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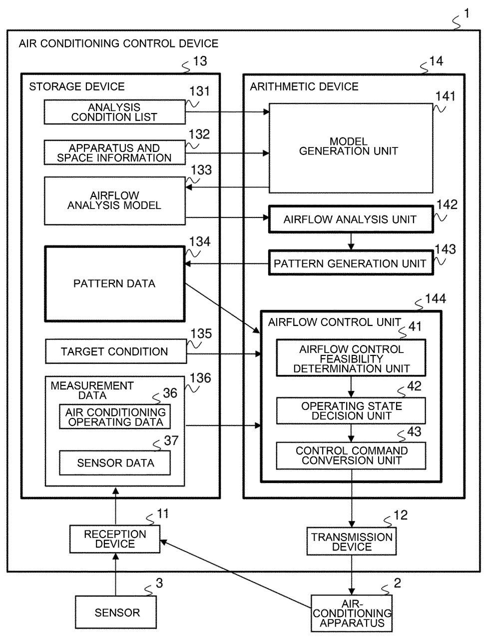
(54) **AIR CONDITIONING CONTROL DEVICE**

(57) An air conditioning control device includes a storage device that stores a plurality of analysis conditions to which respective priorities are assigned, and a result of an airflow analysis for each of the analysis conditions, and an arithmetic device that controls an air-conditioning apparatus. The arithmetic device includes an airflow analysis unit that performs the airflow analysis for the plurality of analysis conditions in order of priority from highest to lowest, an airflow control feasibility determination unit that determines, in accordance with a generation state of an analysis result provided by the airflow analysis unit, whether or not airflow control can be started for the air-conditioning apparatus, and an operating state decision unit that, when the airflow control feasibility determination unit determines that the airflow control can be started, decides on an operating state of the air-conditioning apparatus in accordance with an analysis result provided by the airflow analysis unit.

FIG. 3



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Description

Technical Field

[0001] The present invention relates to an air conditioning control device that controls an air-conditioning apparatus.

Background Art

[0002] To control an air-conditioning apparatus in consideration of a distribution of an indoor environment, an air conditioning control device has been proposed that controls the air-conditioning apparatus by using a fluid analysis method (for example, see Patent Literature 1).

[0003] An air conditioning control device disclosed in Patent Literature 1 includes a room temperature distribution estimation unit, a candidate control amount calculation unit, a controllable amount extraction unit, and an air conditioning control unit, and controls an air-conditioning apparatus including an indoor unit in which a plurality of air outlets are provided.

[0004] The room temperature distribution estimation unit divides a modeled building into a grid of spaces, provides, for each space of the grid, initial conditions, such as the pressure, temperature, and volume of air, that are necessary for calculation, and performs, for all combinations of air volumes of the plurality of air outlets, a process of analyzing a temperature in each space of the grid. The candidate control amount calculation unit extracts a candidate control amount, which is a combination of air volumes of the respective air outlets, in accordance with simulation results provided by the room temperature distribution estimation unit, thermal load information, a target temperature, and a target place.

[0005] The controllable amount extraction unit obtains, in accordance with an interaction table in which air volume values based on a combination of amounts of control of on-off valves provided for the respective air outlets are recorded, and the candidate control amount, controllable amounts representing amounts of control of the on-off valves for the respective air outlets. The air conditioning control unit performs air conditioning control in accordance with the controllable amounts.

Citation List

Patent Literature

[0006]

Patent Literature 1: Japanese Unexamined Patent Application Publication JP 2016- 61 447 A

Summary of the Invention

Technical Problem

[0007] In the air conditioning control device disclosed in Patent Literature 1, however, in a case where there are many conditions, such as air volume related to the air outlets, a huge number of combinations of conditions result, and thus it takes a long time to analyze an airflow prior to the start of airflow control. For this reason, it takes a long time until airflow control starts after the start of the air-conditioning apparatus for airflow control to be started.

[0008] To address the above-described issue, the present invention provides an air conditioning control device that can start airflow control early after an air-conditioning apparatus is started.

Solution to the Problem

[0009] An air conditioning control device according to an embodiment of the present invention includes a storage device configured to store a plurality of analysis conditions to which respective priorities are assigned, and a result of an airflow analysis for each of the analysis conditions, and an arithmetic device configured to control an air-conditioning apparatus. The arithmetic device includes an airflow analysis unit configured to perform the airflow analysis for the plurality of analysis conditions in order of priority from highest to lowest, an airflow control feasibility determination unit configured to determine, in accordance with a generation state of an analysis result provided by the airflow analysis unit, whether or not airflow control can be started for the air-conditioning apparatus, and an operating state decision unit configured to, when the airflow control feasibility determination unit determines that the airflow control can be started, decide on an operating state of the air-conditioning apparatus in accordance with an analysis result provided by the airflow analysis unit.

Advantageous Effects of Invention

[0010] In the embodiment of the present invention, priorities are assigned to the respective plurality of analysis conditions, an airflow analysis is performed for the analysis conditions in order of priority from highest to lowest, and thus airflow control can be started at an early stage at which an airflow analysis for a high-priority analysis condition is completed, making it possible to provide a comfortable environment to a user early.

