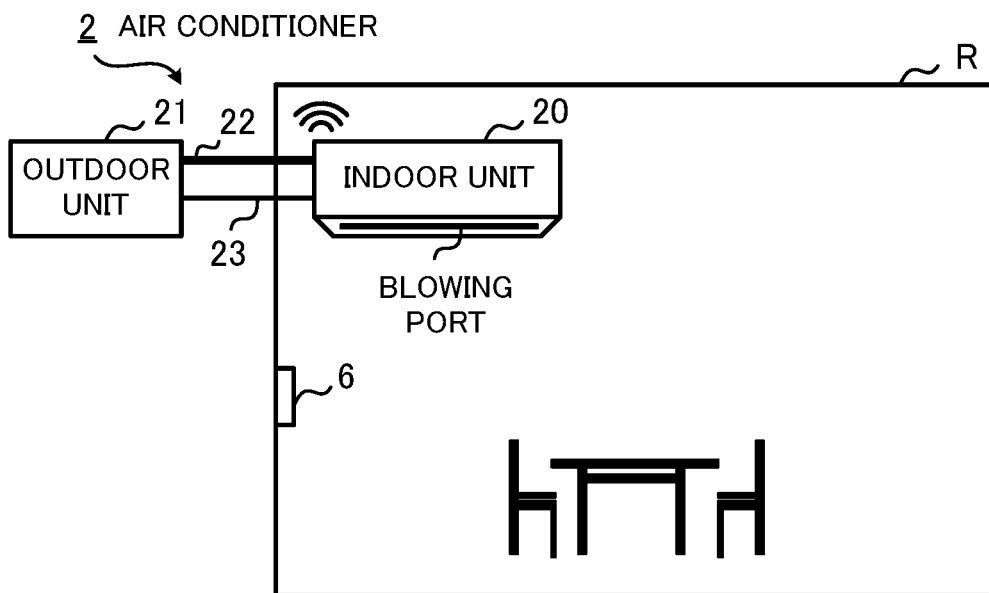


FIG. 3

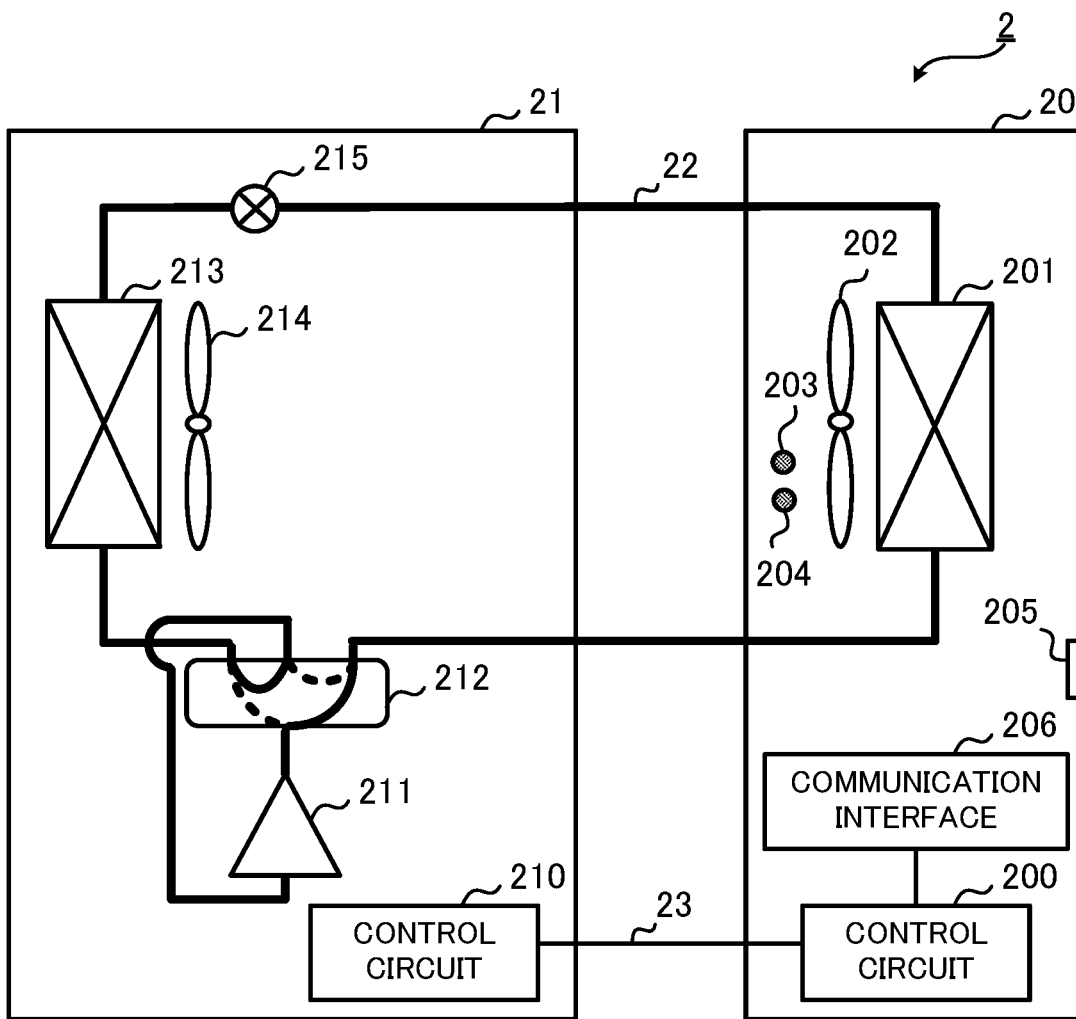


FIG.4

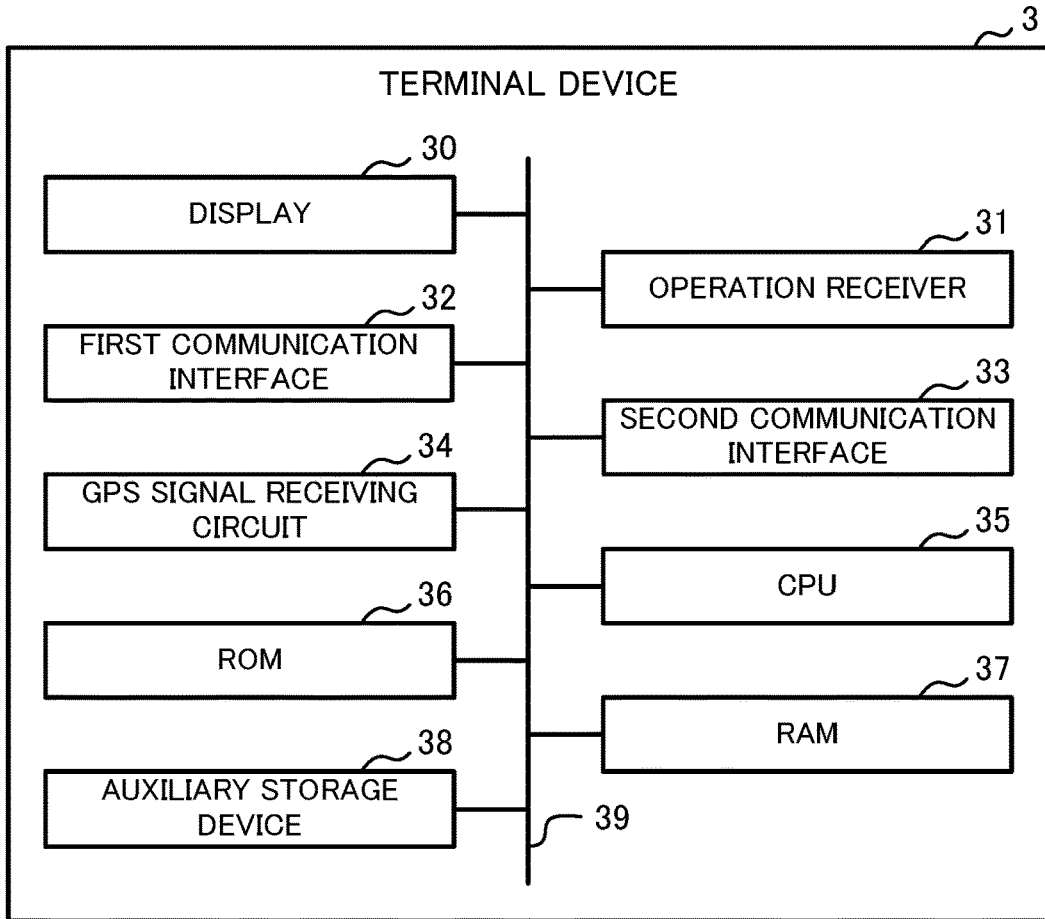


FIG.5

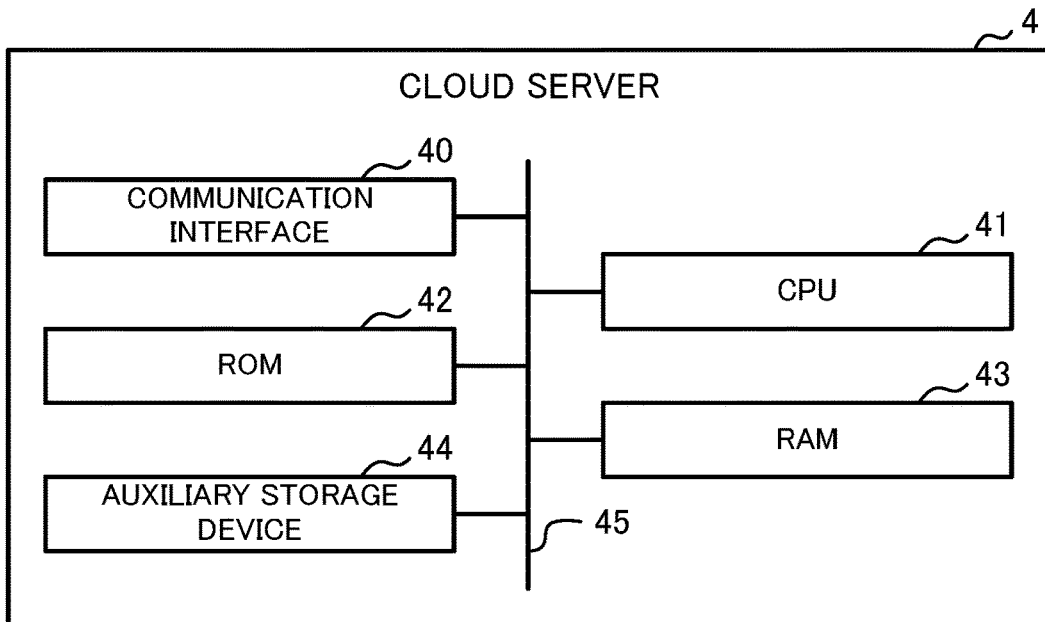


FIG. 6

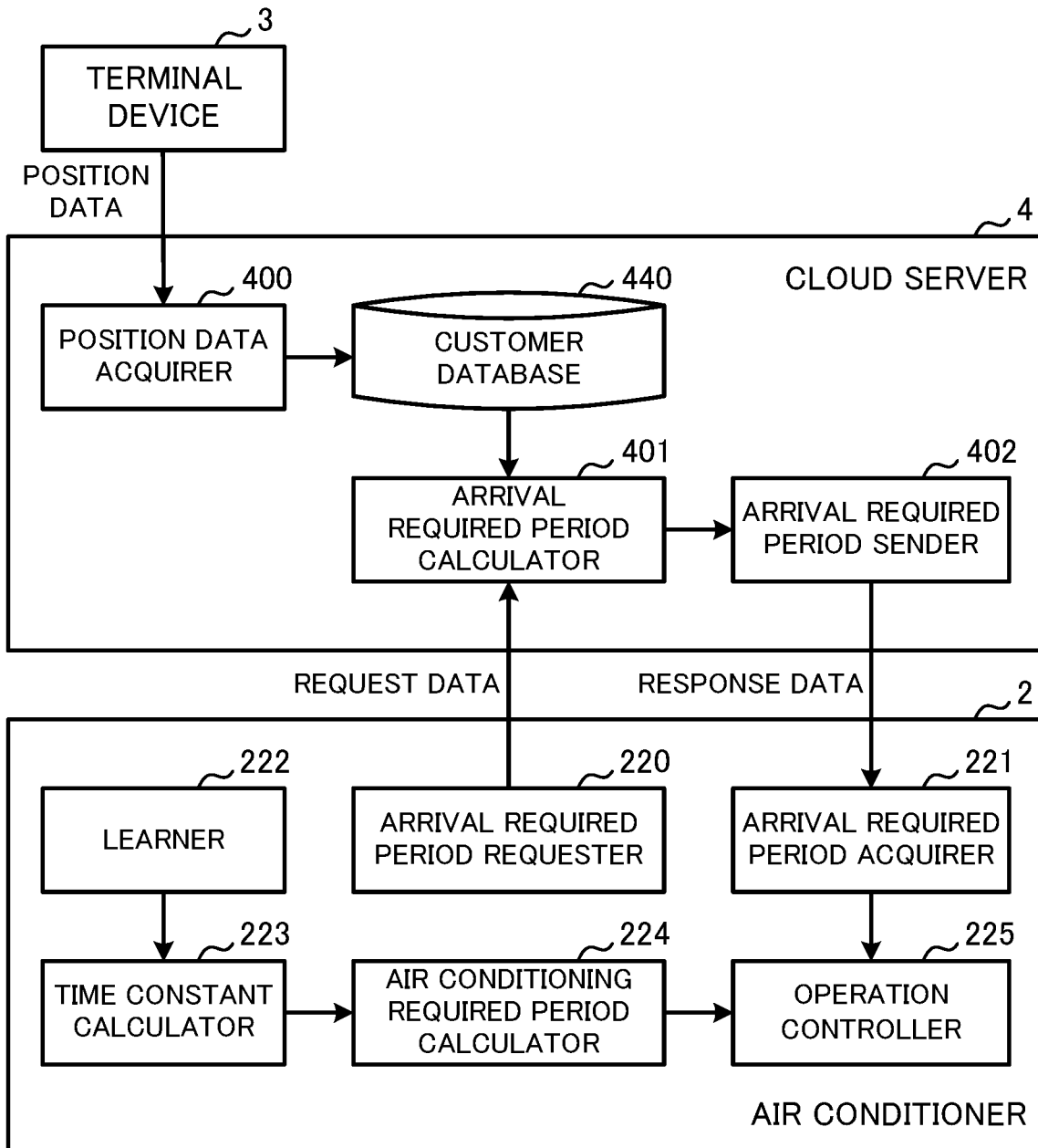


FIG.7

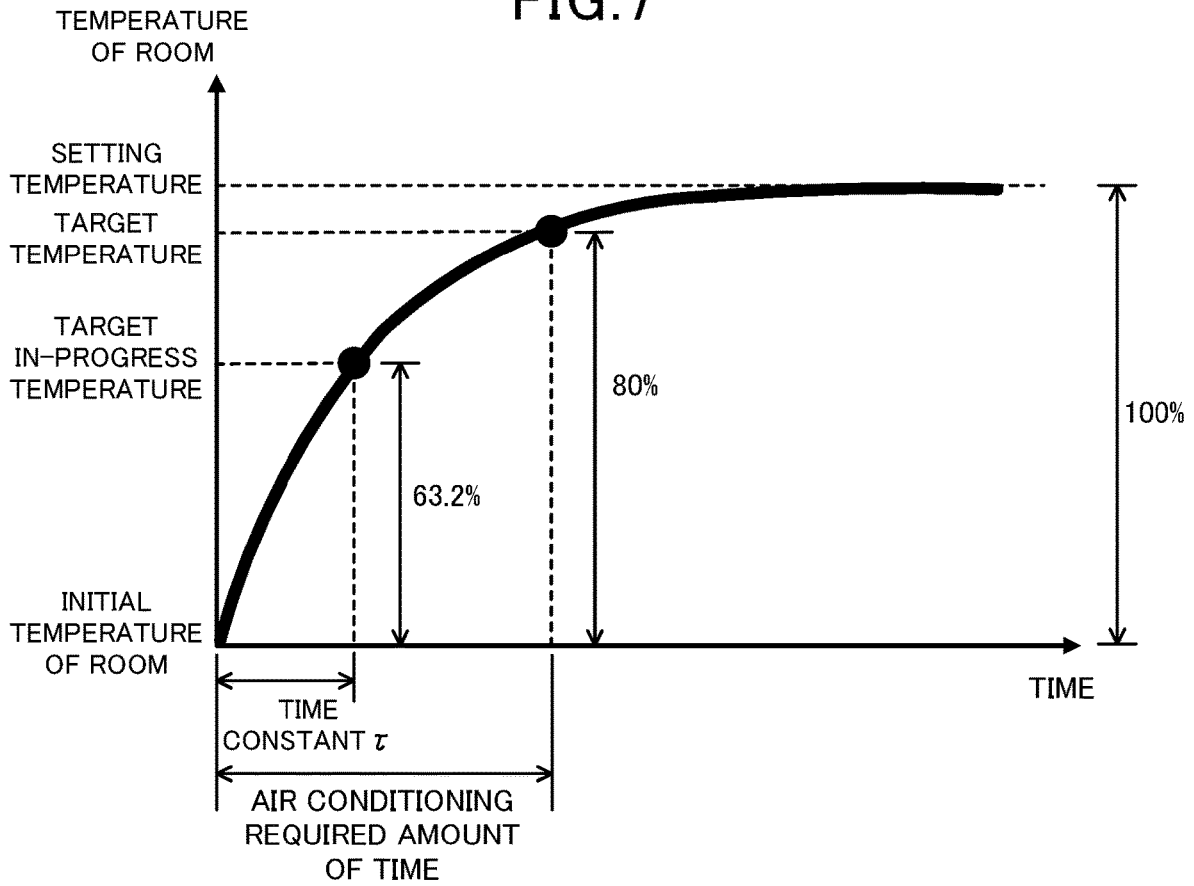


FIG.8

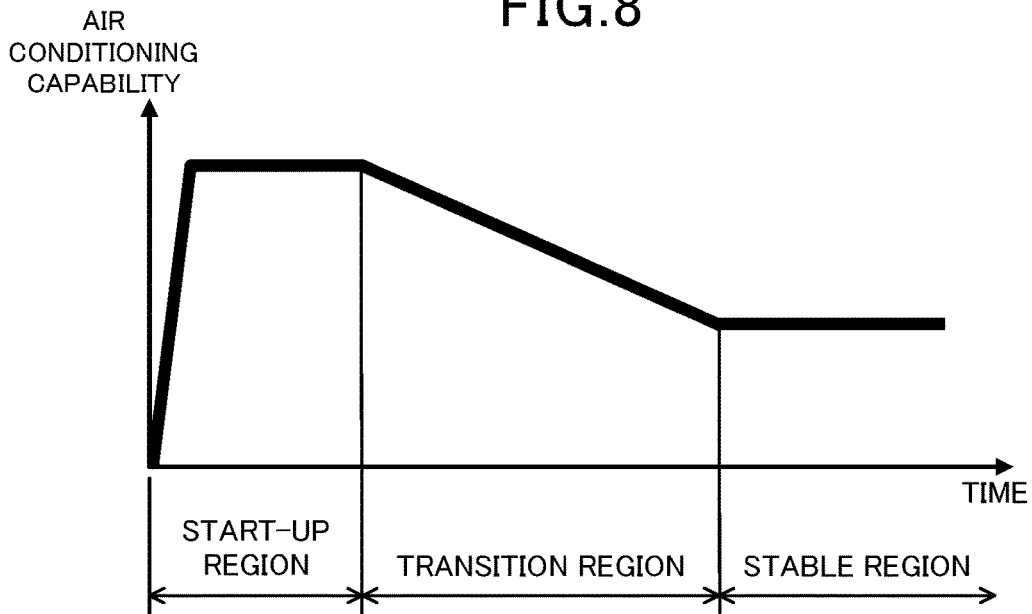


FIG.9

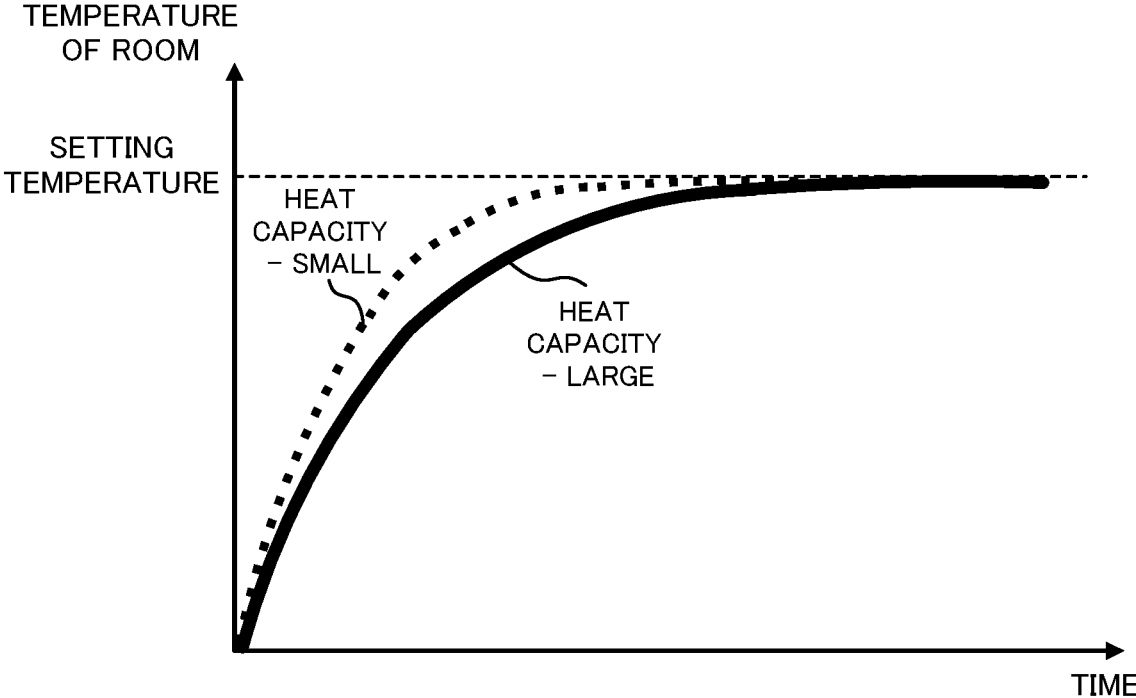


FIG.10

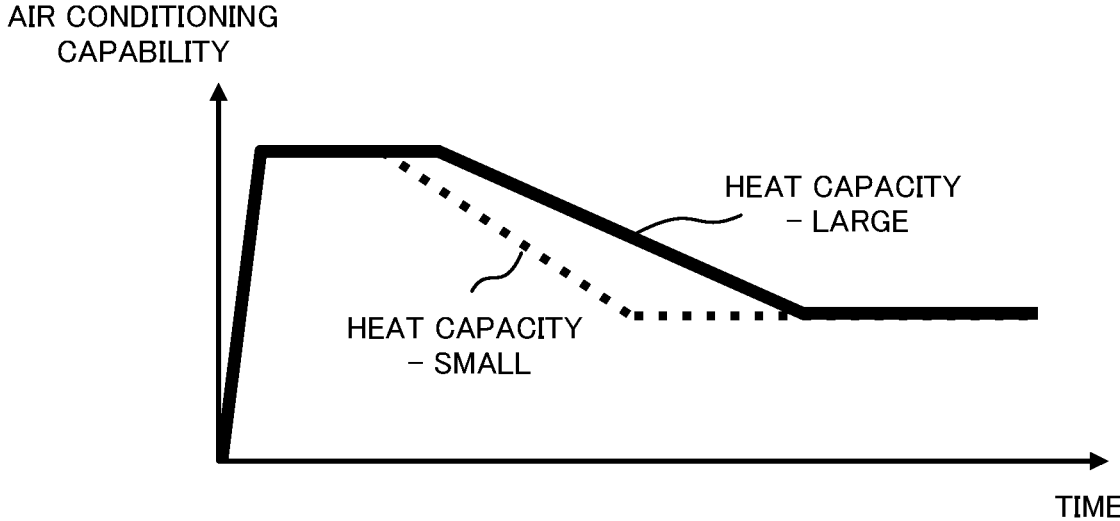


FIG.11

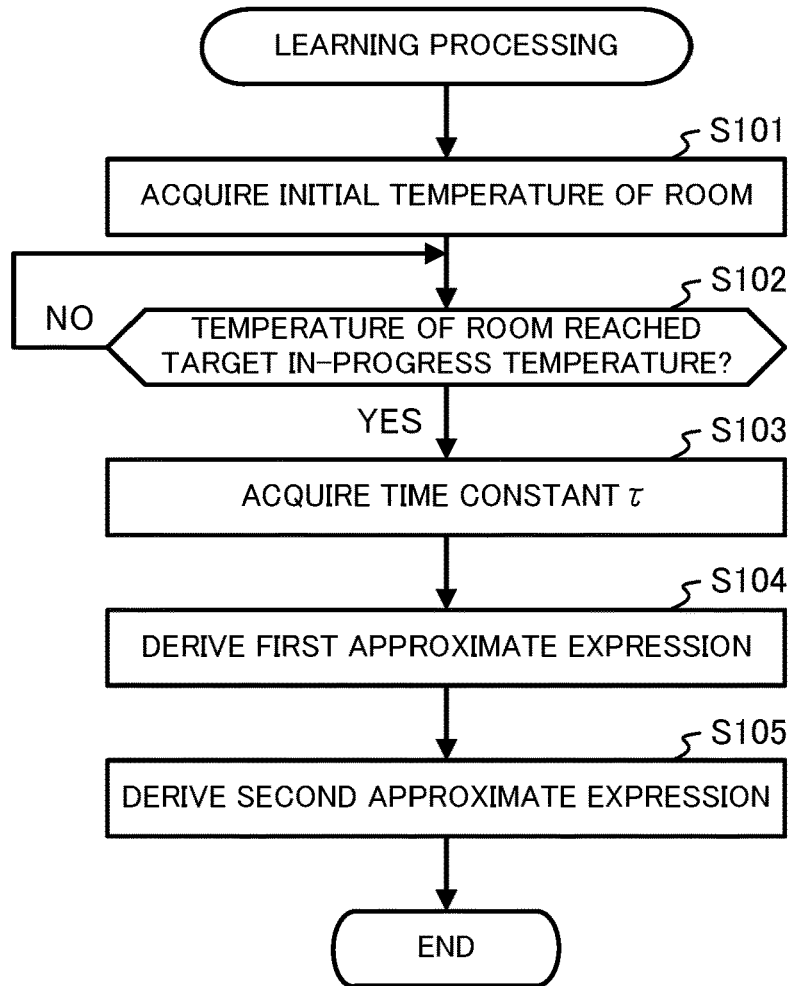


FIG.12

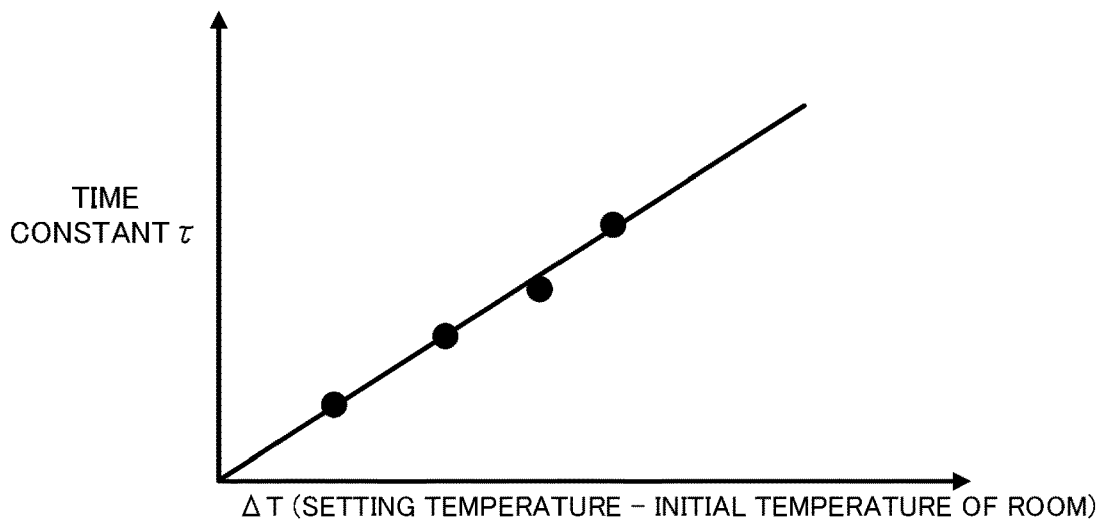


FIG.13

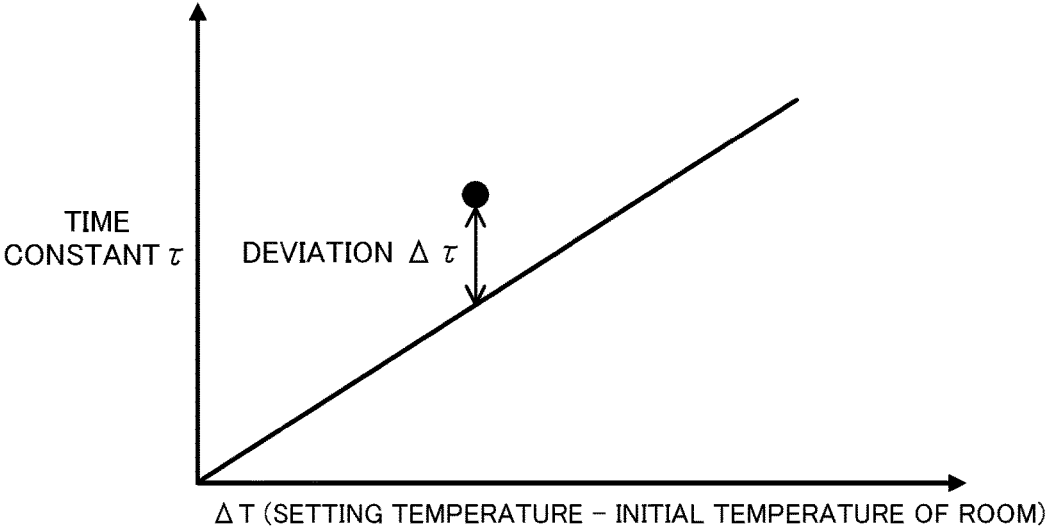


FIG.14

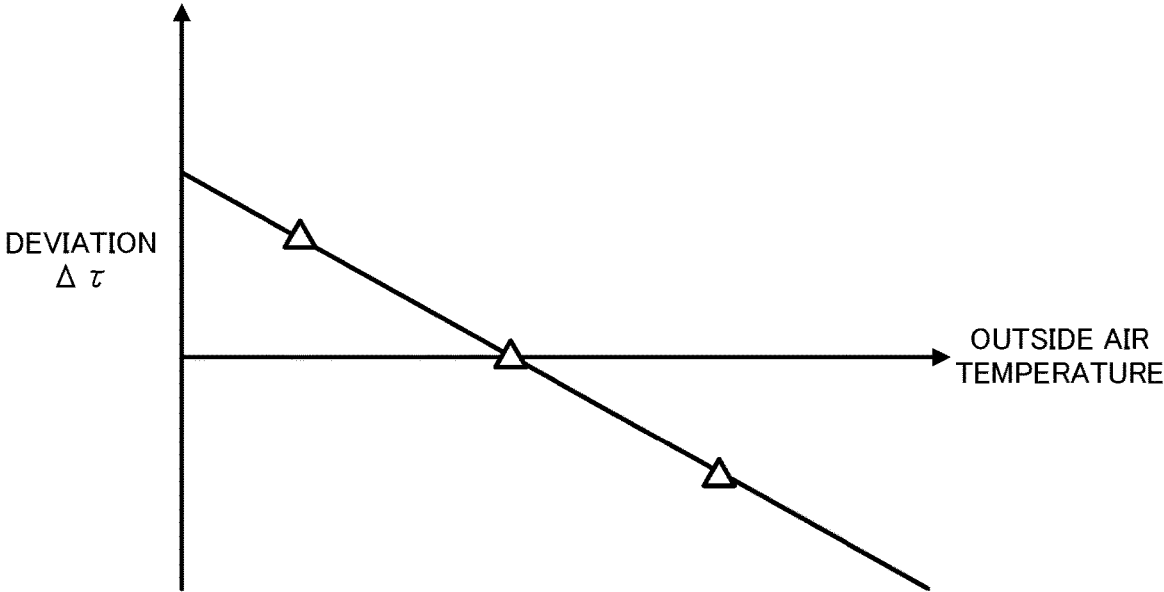
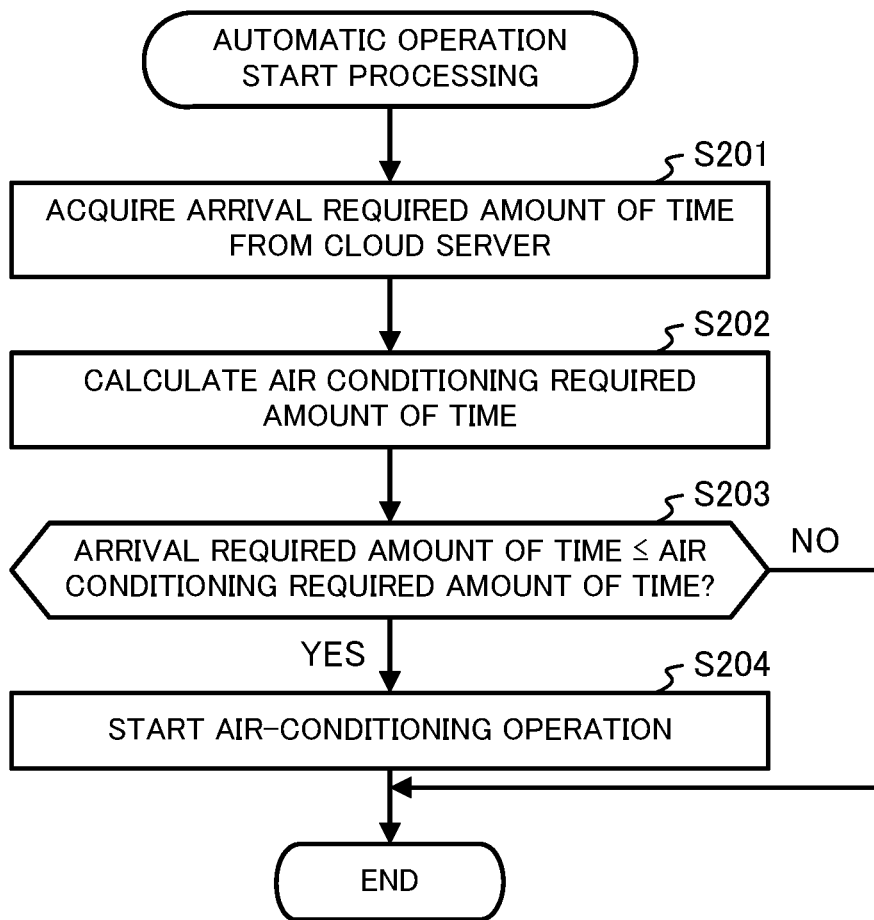


FIG.15



AIR CONDITIONER, CONTROL DEVICE, AIR CONDITIONING SYSTEM, AND AIR CONDITIONING METHOD

TECHNICAL FIELD

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

BACKGROUND ART

[0002] Technology for controlling an air conditioner installed in a house so that a user who arrives at the house can obtain a desired temperature is known (for example, Patent Literature 1).

[0003] In the technology described in Patent Literature 1, a navigation device acquires an outside air temperature from an outside air temperature sensor provided in a vehicle, and acquires a required operating amount of time that is an operating amount of time required for an air conditioner to perform temperature adjustment from the acquired outside air temperature to a desired temperature of the user. Additionally, the navigation device calculates an arrival required amount of time that is an amount of time required to arrive at the house, and sends an operation start command to the air conditioner when the arrival required amount of time is close to the required operating amount of time.

CITATION LIST

Patent Literature

[0004] Patent Literature 1: Unexamined Japanese Patent Application Publication No. 2006-284477

SUMMARY OF INVENTION

Technical Problem

[0005] With the technology described in Patent Literature 1, the navigation device stores, in advance, an adjustment time table in which an adjustment amount of time of the air conditioner, an initial temperature, and a target temperature are associated, and references the adjustment time table on the basis of the outside air temperature and the desired temperature to directly acquire the required operating amount of time of the air conditioner.

[0006] As such, it cannot be said that the accuracy of the acquired required operating amount of time is good, and there is a problem in that the air conditioner is caused to operate at inappropriate timings. Consequently, this may cause insufficient air conditioning, or may cause excessive air conditioning, which leads to an increase in electricity expenses.

[0007] The present disclosure is made to solve such problems mentioned above, and an objective of the present disclosure is to provide an air conditioner and the like capable of starting automatic operation at an appropriate timing by accurately acquiring a required amount of time from when air conditioning of a room is started until a temperature of the room reaches a target temperature.

Solution to Problem

[0008] An air conditioner according to the present disclosure that achieves the objective described above includes:

[0009] arrival required period acquisition means for acquiring an arrival required amount of time that is an amount of time required for a user to arrive at a building;

[0010] first required period acquisition means for acquiring a first required amount of time from when air conditioning of a room of the building is started until a temperature of the room reaches a target in-progress temperature that is a temperature reached prior to reaching a target temperature, the target in-progress temperature being determined based on a setting temperature of the room;