Brief Description of Drawings

[0011]

FIG. 1 is a configuration diagram illustrating an example of an air-conditioning system including an air conditioning control device according to Embodiment 1.
FIG. 2 is a refrigerant circuit diagram illustrating an example of a configuration of an air-conditioning apparatus illustrated in FIG. 1.
FIG. 3 is a block diagram illustrating an example of a configuration of the air conditioning control device according to Embodiment 1.
FIG. 4 is a conceptual diagram representing an example of an analysis condition list illustrated in FIG. 3.
FIG. 5 is a conceptual diagram representing an example of a blowing condition related to an operating state of the air-conditioning apparatus of an analysis condition illustrated in FIG. 4.
FIG. 6 is a conceptual diagram representing an example of a load condition of the analysis condition illustrated in FIG. 4.
FIG. 7 is a conceptual diagram of a case where priorities are managed by using a numerical range.
FIG. 8 is a conceptual diagram representing an example of pattern data illustrated in FIG. 3.
FIG. 9 is a hardware configuration diagram illustrating an example of a configuration of an arithmetic device illustrated in FIG. 3.
FIG. 10 is a hardware configuration diagram illustrating another example of the configuration of the arithmetic device illustrated in FIG. 3.
FIG. 11 is a flowchart illustrating an example of an operation procedure performed by the air conditioning control device according to Embodiment 1.
FIG. 12 is a flowchart illustrating an example of an operation procedure performed in step ST11 illustrated in FIG. 11.
FIG. 13 is a flowchart illustrating an example of an operation procedure performed in step ST15 illustrated in FIG. 11.

Description of Embodiments

Embodiment 1

[0012] An embodiment of an air conditioning control device of the present invention will be described with reference to the drawings. FIG. 1 is a configuration diagram illustrating an example of an air-conditioning system including an air conditioning control device according to Embodiment 1. The air-conditioning system includes an air-conditioning apparatus 2 that conditions air in an air-conditioned space, an air conditioning control device 1 that controls the air-conditioning apparatus 2, and a sensor 3 that measures at least an environment in the air-conditioned space. The air conditioning control device 1 is connected to the air-conditioning apparatus 2 and the sensor 3 via a network 4.

[0013] FIG. 2 is a refrigerant circuit diagram illustrating an example of a configuration of the air-conditioning apparatus illustrated in FIG. 1. As illustrated in FIG. 1, the air-conditioning apparatus 2 includes an outdoor unit 21, an indoor unit 22, and a controller 23. The indoor unit 22 is installed in a room that is an air-conditioned space. As illustrated in FIG. 2, the outdoor unit 21 is connected to the indoor unit 22 via a refrigerant pipe 56.

[0014] The outdoor unit 21 includes a compressor 51, a four-way valve 52, a heat source side heat exchanger 53, an expansion device 54, and an outdoor fan 57. The indoor unit 22 includes a load side heat exchanger 55, an indoor fan 58, and an air direction adjustment unit 59. The compressor 51, the heat source side heat exchanger 53, the expansion device 54, and the load side heat exchanger 55 are connected by the refrigerant pipe 56 to form a refrigerant circuit 50 through which refrigerant circulates. In Embodiment 1, although a case is described where a heat medium that circulates between the outdoor unit 21 and the indoor unit 22 is refrigerant, a heat medium heat exchanger (not illustrated) in which heat is exchanged between water and refrigerant may be provided in the outdoor unit 21 to cause water to circulate between the outdoor unit 21 and the indoor unit 22.

[0015] The air direction adjustment unit 59 is provided at an air outlet of the indoor unit 22. The air direction adjustment unit 59 includes a horizontal flap 61 and a vertical flap 62. For the horizontal flap 61, an angle is changed clockwise or counterclockwise relative to a front direction of the air outlet of the indoor unit 22 to thus change a direction of an airflow sent from the indoor unit 22 in parallel to a floor surface. The direction of an airflow that changes in response to the angle of the horizontal flap 61 is a horizontal air direction. Hereinafter, for an angle of the horizontal air direction, with respect to the front direction of the air outlet of the indoor unit 22, a clockwise angle is represented by a positive value, and a counterclockwise angle is represented by a negative value.

[0016] For the vertical flap 62, at the air outlet of the indoor unit 22, an angle relative to a gravitational direction is changed from the gravitational direction to a horizontal direction to thus change a direction of an airflow sent from the indoor unit 22. In this case, assuming that the gravitational direction is 0°, the horizontal direction is 90°. The direction of an airflow that changes in response to the angle of the vertical flap 62 is a vertical air direction. Representation of an angle representing the vertical air direction is not limited to the case where the gravitational direction is 0° and the horizontal direction is 90°. The gravitational direction may be 90°, and the horizontal direction may be 0°. That is, when the horizontal direction is 0°, an angle of depression corresponds to an angle representing the vertical air direction.

[0017] The controller 23 is, for example, a microcomputer. The controller 23 is connected to the compressor 51, the four-way valve 52, the outdoor fan 57, the expansion device 54, the indoor fan 58, and the air direction adjustment unit 59 via a signal line, which is not illustrated. The controller 23 is a device through which a user or administrator switches the indoor unit 22 on and off or manually changes settings, such as a preset temperature and air volume. The controller 23 may be a remote control.