[0011] second required period acquisition means for acquiring, based on the acquired first required amount of time, a second required amount of time from when the air conditioning of the room is started until the temperature of the room reaches the target temperature; and

[0012] operation control means for starting an air-conditioning operation when the acquired arrival required amount of time is equal to or shorter than the acquired second required amount of time.

Advantageous Effects of Invention

[0013] According to the present disclosure, automatic operation can be started at an appropriate timing.

BRIEF DESCRIPTION OF DRAWINGS

[0014] FIG. 1 is a drawing illustrating the entire configuration of an air conditioning system in an embodiment;

[0015] FIG. 2 is a drawing for explaining an overview of an air conditioner in the embodiment;

[0016] FIG. 3 is a block diagram illustrating a hardware configuration of the air conditioner in the embodiment;

[0017] FIG. 4 is a block diagram illustrating a hardware configuration of a terminal device in the embodiment;

[0018] FIG. 5 is a block diagram illustrating a hardware configuration of a cloud server in the embodiment;

[0019] FIG. 6 is a block diagram illustrating a functional configurations of the air conditioner and the cloud server in the embodiment;

[0020] FIG. 7 is a drawing illustrating an example of a transition of the temperature of a room after the air conditioner in the embodiment has started heating operation;

[0021] FIG. 8 is a drawing illustrating an example of a transition of air conditioning capability after the air conditioner in the embodiment has started the heating operation;

[0022] FIG. 9 is a drawing illustrating examples of the transition of the temperature of the room after the air conditioner in the embodiment has started the heating operation, according to whether the heat capacity of the room is large or small;

[0023] FIG. 10 is a drawing illustrating examples of the transition of air conditioning capability after the air conditioner in the embodiment has started the heating operation, according to whether the heat capacity of the room is large or small;

[0024] FIG. 11 is a flowchart illustrating procedures of learning processing in the embodiment;

[0025] FIG. 12 is a drawing for explaining learning of a first approximate expression in the embodiment;

[0026] FIG. 13 is a drawing for explaining learning of a second approximate expression in the embodiment;

[0027] FIG. 14 is a drawing for explaining learning of the second approximate expression in the embodiment; and

[0028] FIG. 15 is a flowchart for explaining procedures of automatic operation start processing in the embodiment.

DESCRIPTION OF EMBODIMENTS

[0029] Hereinafter, embodiments of the present embodiment are described in detail while referencing the drawings.

[0030] FIG. 1 is a drawing illustrating the entire configuration of an air conditioning system 1 in an embodiment of the present disclosure. The air conditioning system 1 is a system for performing air conditioning of a house H. The air conditioning system 1 includes an air conditioner 2, a terminal device 3, and a cloud server 4.

[0031] Air Conditioner 2

[0032] The air conditioner 2 is a heat-pump-type air conditioner 2 that uses a hydrofluorocarbon (HFC) such as R32 or a natural refrigerant such as CO₂ as a refrigerant. The air conditioner 2 performs air conditioning of a room in the house H. The air conditioner 2 is provided with a vapor compression-type refrigeration cycle, and operates by obtaining electric power from a non-illustrated commercial power supply, power generation facility, power storage facility, or the like. As illustrated in FIG. 2, the air conditioner 2 includes an indoor unit 20 installed in a room R, and an outdoor unit 21 installed outside. The indoor unit 20 and the outdoor unit 21 are connected by refrigerant pipe 22 for circulating the refrigerant, and a communication line 23.