[0018] The controller 23 controls a refrigeration cycle of refrigerant that circulates through the refrigerant circuit 50. The controller 23 controls the four-way valve 52 so that directions in which the refrigerant in the refrigerant circuit 50 flows are switched in response to operation modes of a heating operation and a cooling operation. Furthermore, the controller 23 controls an operating frequency of the compressor 51, an opening degree of the expansion device 54, and a rotation speed of the outdoor fan 57 so that a temperature and a humidity in the room measured by the sensor 3 coincide with respective set values in their predetermined ranges.

[0019] Set values for temperature and humidity in the room are set by the user. The controller 23 transmits air conditioning operating data representing an operating state of the air-conditioning apparatus 2 to the air conditioning control device 1 via the network 4 at fixed time intervals. The fixed time interval is, for example, five minutes.

[0020] Furthermore, when the controller 23 receives a control command from the air conditioning control device 1, the controller 23 controls, in accordance with the control command, a rotation speed of the indoor fan 58, and an angle of the horizontal flap 61 and an angle of the vertical flap 62 in the air direction adjustment unit 59. Air volume and air velocity are adjusted in response to the rotation speed of the indoor fan 58. The horizontal air direction is adjusted in response to the angle of the horizontal flap 61, and the vertical air direction is adjusted in response to the angle of the vertical flap 62.

[0021] When an operation mode is a heating operation, refrigerant receives heat in the heat source side heat exchanger 53, the refrigerant exchanges heat with air in the room in the load side heat exchanger 55 to transfer heat, and thus the air in the room is heated. On the other hand, when an operation mode is a cooling operation, refrigerant transfers heat in the heat source side heat exchanger 53, the refrigerant exchanges heat with air in the room in the load side heat exchanger 55, and thus the air in the room is cooled.

[0022] Next, a case example of the use of the air-conditioning apparatus 2 illustrated in FIG. 1 will be described. In a residential air-conditioning system, in many cases, one indoor unit 22 is installed in one room. For example, a room air conditioner is a typical example of the air-conditioning apparatus 2. The air-conditioning apparatus 2 may be a room air conditioner in which a plurality of indoor units 22 are connected to one outdoor unit.

[0023] Furthermore, the air-conditioning apparatus 2 may be a variable refrigerant flow (VRF) system used, for example, in office buildings. Additionally, the air-conditioning system may be a central air-conditioning system used for air conditioning of an entire large-scale building. The air-conditioning system may be an air-conditioning system that is installed, for example, in a server room and a warehouse and performs air conditioning for objects. Such configurations are examples of the air-conditioning apparatus 2 and the air-conditioning system including the air-conditioning apparatus 2, and the type of the air-conditioning apparatus 2 is not limited to the above-described configurations. Furthermore, an air-conditioned space is also not limited to spaces, for example, in the above-described rooms and buildings.

[0024] Next, the sensor 3 illustrated in FIG. 1 will be described. The sensor 3 is a sensor that measures a physical quantity. The sensor 3 transmits sensor data, which is a measurement value, to the air conditioning control device 1 via the network 4 at fixed time intervals. The fixed time interval is, for example, five minutes. The number of sensors 3 may be one or two or more. FIG. 1 illustrates a case where the sensor 3 includes a plurality of sensors 3-1 to 3-n (n is an integer greater than or equal to two). The sensor 3 acquires information on indoor and outdoor environments. The sensor 3 includes sensors that perform measurements, for example, of temperature, humidity, radiation temperature, thermal images, and airflow velocity. If the sensor 3 includes an infrared sensor, a thermal image is acquired by the infrared sensor.

[0025] In the example of the configuration illustrated in FIG. 1, the sensor 3 is provided separately from the air-conditioning apparatus 2. However, the sensor 3 may be provided in the air-conditioning apparatus 2. For example, a sensor 3 that measures a room temperature, which is a temperature of air in the room, may be provided in the indoor unit 22, and a sensor 3 that measures an outside temperature, which is a temperature of outside air, may be provided in the outdoor unit 21. Incidentally, an outside temperature is not limited to the case where the sensor 3 transmits an outside temperature to the air conditioning control device 1. A server (not illustrated) that provides a weather forecast via a network, such as the Internet, may transmit information on outside temperature to the air conditioning control device 1.

[0026] The network 4 is a communication network that connects the air conditioning control device 1, the air-conditioning apparatus 2, and the sensor 3. A tool for communication in the network 4 may be a wired or wireless tool, or may be a combination of a wired tool and a wireless tool. Furthermore, a communication protocol for communication performed via the network 4 is not limited to a particular protocol and may be a publicly available general-purpose protocol. A communication range of the network 4 may be a narrow range, such as that of a Local Area Network (LAN), or may be a wide range, such as that of the Internet. Furthermore, if the network 4 is a dedicated line operated by a manufacturer of the air-conditioning apparatus 2, a communication protocol used in the network 4 may be a dedicated protocol.

[0027] A configuration of the air conditioning control device 1 will be described with reference to FIGS. 1 and 3. FIG. 3 is a block diagram illustrating an example of a configuration of the air conditioning control device according to Embodiment 1. The air conditioning control device 1 is an information processing device that controls the air-conditioning apparatus 2. The air conditioning control device 1 includes a storage device 13, an arithmetic device 14, a reception device 11, and a transmission device 12.