[0033] As illustrated in FIG. 3, the indoor unit 20 includes a control circuit 200, a heat exchanger 201, a fan 202, a temperature sensor 203, a humidity sensor 204, a thermal image sensor 205, and a communication interface 206.

[0034] The control circuit 200 integrally controls the air conditioner 2. The control circuit 200 includes a central processing unit (CPU), a read only memory (ROM), a random access memory (RAM), a communication interface, and an auxiliary storage device including a readable/writable non-volatile semiconductor memory such as an electrically erasable programmable read-only memory (EEPROM), a flash memory, or the like, and the like, all of which are not illustrated. Details of the functions of the air conditioner 2 realized by the control circuit 200 are described later.

[0035] The heat exchanger 201 performs heat exchange between air in a room (that is, air in the room R) that is taken in by the fan 202 and the refrigerant from the outdoor unit 21. The heat exchanger 201 functions as an evaporator when performing cooling operation, and functions as a condenser when performing heating operation.

[0036] In one example, the fan 202 is a propeller fan, takes in the air in the room through a non-illustrated intake port and, also, blows the air that has been subjected to heat exchange by the heat exchanger 201 into the room through a blowing port (see FIG. 2). A rotation speed of the fan 202, that is, a blowing volume of the fan 202, is adjusted in accordance with a command from the control circuit 200.

[0037] The temperature sensor 203 is a sensor such as a thermistor, a thermocouple, a resistance temperature detector, or the like. The temperature sensor 203 measures the temperature of the air taken in by the fan 202, and outputs a signal indicating a measurement result to the control circuit 200. The humidity sensor 204 is a sensor such as an electric resistance type sensor, a capacitance type sensor, or the like. The humidity sensor 204 measures the humidity of the air taken in by the fan 202, and outputs a signal indicating a measurement result to the control circuit 200.

[0038] The thermal image sensor 205 is an infrared thermography sensor. The thermal image sensor 205 acquires thermal image data of the room, and outputs the acquired thermal image data to the control circuit 200. The control circuit 200 can acquire a position and a surface temperature of a detection target such as a floor, a wall, a window, a piece of furniture, a person, or the like by analyzing the thermal image data acquired by the thermal image sensor 205.

[0039] The communication interface 206 communicates/connects wirelessly to a router 5 that is a Wi-Fi (registered trademark) or similar wireless local area network (LAN) router. The communication interface 206 is hardware for communicating with other devices via the router 5.

[0040] The outdoor unit 21 includes a control circuit 210, a compressor 211, a four-way valve 212, a heat exchanger 213, a fan 214, and an expansion valve 215. The compressor 211, the four-way valve 212, the heat exchanger 213, and the expansion valve 215 of the outdoor unit 21, and the heat exchanger 201 of the indoor unit 20 are connected in a ring-like manner by the refrigerant pipe 22. As a result, the refrigeration cycle is formed.

[0041] The control circuit 210 controls the various components of the outdoor unit 21 in accordance with commands from the control circuit 200 of the indoor unit 20. The control circuit 210 includes a CPU, a ROM, a RAM, a communication interface, and an auxiliary storage device including a readable/writable non-volatile semiconductor memory such as an EEPROM, a flash memory, or the like, and the like, all of which are not illustrated.

[0042] The compressor 211 compresses the refrigerant. Specifically, the compressor 211 compresses the low-temperature and low-pressure refrigerant, and discharges the resulting high-pressure, high-temperature refrigerant to the four-way valve 212. The compressor 211 includes an inverter circuit capable of changing an operating capacity in accordance with a driving frequency. The operating capacity is the amount of refrigerant that the compressor 211 sends per unit. The compressor 211 changes the operating capacity in accordance with a command from the control circuit 210.

[0043] The four-way valve 212 is a valve for switching a circulation direction of the refrigerant. When performing heating operation, the four-way valve 212 is switched as illustrated by the solid lines of FIG. 3. As a result, the refrigerant circulates, in order, through the compressor 211, the four-way valve 212, the heat exchanger 201, the expansion valve 215, and the heat exchanger 213. Meanwhile, when performing cooling operation, the four-way valve 212 is switched as illustrated by the dashed lines of FIG. 3. As a result, the refrigerant circulates, in order, through the compressor 211, the four-way valve 212, the heat exchanger 213, the expansion valve 215, and the heat exchanger 201.

[0044] The heat exchanger 213 performs heat exchange between outdoor air taken in by the fan 214 (that is, outside air) and the refrigerant. The heat exchanger 213 functions as a condenser when performing cooling operation, and functions as an evaporator when performing heating operation.

[0045] In one example, the fan 214 is a propeller fan, takes in the outside air and, also, blows the air, that has been subjected to heat exchange by the heat exchanger 213, outside.

[0046] The expansion valve 215 is installed between the heat exchanger 213 and the heat exchanger 201, and decompresses and expands the refrigerant flowing in the refrigerant pipe 22. In one example, the expansion valve 215 is an

electronic expansion valve in which the degree of opening of a restrictor can be adjusted by a stepping motor (not illustrated in the drawings). The expansion valve **215** changes the degree of opening in accordance with a command from the control circuit **210** to adjust the pressure of the refrigerant.

[0047] Note that, while not illustrated in the drawings, the air conditioner **2** further includes an outside air temperature sensor that measures an outside air temperature, an outside humidity sensor that measures an outside humidity, and a plurality of refrigerant temperature sensors that measure a temperature of the refrigerant flowing in the refrigerant pipe **22**.

[0048] Air Conditioning Remote Controller **6**

[0049] An air conditioning remote controller **6** illustrated in FIG. **2** is installed embedded in a wall of the room **R** or, alternately, is installed in a mode hung on the wall. The air conditioning remote controller **6** is a remote controller for receiving, from a user in the room **R**, operations pertaining to air conditioning. The air conditioning remote controller **6** wiredly or wirelessly communicates with/is connected to the control circuit **200** of the indoor unit **20**. By operating the air conditioning remote controller **6**, the user can command the air conditioner **2** to, for example, start or stop the cooling operation, the heating operation, a blowing operation, a dehumidification operation, or the like, and can command changes of the setting temperature, a blowing speed, a blowing direction, and the like.

[0050] Terminal Device **3**

[0051] The terminal device **3** is a portable electronic device such as a smartphone, a tablet terminal, or the like. As illustrated in FIG. **4**, the terminal device **3** includes a display **30**, an operation receiver **31**, a first communication interface **32**, a second communication interface **33**, a GPS signal receiving circuit **34**, a CPU **35**, a ROM **36**, a RAM **37**, and an auxiliary storage device **38**. These constituents are connected to each other via a bus **39**.

[0052] The display **30** includes a display device such as a liquid crystal display, an organic electro luminescence (EL) display, or the like. On the basis of the control of the CPU **35**, the display **30** displays various types of screens and the like that correspond to user operations.

[0053] The operation receiver **31** includes one or more input devices such as a push button, a touch panel, a touch pad, or the like. The operation receiver **31** receives operation inputs from the user, and sends signals pertaining to the received operations to the CPU **35**.

[0054] The first communication interface **32** is hardware for communicating using a predetermined short-range wireless method. For example, when the terminal device **3** is carried by a user that is present in the house **H**, the first communication interface **32** connects to the router **5** and communicates with the cloud server **4** across the internet. When the terminal device **3** is carried by a user that is outside, the first communication interface **32** connects to a non-illustrated access point (AP), and communicates with the cloud server **4** across the internet.

[0055] The second communication interface **33** is hardware for communicating using a predetermined broadband wireless method. When the terminal device **3** is carried by a user that is outside and is unable to connect to the AP, the second communication interface **33** connects to a non-illustrated base station and communicates with the cloud server **4** across the internet.

[0056] The GPS signal receiving circuit **34** is a circuit that receives a GPS signal from a global positioning system (GPS) satellite, calculates a latitude and longitude on the basis of the received GPS signal, and outputs the calculated latitude and longitude to the CPU **35**.

[0057] The CPU **35** integrally controls the terminal device **3**. The ROM **36** stores a plurality of firmware and data to be used when executing these firmware. The RAM **37** is used as a working area of the CPU **35**.

[0058] The auxiliary storage device **38** includes an EEPROM, a flash memory, or similar readable/writable non-volatile semiconductor memory, and the like. The auxiliary storage device **38** stores various types of programs including an application program pertaining to remote control and automatic operation of the air conditioner **2** (hereinafter referred to as “air conditioner app”), and data to be used when executing these programs. The air conditioner app can be downloaded to the terminal device **3** from the cloud server **4**, another program distribution server, or the like.

[0059] The air conditioner app can be stored and distributed on a non-transitory computer-readable recording medium such as a compact disc read only memory (CD-ROM), a digital versatile disc (DVD), a magneto-optical (MO) disc, a universal serial bus (USB) memory, a memory card, a hard disk drive (HDD), a solid state drive (SSD), or the like.

[0060] The user can realize the same functions as the air conditioning remote controller **6** on the terminal device **3** by starting the air conditioner app. Specifically, the terminal device **3** accesses the cloud server **4** and displays a non-illustrated operation screen. Then, the terminal device **3** receives, from the user, an operation for commanding the start or stop of the cooling operation, the heating operation, the blowing operation, the dehumidification operation, or the like, an operation for commanding a change of the setting temperature, the blowing speed, the blowing direction, or the like, or the like. The terminal device **3** sends, to the cloud server **4**, data indicating the content of the received operation, and the cloud server **4** controls the air conditioner **2** on the basis of the content of that operation.

[0061] Additionally, when the air conditioner app is running, the terminal device **3** periodically generates data (hereinafter referred to as “position data”) including an identification (ID) of the terminal device **3** and the latitude and longitude calculated on the basis of the GPS signal, and sends the generated position data to the cloud server **4**.

[0062] Cloud Server **4**

[0063] The cloud server **4** is an example of the server. The cloud server **4** is a server computer that is installed and operated by a manufacturer, a sales company, or the like of the air conditioner **2**, and is connected to the internet. As illustrated in FIG. **5**, the cloud server **4** includes a communication interface **40**, a CPU **41**, a ROM **42**, a RAM **43**, and an auxiliary storage device **44**. These constituents are connected to each other via a bus **45**.

[0064] The communication interface **40** is hardware for communicating with other devices across the internet. The CPU **41** integrally controls the cloud server **4**. Details of the functions of the cloud server **4** realized by the CPU **41** are described later. The ROM **42** stores a plurality of firmware and data to be used when executing these firmware. The RAM **43** is used as a working area of the CPU **41**.