[0028] The reception device 11 acquires air conditioning operating data from the air-conditioning apparatus 2 at fixed time intervals and causes the storage device 13 to store the acquired data. The reception device 11 acquires sensor data from the sensor 3 at fixed time intervals and causes the storage device 13 to store the acquired data. The fixed time interval is, for example, five minutes. In Embodiment 1, although the case is described where the time intervals at which the reception device 11 acquires data from the air-conditioning apparatus 2 are the same as the time intervals at which the reception device 11 acquires data from the sensor 3, the time intervals at which data is acquired from the air-conditioning apparatus 2 may be different from the time intervals at which data is acquired from the sensor 3. When a control command to the air-conditioning apparatus 2 is decided on by the arithmetic device 14, the transmission device 12 transmits the decided control command to the air-conditioning apparatus 2.

[0029] The storage device 13 stores an analysis condition list 131, apparatus and space information 132, an airflow analysis model 133, pattern data 134, a target condition 135, and measurement data 136 including air conditioning operating data 36 and sensor data 37. The storage device 13 is, for example, a Hard Disk Drive (HDD). The storage device 13 may be a semiconductor memory.

[0030] Information that the storage device 13 illustrated in FIG. 3 stores will be described with reference to FIGS. 4 to 6. FIG. 4 is a conceptual diagram representing an example of the analysis condition list illustrated in FIG. 3. FIG. 5 is a conceptual diagram representing an example of a blowing condition related to an operating state of the air-conditioning apparatus of an analysis condition illustrated in FIG. 4. FIG. 6 is a conceptual diagram representing an example of a load condition of the analysis condition illustrated in FIG. 4.

[0031] In the analysis condition list 131, a plurality of analysis conditions including a combination of a blowing condition and a load condition are set. In the example illustrated in FIG. 4, a pattern name, an operation mode, a priority, a load condition, a blowing condition, and a pattern generation state are listed corresponding to an identifier of each of the analysis conditions. A pattern generation state represents whether or not pattern data has been generated in accordance with a result of an airflow analysis performed based on an analysis condition. The pattern data will be described in detail later.

[0032] As illustrated in FIG. 4, a priority is assigned to each analysis condition. In Embodiment 1, priorities are represented by positive integers. For example, 1 is assigned to a highest priority, and 10 is assigned to a lowest priority. As priorities, unique integers may be assigned to respective analysis conditions, or the same integer may be assigned to analysis conditions. For example, there may be a plurality of analysis conditions with the priority of 1, or there may be one analysis condition with the priority of 1.

[0033] Priorities to be assigned to respective analysis conditions are set, for example, in accordance with the air conditioning operating data 36. Of past operating states of the air-conditioning apparatus 2, as the frequency of occurrence of an operating state increases, a higher priority is assigned to an analysis condition corresponding to the operating state. The frequency of occurrence is calculated in accordance with track record data of an operating state stored by the storage device 13 in a predetermined period, such as a fixed period (three months), in the past. A specific example of the frequency of occurrence will be described.

[0034] For the sake of simplicity of explanation, assuming that a condition that significantly affects the frequency of occurrence of an operating state is a blowing condition, the frequency of occurrence is obtained, for example, as described below. In track record data, for variables of temperature, air volume, and air direction at the air outlet, the numbers of times coincidences with their respective set values occur are counted. Subsequently, among these numbers of times of occurrence, the numbers of times coincidences of these three variables with their respective set values occur are each the frequency of occurrence. In a case where the indoor unit 22 includes a plurality of air outlets, the frequency of occurrence is calculated for each air outlet.

[0035] In the blowing condition, conditions, such as the state of the compressor 51, and blowing air velocity and blowing air directions at the air outlet of the indoor unit 22, are set. The state of compressor 51 refers to an on-state or off-state. The blowing air directions are information including a horizontal air direction and a vertical air direction. In the blowing condition, blowing air volume and blowing air temperature may be included. The number of air outlets provided in the indoor unit 22 may be one or two or more.

[0036] Furthermore, a plurality of indoor units 22 may be installed in a room that is a common air-conditioned space. In a case where a plurality of air outlets are provided in the indoor unit 22, the blowing condition includes a combination of blowing conditions set for the respective air outlets. In a case where a plurality of indoor units 22 are installed in the room, the blowing condition includes a combination of blowing conditions set for air outlets of the respective indoor units 22.

[0037] The load condition is a condition related to the inflow of heat to the room and the outflow of heat from the room. In the load condition, for example, a boundary condition, a heat passage condition, and a heat generation condition are set. The boundary condition is a condition related to, from a boundary surface, such as a wall surface of the room where the air-conditioning apparatus 2 is installed, the inflow and outflow of heat generated, for example, due to a difference between temperatures inside and outside the room. The heat passage condition is a condition related to the inflow of heat to the room and outflow of heat from the room through openings, such as a window and a door. The heat generation condition is a condition related to the amount of heat generated in the room, for example, due to a human body and office automation equipment.

[0038] FIG. 6 is a table representing, as an example of a load condition, a condition related to the inflow of heat to the air-conditioned space and outflow of heat from the air-conditioned space. The load condition illustrated in FIG. 6 includes some parts of the boundary condition, the heat passage condition, and the heat generation condition. In the table of the load condition, values of a surface temperature of a wall, a surface temperature of a ceiling, and a surface temperature of a floor are set corresponding to an identifier of a load condition.

[0039] In FIG. 6, the surface temperature of the wall is represented by a wall temperature Tw, the surface temperature of the ceiling is represented by a ceiling temperature Tc, and the surface temperature of the floor is represented by a floor temperature Tf. In the case of a load condition H1, a wall temperature Tw = 15 °C, a ceiling temperature Tc = 25 °C, and a floor temperature Tf = 15 °C are set. In FIG. 6, for example, an expression of Tw = 15 °C may refer not only to the case where the wall temperature coincides with 15 °C, but also the case where the wall temperature falls within an acceptable range of $\pm \Delta T$ with respect to 15 °C as a central value. For example, ΔT is 2 °C.

[0040] FIG. 7 is a conceptual diagram of a case where priorities are managed by using a numerical range. In an example illustrated in FIG. 7, priorities are divided into two conditions of an essential condition and an additional condition and are set and managed. For each of the essential condition and the additional condition, a maximum priority and a minimum priority are set. For the essential condition, a priority range of analysis conditions for allowing airflow control to be started is set. Specifically, the essential condition represents that, when an airflow analysis is performed for analysis conditions ranging from an analysis condition to which the maximum priority is assigned to an analysis condition to which the minimum priority is assigned, airflow control can be started.

[0041] For the additional condition, a priority range of analysis conditions for which an airflow analysis is performed after airflow control is started is set. Specifically, the additional condition represents that, after airflow control is started, for analysis conditions ranging from an analysis condition to which the maximum priority is assigned to an analysis condition to which the minimum priority is assigned, an airflow analysis and accumulation of a result of the analysis can be performed in parallel with the airflow control.

[0042] In the example illustrated in FIG. 7, for the essential condition, an integer of 1 is set for the maximum priority, and an integer of 3 is set for the minimum priority. In this case, when an airflow analysis is completed for analysis conditions to which priorities greater than or equal to 1 and less than or equal to 3 are assigned, airflow control can be started. Furthermore, for the additional condition, an integer of 4 is set for the maximum priority, and an integer of 10 is set for the minimum priority. In this case, after airflow control is started, for analysis conditions to which priorities greater than or equal to 4 and less than or equal to 10 are assigned, an airflow analysis and accumulation of a result of the analysis can be performed in parallel with the airflow control. In the example illustrated in FIG. 7, for the essential condition, the maximum priority is 1 and the minimum priority is 3, but the minimum priority may be 1 that is the same as the maximum priority.

[0043] The apparatus and space information 132 is information necessary for generating the airflow analysis model 133 and includes space information and apparatus information. The space information is information on the air-conditioned space where the air-conditioning apparatus 2 is installed. For example, the space information is information on a room that is the air-conditioned space and includes the shape of the room, the arrangement of a window, a door, furniture and fixtures, and others, and thermal insulation performance representing thermal properties of a wall surface.

[0044] The apparatus information is information on the performance of the air-conditioning apparatus 2. For example, the apparatus information is information including the location of the air outlet of the air-conditioning apparatus 2, the capability and efficiency of the air-conditioning apparatus 2, and blowing air temperature, air volume, and air direction that are able to be set. Pieces of information described here is an example, and the apparatus and space information

132 is not limited to these pieces of information.

[0045] The airflow analysis model 133 is a model used, for example, for a Computational Fluid Dynamics (CFD) analysis method. The airflow analysis model 133 is generated in accordance with the apparatus and space information, and an analysis condition in the analysis condition list.

[0046] FIG. 8 is a conceptual diagram representing an example of the pattern data illustrated in FIG. 3. The pattern data is generated in accordance with a result of an airflow analysis and is data representing tendencies of distributions of environments, such as temperature and air velocity in the air-conditioned space. The pattern data 134 illustrated in FIG. 3 refers to information, such as a table in which a plurality of pieces of pattern data are recorded. A method of generating a pattern data illustrated in FIG. 8 will be described later.

[0047] The target condition 135 is a setting condition for a target of an environment created by an operation performed by the air-conditioning apparatus 2 for the air-conditioned space. For example, the target condition 135 refers to, for each of elements, such as temperature and air velocity, upper limit values and lower limit values of acceptable ranges that are to be satisfied by the air-conditioned space. The target condition 135 may be a setting condition for one element, or may be setting conditions for a plurality of elements. For example, the target condition 135 may be set for a blowing condition including a combination of a plurality of elements. Furthermore, as the target condition 135, a target value may be predetermined for each element, or the target condition 135 may be set by the user via a remote control (not illustrated).

[0048] Here, the difference between the target condition 135 and an analysis condition to which a high priority is assigned will be described. The target condition 135 is a setting condition for creating an ideal environment resulting from the air-conditioned space or an ideal environment considered comfortable by the user. On the other hand, an analysis condition to which a high priority is assigned is an analysis condition for performing an airflow analysis on a priority basis to perform airflow control necessary for creating an environment of the target condition 135 in response to a current environment of the air-conditioned space.