[0065] The auxiliary storage device 44 is a storage device that includes an HDD or a readable/writable non-volatile semiconductor memory, such as an EEPROM, a flash memory, and the like. The auxiliary storage device 44 stores a program for supporting the automatic operation of the air conditioner 2 (hereinafter referred to as “automatic operation support program”), and data to be used when executing the automatic operation support program. In addition, the auxiliary storage device 44 stores various types of programs including a program for realizing remote control of the air conditioner 2 by the user, and data to be used when executing these programs.

[0066] The automatic operation support program described above can be downloaded to the cloud server 4 from another server installed and operated by the manufacturer, the sales company, or the like of the air conditioner 2. Additionally, the automatic operation support program can be stored and distributed on a non-transitory computer-readable recording medium such as a CD-ROM, a DVD, a magneto-optical disk, a USB memory, a memory card, an HDD, an SSD, or the like.

[0067] Functions of Air Conditioner 2 and Cloud Server 4

[0068] As characteristic functions of the present embodiment, the air conditioning system 1 includes a function of starting the automatic operation at an appropriate timing so that the temperature of the room R when the user, that is outside, returns home is a target temperature (hereinafter referred to as “automatic operation starting function”). In the present disclosure, the target temperature is a temperature at which the user, immediately after returning home, feels comfortable and, in general, is a few degrees Celsius lower when performing heating operation and a few degrees Celsius higher when performing cooling operation than the setting temperature of the room R.

[0069] FIG. 6 is a block diagram illustrating the functional configurations of the air conditioner 2 and the cloud server 4 for realizing the automatic operation starting function described above. As illustrated in FIG. 6, the air conditioner 2 includes an arrival required period requester 220, an arrival required period acquirer 221, a learner 222, a time constant calculator 223, an air conditioning required period calculator 224, and an operation controller 225. These functional components of the air conditioner 2 are realized as a result of the CPU of the control circuit 200 of the indoor unit 20 executing the air conditioning program stored in the auxiliary storage device of the control circuit 200.

[0070] Note that the functions of the air conditioner 2 illustrated in FIG. 6 are characteristic functions of the air conditioner 2 in the present embodiment and, in addition thereto, the air conditioner 2 includes the functions of a typical air conditioner, functions for performing air conditioning on the basis of remote control of a user via the terminal device 3, and the like. However, descriptions of these functions are omitted.

[0071] As illustrated in FIG. 6, the cloud server 4 includes a position data acquirer 400, an arrival required period calculator 401, and an arrival required period sender 402. These functional components of the cloud server 4 are realized as a result of the CPU 41 executing the aforementioned automatic operation support program stored in the auxiliary storage device 44.

[0072] Note that the functions of the cloud server 4 illustrated in FIG. 6 are characteristic functions of the cloud server 4 of the present embodiment and, in addition thereto,

the cloud server 4 includes a function for receiving a user registration from the user, a function of controlling the air conditioner 2 on the basis of remote control of the user via the terminal device 3, and the like. However, descriptions of these functions are omitted.

[0073] In the cloud server 4, the position data acquirer 400 receives and acquires the position data that is sent periodically from the terminal device 3. The position data acquirer 400 stores the acquired position data in a customer database 440. The customer database 440 is a database for managing information related to the user of the air conditioner 2, having performed the user registration (in other words, a customer). The customer database 440 is stored in the auxiliary storage device 44.

[0074] Customer information and a history of the position data are stored for every customer in the customer database 440. The customer information is information registered in the customer database 440 as a result of a prior user registration performed by the user via the terminal device 3. In one example, the customer information includes a user ID, a password, identification information of the air conditioner 2, position information of the house H (for example, the latitude and longitude, an address, or the like), an ID of the terminal device 3, and the like. In one example, the identification information of the air conditioner 2 includes a serial number of the air conditioner 2.

[0075] In the air conditioner 2, the arrival required period requester 220 periodically requests, to the cloud server 4, sending of an arrival required amount of time that is an amount of time required for the user that is outside to arrive at the house H (that is, to return home). Specifically, the arrival required period requester 220 sends data indicating this request (hereinafter referred to as “request data”) to the cloud server 4 across the internet.

[0076] The arrival required period calculator 401 of the cloud server 4 is an example of the arrival required period calculation means. When the arrival required period calculator 401 receives the request data sent from the air conditioner 2, the arrival required period calculator 401 calculates the arrival required amount of time of the user. Specifically, the arrival required period calculator 401 calculates the arrival required amount of time of the user on the basis of the history of the position data sent from the terminal device 3 owned by the user of the air conditioner 2, and the position information of the house H of the user, which are stored in the customer database 440.

[0077] Specifically, the arrival required period calculator 401 calculates a distance (hereinafter referred to as “user distance”) between a current position of the user (more specifically, of the terminal device 3) and the position of the house H on the basis of the position information of the house H and the most recent position data. Additionally, the arrival required period calculator 401 calculates a movement speed of the user in the direction of the house H from the history of the position data. The arrival required period calculator 401 calculates the arrival required amount of time from the calculated user distance and the calculated movement speed. The arrival required period calculator 401 supplies the calculated arrival required amount of time to the arrival required period sender 402.

[0078] Note that, when the user distance exceeds a predetermined maximum distance or is less than a predetermined minimum distance, the arrival required period calculator 401 does not calculate the arrival required amount of

time and, instead, supplies, to the arrival required period sender **402** and as the arrival required amount of time, a predetermined amount of time (for example, 0 minutes) indicating that the arrival required amount of time cannot be calculated.

[0079] The arrival required period sender **402** is an example of the arrival required period sending means. When the arrival required amount of time is supplied from the arrival required period calculator **401**, the arrival required period sender **402** sends, across the internet and to the air conditioner **2** that is the sender of the request data, data including the arrival required amount of time (hereinafter referred to as “response data”).

[0080] In the air conditioner **2**, the arrival required period acquirer **221** is an example of the arrival required period acquisition means. When the arrival required period acquirer **221** receives the response data sent from the cloud server **4**, the arrival required period acquirer **221** extracts and acquires the arrival required amount of time from the received response data. The arrival required period acquirer **221** supplies the acquired arrival required amount of time to the operation controller **225**.

[0081] The learner **222** is an example of the learning means. The learner **222** derives, by learning, a first approximate expression f1 and a second approximate expression f2 for deriving a time constant τ . Firstly, what the time constant τ indicates in the present embodiment is described in detail with reference to FIGS. 7 to 10. FIGS. 7 to 10 illustrate examples of the transition of the temperature of the room or the air conditioning capability (that is, the heating capability) after the air conditioner **2** has started the heating operation. FIG. 7 illustrates a transition of the temperature of the room, FIG. 8 illustrates a transition of the air conditioning capability, FIG. 9 illustrates a transition of the temperature of the room according to whether the heat capacity of the room is large or small, and FIG. 10 illustrates a transition of the air conditioning capability according to whether the heat capacity of the room is large or small.

[0082] As illustrated in FIGS. 7 to 10, as with a typical air conditioner, the air conditioner **2** makes the temperature of the room changes gradual by reducing the air conditioning capability as the temperature of the room approaches the setting temperature. Specifically, the air conditioner **2** controls the air conditioning capability in accordance with a difference between the setting temperature and the temperature of the room. For example, when a temperature rise rate is in a range from 0 to 70% when performing heating operation, the air conditioner **2** operates at maximum air conditioning capability (that is, maximum heating capability) in order to quickly raise the temperature of the room (hereinafter this region is referred to as “start-up region”). Moreover, as the temperature of the room rises and approaches the setting temperature, the heating capability is gradually reduced so that the temperature of the room does not exceed the setting temperature (hereinafter, this region is referred to as “transition region”), and the heating capability is maintained at a level where the temperature of the room substantially matches the setting temperature (hereinafter, this region is referred to as “stable region”).

[0083] In the start-up region, variations in changes in the temperature of the room are small due to operating at a substantially constant air conditioning capability. Meanwhile, from the transition region to the stable region, variations are more likely to occur due to the air conditioning

capability changing depending on conditions and due to the temperature changes becoming gradual.

[0084] Accordingly, the temperature of the room is assumed to change exponentially as in Equation 1 below.

$$T - T_{ini} = (T_{set} - T_{ini}) \times (1 - e^{-t/\tau}) \quad (\text{Equation 1})$$

T (° C.): Temperature of room

Tset (° C.): Setting temperature

Tini (° C.): Initial temperature of room

t (minutes): Time

τ (minutes): Time constant

[0085] The time constant τ is an example of the first required amount of time. From Equation 1, when performing heating operation, the time constant τ is an amount of time required to reach a temperature increased, from the initial temperature of the room (that is, the temperature of the room when starting heating), 63.2% of a temperature difference between the setting temperature and the initial temperature of the room. Hereinafter, the temperature of the room at the time of the time constant τ is referred to as a “target in-progress temperature”.

[0086] When the time constant τ is acquired, the required amount of time until the predetermined target temperature can be easily calculated using Equation 1 above. Hereinafter, this required amount of time is referred to as an “air conditioning required amount of time”. The air conditioning required amount of time is an example of the second required amount of time. For example, when the target temperature is a temperature increased, from the initial temperature of the room, 80% of the temperature difference between the setting temperature and the initial temperature of the room, the air conditioning required amount of time is the time constant $\tau \times 1.6$.

[0087] Even when air conditioners have the same specifications, the time constant τ differs depending on the heat capacity of the room (amount of heat required to raise the temperature of the room 1° C.). The heat capacity of the room is determined by the size of the room, differences in the structure such as reinforced concrete or wood, the type of building materials (the physical properties of the materials used in the walls, floor, and ceiling), the amount of furniture, and the like. FIGS. 9 and 10 illustrate comparisons of rooms having small heat capacity and rooms having large heat capacity. When outputting a constant heating capability in the start-up region, the temperature changes become gradual and the time constant τ increases as the room has a larger heat capacity. Thus, an appropriate time constant τ corresponding to the room can be obtained by performing learning after the air conditioner **2** is installed.

[0088] The learner **222** derives, by learning, the first approximate expression f1 (Tset, Tini) and the second approximate expression f2 (To: outside air temperature) for calculating the appropriate time constant τ . FIG. 11 is a flowchart illustrating the procedures of learning processing executed by the learner **222**. The learning processing is executed every time the air-conditioning operation is started, regardless of whether started by automatic operation or manual operation.