[0049] The air conditioning operating data 36 is, for example, a set value, such as a preset temperature, information on an operating state, such as air volume, a horizontal air direction, and a vertical air direction, and information used for air conditioning control, such as a room temperature, an outside temperature, a refrigerant temperature, and a refrigerant flow rate. The information used for air conditioning control is measured by the sensor 3 provided in the air-conditioning apparatus 2.

[0050] The sensor data 37 is data measured by the sensor 3, such as a temperature sensor, installed in the room. In a case where the sensor 3 is installed in the air-conditioning apparatus 2, the air conditioning operating data 36 may include the sensor data 37.

[0051] Next, a configuration of the arithmetic device 14 illustrated in FIG. 3 will be described. The arithmetic device 14 includes a model generation unit 141, an airflow analysis unit 142 that performs an airflow analysis for each analysis condition, a pattern generation unit 143 that generates pattern data from an analysis result, and an airflow control unit 144 that controls the airflow of the air-conditioning apparatus 2 in accordance with pattern data or an analysis result.

[0052] The model generation unit 141 generates a model used for an airflow analysis. First, the model generation unit 141 generates, in accordance with the apparatus and space information, shape data in which a room shape, the arrangement of a window and furniture and fixtures, the location of the air outlet of the air-conditioning apparatus 2 are specified, and performs a process of dividing an area to be analyzed into a plurality of small spaces.

[0053] Furthermore, the model generation unit 141 sets, in accordance with an analysis condition, a condition related to the inflow of heat to the area to be analyzed and outflow of heat from the area to be analyzed through a wall surface, a condition for heat generation such as human body heat generation, office automation equipment heat generation or the like taking into consideration the locations of the furniture and fixtures, a suction condition including inflow air temperature and three-dimensional inflow air velocity at the location of an air inlet, and a blowing condition including, for example, outflow air volume at the air outlet.

[0054] The airflow analysis unit 142 performs a calculation for the airflow analysis model, for example, by using the CFD analysis method to obtain distributions of temperature and air velocity in the room that is an air-conditioned space. For example, the airflow analysis unit 142 divides the air-conditioned space into a large number of extremely small areas and calculates a temperature and an air velocity in each extremely small area by using the airflow analysis model.

[0055] Governing equations of a fluid used in a CFD analysis are, for example, as follows.

[Math. 1]

$$\nabla \cdot u = 0 \quad \cdots \quad (1)$$

[Math. 2]

$$\rho\left(\frac{\partial u}{\partial t}+(u\cdot\nabla u)\right)=-\nabla p+\nabla\cdot(\mu\nabla u)+(\rho-\rho_0)g \quad \cdot\cdot\cdot \quad (2)$$

[Math. 3]

$$C_p\left(\frac{\partial T}{\partial t}+u\cdot\nabla T\right)=\nabla\cdot(k\nabla T)+Q \quad \cdot\cdot\cdot \quad (3)$$

[0056] Here, u denotes three-dimensional velocity vector, t denotes time, p denotes pressure, ρ denotes density, μ denotes viscosity coefficient, ρ_0 denotes reference density, g denotes gravitational acceleration, C_p denotes specific heat at constant pressure, T denotes temperature, k denotes thermal conductivity, and Q denotes the amount of internal heat generation.

[0057] Equation (1) is a continuity equation representing conservation of mass of a fluid. Equation (2) is an incompressible Navier-stokes equation representing conservation of momentum. Equation (3) is an energy equation. The airflow analysis unit 142 solves these Equations (1) to (3) with an appropriate initial value and under the boundary condition to thereby calculate, for example, a temperature and an air velocity in each divided area. In this case, the air conditioning operating data 36 of the air-conditioning apparatus 2 and the sensor data 37 are used as an initial value and a boundary condition value in an airflow analysis.

[0058] Analysis conditions included in the airflow analysis model have priorities, and the airflow analysis unit 142 performs an airflow analysis for the analysis conditions in order of priority. After an airflow analysis for an analysis condition to which a predetermined priority is assigned is completed, a state is entered in which airflow control can be started. Subsequently, airflow control is executed by the airflow control unit 144 at fixed time intervals (for example, an interval of five minutes). Meanwhile, the airflow analysis unit 142 may temporarily stop a calculation for an analysis condition for which an airflow analysis has not been performed, or may continue a calculation by using parallel processing.

[0059] For example, of past operating states of the air-conditioning apparatus 2, when a high priority is assigned to an analysis condition corresponding to an operating state whose frequency of occurrence is high, the airflow control unit 144 can start, for an operating state with a good operation track record, airflow control using an airflow analysis at an early stage. In this case, of operating states with operation track records in the past, the air-conditioning apparatus 2 is enabled to start the most efficient operation early. On the other hand, for an operating state with a poor operation track record, the airflow analysis unit 142 continuously performs an airflow analysis even after airflow control is started, and thus an analysis result based on an analysis condition corresponding to the operating state with a poor operation track record is accumulated. Subsequently, the airflow control unit 144 enables the operating state with a poor operation track record to be also included in options for airflow control.

[0060] The pattern generation unit 143 performs statistical processing on an airflow analysis result and thus generates pattern data representing, with variables fewer in number than the airflow analysis result, a tendency of a distribution of an environment in the air-conditioned space. The storage device 13 stores the generated pattern data, and thus storage data capacity can be reduced in comparison with a case where storage is performed in the form of an airflow analysis result. FIG. 8 illustrates an example of pattern data. As an example of a variable, the case of temperature will be described. The pattern generation unit 143 generates pattern data as described below.

[0061] First, the pattern generation unit 143 divides a room that is an air-conditioned space into a plurality of small areas, and extracts, of measurement values of temperature in the respective small areas, a measurement value of temperature in an area where a resident may exist. The area where a resident may exist is, for example, an area from the floor surface up to a height of 1.1 m. Next, the pattern generation unit 143 sets a plurality of temperature ranges in accordance with, of temperature, a upper limit value and a lower limit value that are predetermined, and the number of divisions of a range of temperature. Then, the pattern generation unit 143 projects a small area included in each temperature range onto a plane in parallel to the floor surface and generates pattern data representing a temperature distribution so that the total of the percentages of areas in the plane onto which projection has been made reaches 100 %.

[0062] Taking FIG. 8 as an example, a description will be given. When the lower and upper limits of the range of temperature are 20 °C and 30 °C and the unit of division of temperature is 1 °C, the range of temperature is set into 10 divisions including a first division greater than or equal to 20 °C and less than 21 °C, a second division greater than or equal to 21 °C and less than 22 °C, ···, and a tenth division greater than or equal to 29 °C and less than 30 °C. When the range of temperature is divided into 10 divisions, pattern data represents an occurrence rate (%) representing what percentage of the area where a resident may exist small areas belonging to each temperature range account for.

[0063] Referring to FIG. 8, pattern data will be described that differs according to patterns. For pattern data with a pattern name of pattern001, an occurrence rate in the fifth division is 44.43 %, and an occurrence rate in the seventh division is 9.7 %. On the other hand, for pattern data with a pattern name of pattern002, an occurrence rate in the fifth division is 5.26 %, and an occurrence rate in the seventh division is 40.16 %. It can be seen that a room temperature of a pattern with the pattern name of pattern002 is higher than that of a pattern with the pattern name of pattern 001.

[0064] The method of generating pattern data described with reference to FIG. 8 is an example, and another method may be used. Furthermore, a variable is not limited to the case of temperature. Even in cases where variables are other elements, such as air velocity, humidity, and comfort index, the pattern generation unit 143 can generate pattern data as in the case where a variable is temperature.

[0065] The number of variables is not limited to one and may be two or more. Pattern data is represented by a frequency distribution based on any one or more of temperature, humidity, air velocity, and comfort index in the room in an analysis result. A result from an airflow analysis is replaced with pattern data to compress the data size of the analysis result, enabling a reduction in the storage capacity of the storage device 13.

[0066] The airflow control unit 144 includes an airflow control feasibility determination unit 41, an operating state decision unit 42, and a control command conversion unit 43. The airflow control feasibility determination unit 41 determines, in accordance with a generation state of pattern data provided by the pattern generation unit 143, whether or not airflow control can be started. Pattern data is generated corresponding to an analysis condition to which a priority is assigned. When generation of all pieces of pattern data corresponding to analysis conditions for which higher priorities are set has been completed, the airflow control feasibility determination unit 41 determines that airflow control can be started.

[0067] When the airflow control feasibility determination unit 41 determines that airflow control can be started, the operating state decision unit 42 selects, in accordance with the measurement data 136, pattern data that achieves an environment closest to a target condition from among a plurality of pieces of pattern data that have been generated, and decides on an operating state.

[0068] The control command conversion unit 43 converts the operating state decided on by the operating state decision unit 42 into a control command to actually give an instruction to the air-conditioning apparatus 2. Subsequently, the control command conversion unit 43 transmits the control command to the air-conditioning apparatus 2.

[0069] Incidentally, in Embodiment 1, a case is described where, in determining whether or not airflow control can be started, the airflow control feasibility determination unit 41 makes a determination in accordance with a generation state of pattern data. However, a determination may be made in accordance with a generation state of an analysis result provided by the airflow analysis unit 142.

[0070] Furthermore, as a method of setting a priority, a method using the frequency of occurrence of an operating state in a fixed period has been described, but the method is not limited to this method. From among a plurality of operating states, a high-priority operating state may be selected by the user. Furthermore, high-priority operating states may be randomly set, such as that a high-priority operating state is preset at regular intervals for a range in which the operation of the air-conditioning apparatus 2 is possible.

[0071] Furthermore, an example of another method of setting a priority will be described. For example, it is conceivable that a range of selectable operating states of the air-conditioning apparatus 2 is divided into a plurality of ranges in advance, that a high priority is assigned to one typical operating state in each divided range, and that a relatively lower priority than the priority of the typical operating state is assigned to other operating states. In this case, an optimum operating state can be decided on from typical conditions early, and the range of selectable operating states can be gradually expanded to other conditions.