[0089] The learner **222** acquires the temperature of the room R at the time of operation start, that is, acquires the initial temperature of the room (step S101). The learner **222** determines whether the temperature has reached the target in-progress temperature (step S102). When the temperature has reached the target in-progress temperature (step S102;

YES), the learner 222 acquires an elapsed time from the operation start, that is, acquires the time constant τ (step S103).

[0090] The learner 222 derives the first approximate expression $f1$ (Tset, Tini) (step S104). FIG. 12 illustrates a plot example of the time constant τ acquired by repeating, a plurality of times, the learning processing when performing heating operation. In the example of FIG. 12, the temperature difference ΔT between the setting temperature and the initial temperature of the room is represented on the horizontal axis, and the time constant τ is represented on the vertical axis. As understood from FIG. 12, as the temperature difference $\Delta\tau$ increases, the amount of heat, with respect to the heat capacity of the room R, for changing the temperature from the initial temperature of the room to the setting temperature increases and, as such, when the air conditioner 2 operates at a constant air conditioning capability, the time constant τ increases. The learner 222 derives the first approximate expression $f1$ (Tset, Tini) by calculating the slope of the linear approximation of the time constant τ relative to the temperature difference ΔT from the plot of the time constant τ .

[0091] Next, the learner 222 derives the second approximate expression $f2$ (To) (step S105). A deviation between the first approximate expression $f1$ (Tset, Tini) and the time constant τ is defined as $\Delta\tau$ (see FIG. 13). FIG. 14 illustrates a plot example of the deviation $\Delta\tau$ acquired by repeating, a plurality of times, the learning processing when performing heating operation. In the example of FIG. 14, the outside air temperature is represented on the horizontal axis, and the deviation $\Delta\tau$ is represented on the vertical axis. As understood from FIG. 14, when performing heating operation, as the outside air temperature decreases, the thermal load increases and, as a result, the time constant τ increases more than the first approximate expression $f1$ (Tset, Tini) ($\Delta\tau$ is positive). Meanwhile, the thermal load decreases as the outside air temperature increases and, as a result, the time constant τ decreases more than the first approximate expression $f1$ (Tset, Tini) ($\Delta\tau$ is negative). The learner 222 derives the second approximate expression $f2$ (To) from the plot of the deviation $\Delta\tau$ by calculating the slope and the intercept of the linear approximation of the deviation $\Delta\tau$ relative to the outside air temperature.

[0092] The time constant calculator 223 is an example of the first required period acquisition means. The time constant calculator 223 calculates, on the basis of parameters that are the setting temperature, the initial temperature of the room, and the outside air temperature, and the learning results of the learner 222, the time constant τ that is the required amount of time from when air conditioning of the room R is started to when the temperature of the room R reaches the target in-progress temperature. Specifically, the time constant calculator 223 calculates the time constant τ on the basis of Equation 2 below.

$$\text{Time constant } \tau = f1(\text{Tset}, \text{Tini}) + f2(\text{To}) \quad (\text{Equation 2})$$

[0093] The air conditioning required period calculator 224 is an example of the second required period acquisition means. The air conditioning required period calculator 224 calculates an air conditioning required amount of time from when air conditioning of the room R is started to when the temperature of the room R reaches the target temperature. Specifically, the air conditioning required period calculator 224 calculates the air conditioning required amount of time

on the basis of the time constant τ calculated by the time constant calculator 223, the target temperature, and Equation 1 described above. The air conditioning required period calculator 224 supplies the calculated air conditioning required amount of time to the operation controller 225.

[0094] The operation controller 225 is an example of the operation control means. When the arrival required amount of time acquired by the arrival required period acquirer 221 is other than 0 minutes, the operation controller 225 compares that arrival required amount of time and the air conditioning required amount of time calculated by the air conditioning required period calculator 224, and starts the air-conditioning operation when the arrival required amount of time is equal to or shorter than the air conditioning required amount of time.

[0095] FIG. 15 is a flowchart illustrating the procedures of automatic operation start processing executed by the air conditioner 2. When operation is stopped, the air conditioner 2 periodically (for example, on a one-minute cycle) repeatedly executes the automatic operation start processing.

[0096] The air conditioner 2 acquires, from the cloud server 4, the arrival required amount of time that is the required amount of time for the user that is outside to arrive at the house H (that is, to return home) (step S201).

[0097] The air conditioner 2 calculates the air conditioning required amount of time that is the required amount of time from when air conditioning of the room R is started to when the temperature of the room R reaches the target temperature (step S202). Then, the air conditioner 2 determines whether the acquired arrival required amount of time is equal to or shorter than the calculated air conditioning required amount of time (step S203).

[0098] When a determination is made that the arrival required amount of time is not equal to or shorter than the air conditioning required amount of time (step S203; NO), the air conditioner 2 ends the automatic operation start processing of the present cycle.

[0099] However, when a determination is made that the arrival required amount of time is equal to or shorter than the air conditioning required amount of time (step S203; YES), the air conditioner 2 starts the air-conditioning operation (step S204), and ends the automatic operation start processing of the present cycle.

[0100] As described above, according to the air conditioning system 1 of the present embodiment, the air conditioner 2 calculates the time constant τ that is the required amount of time for the initial temperature of the room R to reach the target in-progress temperature that is the temperature of the start-up region, and calculates the air conditioning required amount of time on the basis of the calculated time constant τ . Thus, the required amount of time from when air conditioning of the room R is started to when the temperature of the room reaches the target temperature can be accurately acquired. As a result, when the user is outside, automatic operation can be started at an appropriate timing, and comfort and energy saving can be improved.

[0101] Additionally, since the time constant τ is calculated on the basis of the first approximate expression $f1$ (Tset, Tini) and the second approximate expression $F2$ (To) derived by the learning, an appropriate time constant τ corresponding to the heat capacity of the room R can be obtained.

[0102] Note that the present disclosure is not limited to the embodiment described above, and various modifications of are possible without departing from the spirit and scope of the present disclosure.

[0103] For example, in the embodiment described above, the automatic operation starting function is described using a case of a heating operation as an example, but the technical concept of the present disclosure can be applied to a cooling operation as well.

[0104] In the embodiment described above, the target in-progress temperature that is the temperature of the start-up region when heating operation is performed is set, on the basis of Equation 1, to a temperature increased, from the initial temperature, 63.2% of the temperature difference between the setting temperature and the initial temperature. However, the target in-progress temperature is not limited thereto. A configuration is possible in which the target in-progress temperature is determined by a suitable exponential equation based on the specifications of the target air conditioner. Alternately, a configuration is possible in which the target in-progress temperature is determined on the basis of the setting temperature and a constant c ($>0^{\circ}\text{C.}$) obtained from the specification of the air conditioner. For example, the target in-progress temperature may be determined on the basis of the setting temperature—the constant c when performing heating operation, and on the basis of the setting temperature+the constant c when performing cooling operation.

[0105] Moreover, a configuration is possible in which, as the parameter of the second approximate expression f2, weather information such as an amount of solar radiation, the weather, and the like may be used, or indoor information such as the temperature of the floor, the walls, or the window, an open/closed state of a door, the presence/absence of internal heat generation, and the like is used. The air conditioner 2 may acquire the weather information via the cloud server 4 from a non-illustrated weather server, or directly from the weather server. The air conditioner 2 can acquire the indoor information by analyzing the thermal image data acquired by the thermal image sensor 205.

[0106] A configuration is possible in which the first approximate expression f1 is derived in accordance with the season, month, time block, time, or the like, and used.

[0107] A configuration is possible in which the user registers the target temperature in the air conditioner 2 in advance via the terminal device 3 or the air conditioning remote controller 6, or the target temperature is set automatically by the air conditioner 2 on the basis of physical information of the user that the user registers in advance in the air conditioner 2. Examples of the physical information include characteristics to thermal environments (sensitive to heat, sensitive to cold, and the like), gender, age, weight, height, and the like. Alternately, a configuration is possible in which the air conditioner 2 sets the target temperature on the basis of information such as the amount of clothing worn by the user, thermal sensation, an amount of activity, of the like. The air conditioner 2 can acquire the amount of clothing worn by the user and the thermal sensation by analyzing the thermal image data when the user is at home.

[0108] Additionally, the air conditioner 2 can acquire the amount of activity of the user from the cloud server 4. In such a case, the cloud server 4 calculates the amount of activity of the user on the basis of a movement speed of the user, a movement means (walking, bus, train, car, or the like)

registered in advance, step data acquired from the terminal device 3, and the like. Moreover, a configuration is possible in which, when the user is wearing a wearable sensor that measures biodata, the cloud server 4 calculates the amount of activity of the user on the basis of the biodata of the user acquired by communicating with the wearable sensor. The biodata includes body temperature, heart rate, perspiration amount, and the like.

[0109] A configuration is possible in which the cloud server 4 manages the physical information of the user and the like using the customer database 440. Furthermore, a configuration is possible in which the cloud server 4 determines the target temperature as described above, and notifies the air conditioner 2 of the determined target temperature.

[0110] While not illustrated in any of the drawings, a configuration is possible in which the air conditioner 2 further includes a time keeper (example of the time keeping means) that measures an amount of time from when automatic operation is started to when the user arrives at the house H; and a temperature on-arrival acquirer (example of the temperature on-arrival acquisition means) that acquires the temperature of the room R at arrival of the user at the house H, wherein the air conditioning required period calculator 224 determines, on the basis of the amount of time measured by the time keeper and the temperature acquired by the temperature on-arrival acquirer, a correction value α to be used when calculating the next air conditioning required amount of time.

[0111] In the modified examples described above, in a case in which, for example, when performing heating operation, the amount of time measured by the time keeper is equal to or longer than the air conditioning required amount of time, and the temperature acquired by the temperature on-arrival acquirer is lower than the target temperature, in the calculation of the next air conditioning required amount of time, the air conditioning required period calculator 224 adds the correction value α (>0 minutes) to the amount of time calculated on the basis of the time constant τ , the target temperature, and Equation 1 to calculate the air conditioning required amount of time. As a result, variations of the air conditioning required amount of time can be mitigated, and a variety of map apps made by other developers (specifically, arrival required period estimation algorithms) and the air conditioner 2 can be linked to each other.

[0112] A configuration is possible in which the arrival required period calculator 401 of the cloud server 4 calculates the user distance and/or the arrival required amount of time each time the position data is acquired from the terminal device 3.

[0113] A configuration is possible in which, instead of executing the automatic operation start processing (see FIG. 15) periodically unconditionally when operation is stopped, the air conditioner 2 starts the periodic execution of the automatic operation start processing with the receipt of a processing start command from the cloud server 4 as a trigger. In such a case, the cloud server 4 may send the processing start command to the air conditioner 2 when the user distance is equal to or shorter than a predetermined distance (for example, the maximum distance described above), may send the processing start command to the air conditioner 2 when the arrival required amount of time is equal to or shorter than a predetermined maximum amount of time, or may send the processing start command to the air

conditioner 2 when a predetermined operation is performed via the terminal device 3 by the user.

[0114] Furthermore, the cloud server 4 may send a processing stop command to the air conditioner 2 when the user distance exceeds the maximum distance, may send the processing stop command to the air conditioner 2 when the arrival required amount of time exceeds the maximum amount of time, or may send the processing stop command to the air conditioner 2 when a predetermined operation is performed via the terminal device 3 by the user. When the processing stop command is received from the cloud server 4, the air conditioner 2 stops the periodic execution of the automatic operation start processing.

[0115] A configuration is possible in which the terminal device 3 calculates the arrival required amount of time and notifies the air conditioner 2 of the calculated arrival required amount of time via the cloud server 4 or directly, or the air conditioner 2 calculates the arrival required amount of time on the basis of the position data received directly or indirectly from the terminal device 3.

[0116] A configuration is possible in which the functions (see FIG. 6) of the air conditioner 2 are realized by the control circuit 210 of the outdoor unit 21.

[0117] A configuration is possible in which, as an example of the control device, the cloud server 4, the terminal device 3, or the air conditioning remote controller 6 is provided with the functions of all or any of the learner 222, the time constant calculator 223, the air conditioning required period calculator 224, and the operation controller 225 of the air conditioner 2.

[0118] A configuration is possible in which a device such as a home energy management system (HEMS) controller installed in the house H is provided with the same functions (see FIG. 6) as the cloud server 4 and, as an example of the control device, is provided with the functions of all or any of the learner 222, the time constant calculator 223, the air conditioning required period calculator 224, and the operation controller 225 of the air conditioner 2.

[0119] A configuration is possible in which the communication between the indoor unit 20 of the air conditioner 2 and the cloud server 4 is performed on the basis of 5th Generation Mobile Communication System (5G) low power wide area (LPWA).

[0120] A configuration is possible in which the air conditioner 2 does not include the communication interface 206 and communicates with the cloud server 4 via a non-illustrated external communication adapter.

[0121] A configuration is possible in which the air conditioner 2 is installed in each of a plurality of rooms of the house H. In such a case, each air conditioner 2 retains, in advance, the ID of the terminal device 3 possessed by the user corresponding to the room in which that air conditioner 2 is installed. Moreover, each air conditioner 2 acquires, by specifying the ID of the terminal device 3, the arrival required amount of time of the user possessing that terminal device 3 having the specified ID from the cloud server 4 to execute the automatic operation start processing (see FIG. 15).

[0122] A configuration is possible in which all or a portion of the functional components (see FIG. 6) of the air conditioner 2 are realized by dedicated hardware, or all or a portion of the functional components (see FIG. 6) of the cloud server 4 are realized by dedicated hardware. Examples of the dedicated hardware include a single circuit, a com-

posite circuit, a programmed processor, an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), and combinations thereof.

[0123] The present disclosure is also applicable to systems for air conditioning buildings other than houses.

[0124] The technical concept of the various modified examples described above may be realized independently, or may be appropriately combined and realized.

[0125] The foregoing describes some example embodiments for explanatory purposes. Although the foregoing discussion has presented specific embodiments, persons skilled in the art will recognize that changes may be made in form and detail without departing from the broader spirit and scope of the invention. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense. This detailed description, therefore, is not to be taken in a limiting sense, and the scope of the invention is defined only by the included claims, along with the full range of equivalents to which such claims are entitled.

INDUSTRIAL APPLICABILITY

[0126] The present disclosure is preferably used in an air conditioning system that performs air conditioning of a building.

REFERENCE SIGNS LIST

[0127]	1	Air conditioning system
[0128]	2	Air conditioner
[0129]	3	Terminal device
[0130]	4	Cloud server
[0131]	5	Router
[0132]	6	Air conditioning remote controller
[0133]	20	Indoor unit
[0134]	21	Outdoor unit
[0135]	22	Refrigerant pipe
[0136]	23	Communication line
[0137]	30	Display
[0138]	31	Operation receiver
[0139]	32	First communication interface
[0140]	33	Second communication interface
[0141]	34	GPS signal receiving circuit
[0142]	35, 41	CPU
[0143]	36, 42	ROM
[0144]	37, 43	RAM
[0145]	38, 44	Auxiliary storage device
[0146]	39, 45	Bus
[0147]	40, 206	Communication interface
[0148]	200, 210	Control circuit
[0149]	201, 213	Heat exchanger
[0150]	202, 214	Fan
[0151]	203	Temperature sensor
[0152]	204	Humidity sensor
[0153]	205	Thermal image sensor
[0154]	211	Compressor
[0155]	212	Four-way valve
[0156]	215	Expansion valve
[0157]	220	Arrival required period requester
[0158]	221	Arrival required period acquirer
[0159]	222	Learner
[0160]	223	Time constant calculator
[0161]	224	Air conditioning required period calculator
[0162]	225	Operation controller
[0163]	400	Position data acquirer

[0164] 401 Arrival required period calculator

[0165] 402 Arrival required period sender

[0166] 440 Customer database

1. An air conditioner, comprising:

processing circuitry to

acquire an arrival required amount of time that is an amount of time required for a user to arrive at a building;

acquire a first required amount of time from when air conditioning of a room of the building is started until a temperature of the room reaches a target in-progress temperature that is a temperature reached prior to reaching a target temperature, the target in-progress temperature being determined based on a setting temperature of the room,

acquire, based on the acquired first required amount of time, a second required amount of time from when the air conditioning of the room is started until the temperature of the room reaches the target temperature, and

start an air-conditioning operation when the acquired arrival required amount of time is equal to or shorter than the acquired second required amount of time.

2. The air conditioner according to claim 1, wherein the processing circuitry acquires the second required amount of time based on the first required amount of time, the target temperature, and a predetermined exponential function expression.

3. The air conditioner according to claim 1, wherein the processing circuitry

derives, by learning, a first approximate expression for calculating the first required amount of time, the first approximate expression having, as parameters, the setting temperature and the temperature of the room at start of the air conditioning, and

acquires the first required amount of time based on the first approximate expression.

4. The air conditioner according to claim 3, wherein the processing circuitry

derives, by learning, a second approximate expression for calculating a correction value of a value derived by the first approximate expression, the second approximate expression having an outside air temperature as a parameter, and

acquires the first required amount of time based on the first approximate expression and the second approximate expression.

5. The air conditioner according to claim 1, wherein the processing circuitry

measures an amount of time from when an air-conditioning operation is started to when the user arrives at the building,

acquires the temperature of the room at arrival of the user at the building, and

determines, based on the measured amount of time and the acquired temperature of the room, a correction value to be used when calculating the second required amount of time of a next time.

6. A control device, comprising:

processing circuitry to

acquire an arrival required amount of time that is an amount of time required for a user to arrive at a building,

acquire a first required amount of time from when air conditioning of a room of the building is started until a temperature of the room reaches a target in-progress temperature that is a temperature reached prior to reaching a target temperature, the target in-progress temperature being determined based on a setting temperature of the room,

acquire, based on the acquired first required amount of time, a second required amount of time from when the air conditioning of the room is started until the temperature of the room reaches the target temperature, and

cause an air conditioner to start an air-conditioning operation when the acquired arrival required amount of time is equal to or shorter than the acquired second required amount of time.

7. An air conditioning system, comprising:

a terminal device, a server, and an air conditioner, wherein the terminal device is configured to periodically send position data related to a position of terminal device to the server,

the server includes

first processing circuitry to

calculate, based on the position data, an arrival required amount of time required for a user to arrive at a building, and

send the calculated arrival required amount of time to the air conditioner, and

the air conditioner includes

second processing circuitry to

acquire the arrival required amount of time from the server,

acquire a first required amount of time from when air conditioning of a room of the building is started until a temperature of the room reaches a target in-progress temperature that is a temperature reached prior to reaching a target temperature, the target in-progress temperature being determined based on a setting temperature of the room,

acquire, based on the acquired first required amount of time, a second required amount of time from when the air conditioning of the room is started until the temperature of the room reaches the target temperature, and

start an air-conditioning operation when the acquired arrival required amount of time is equal to or shorter than the acquired second required amount of time.

8. An air conditioning method, comprising:

acquiring an arrival required amount of time that is an amount of time required for a user to arrive at a building;

acquiring a first required amount of time from when air conditioning of a room of the building is started until a temperature of the room reaches a target in-progress temperature that is a temperature reached prior to reaching a target temperature, the target in-progress temperature being determined based on a setting temperature of the room;

acquiring, based on the acquired first required amount of time, a second required amount of time from when the air conditioning of the room is started until the temperature of the room reaches the target temperature; and

starting an air-conditioning operation when the acquired arrival required amount of time is equal to or shorter than the acquired second required amount of time.

9. The air conditioner according to claim 2, wherein the processing circuitry

derives, by learning, a first approximate expression for calculating the first required amount of time, the first approximate expression having, as parameters, the setting temperature and the temperature of the room at start of the air conditioning, and

acquires the first required amount of time based on the first approximate expression.

10. The air conditioner according to claim 2, wherein the processing circuitry

measures an amount of time from when an air-conditioning operation is started to when the user arrives at the building,

acquires the temperature of the room at arrival of the user at the building, and

determines, based on the measured amount of time and the acquired temperature of the room, a correction value to be used when calculating the second required amount of time of a next time.

11. The air conditioner according to claim 3, wherein the processing circuitry

measures an amount of time from when an air-conditioning operation is started to when the user arrives at the building,

acquires the temperature of the room at arrival of the user at the building, and

determines, based on the measured amount of time and the acquired temperature of the room, a correction value to be used when calculating the second required amount of time of a next time.

12. The air conditioner according to claim 4, wherein the processing circuitry

measures an amount of time from when an air-conditioning operation is started to when the user arrives at the building,

acquires the temperature of the room at arrival of the user at the building, and

determines, based on the measured amount of time and the acquired temperature of the room, a correction value to be used when calculating the second required amount of time of a next time.

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