[0072] An example of a range of selectable operating states will be described. Here, a case will be described where an operating state is a vertical air direction at the air outlet of the indoor unit 22. Assume that a gravitational direction is at an angle of 0°, that a horizontal direction is at an angle of 90°, that a range of selectable vertical air directions is from the angle of 0 to 90°, and that vertical air directions can be set in one-degree increments. In this case, the range of selectable operating states is divided into three divisions.

[0073] The three divisions are a first division greater than or equal to 0° and less than 30°, a second division greater than or equal to 30° and less than 60°, and a third division greater than or equal to 60° and less than or equal to 90°. In the first division, a high priority is assigned to an angle of 15° as a representative value, and a relatively lower priority than the priority of the representative value is assigned to other angles. In the second division, a high priority is assigned to an angle of 45° as a representative value, and a relatively lower priority than the priority of the representative value is assigned to other angles. In the third division, a high priority is assigned to an angle of 75° as a representative value, and a relatively lower priority than the priority of the representative value is assigned to other angles.

[0074] In this example, the airflow analysis unit 142 performs an airflow analysis for analysis conditions of angles of vertical air directions of 15°, 45°, and 75° on a priority basis. Subsequently, the airflow analysis unit 142 performs an airflow analysis for analysis conditions of angles of vertical air directions other than the angles of 15°, 45°, and 75°. At a stage at which an airflow analysis for a typical operating state is completed in each divided range, airflow control can be started, and the most efficient operation of typical operating states can be performed.

[0075] Here, an example of hardware of the arithmetic device 14 of the air conditioning control device 1 illustrated in

FIG. 3 will be described. FIG. 9 is a hardware configuration diagram illustrating an example of a configuration of the arithmetic device illustrated in FIG. 3. In a case where various functions of the arithmetic device 14 are executed by hardware, the arithmetic device 14 illustrated in FIG. 3 is constituted by a processing circuit 80 as illustrated in FIG. 9. Functions of the model generation unit 141, the airflow analysis unit 142, the pattern generation unit 143, and the airflow control unit 144 that are illustrated in FIG. 3 are implemented by the processing circuit 80.

[0076] In a case where each function is executed by hardware, the processing circuit 80 corresponds to, for example, a single circuit, a complex circuit, a programmed processor, a parallel programmed processor, an Application Specific Integrated Circuit (ASIC), a Field-Programmable Gate Array (FPGA), or a combination of these. Functions of units that are the model generation unit 141, the airflow analysis unit 142, the pattern generation unit 143, and the airflow control unit 144 may be implemented by respective processing circuits 80. Alternatively, the functions of the units that are the model generation unit 141, the airflow analysis unit 142, the pattern generation unit 143, and the airflow control unit 144 may be implemented by one processing circuit 80.

[0077] Furthermore, an example of other hardware of the arithmetic device 14 illustrated in FIG. 3 will be described. FIG. 10 is a hardware configuration diagram illustrating another example of the configuration of the arithmetic device illustrated in FIG. 3. In a case where various functions of the arithmetic device 14 are executed by software, the arithmetic device 14 illustrated in FIG. 3 is constituted by a processor 81, such as a Central Processing Unit (CPU), and a memory 82 as illustrated in FIG. 10. Functions of the model generation unit 141, the airflow analysis unit 142, the pattern generation unit 143, and the airflow control unit 144 are implemented by the processor 81 and the memory 82. FIG. 10 illustrates that the processor 81 and the memory 82 are connected to each other via a bus 83 in such a manner that they can communicate with each other.

[0078] In a case where each function is executed by software, the functions of the model generation unit 141, the airflow analysis unit 142, the pattern generation unit 143, and the airflow control unit 144 are implemented by software, firmware, or a combination of software and firmware. Software and firmware are written as programs and stored in the memory 82. The processor 81 reads out a program stored in the memory 82 and executes the program to thereby implement a function of each unit.

[0079] As the memory 82, for example, non-volatile semiconductor memories, such as a Read Only Memory (ROM), a flash memory, an Erasable and Programmable ROM (EPROM), and an Electrically Erasable and Programmable ROM (EEPROM), are used. Furthermore, as the memory 82, a volatile semiconductor memory, such as a Random Access Memory (RAM), may be used. Additionally, as the memory 82, detachable recording media, such as a magnetic disk, a flexible disk, an optical disc, a Compact Disc (CD), a Mini Disc (MD), and a Digital Versatile Disc (DVD), may be used.

[0080] Next, the operation of the air conditioning control device 1 according to Embodiment 1 will be described. FIG. 11 is a flowchart illustrating an example of an operation procedure performed by the air conditioning control device according to Embodiment 1. A trigger for the start of a process flow illustrated in FIG. 11 is, for example, reception, by the air conditioning control device 1, of an operation start notification signal representing that an operation has been started from the air-conditioning apparatus 2. In this case, the controller 23 of the air-conditioning apparatus 2 transmits the operation start notification signal to the air conditioning control device 1 when the operation is started.

[0081] In step ST11, the airflow control feasibility determination unit 41 determines whether or not airflow control can be started. For example, the airflow control feasibility determination unit 41 determines whether or not generation of pattern data has been completed by the pattern generation unit 143 by using a result of an airflow analysis based on an analysis condition to which a higher priority than a predetermined priority is assigned. As a result of the determination made in step ST11, when generation of pattern data corresponding to a high-priority analysis condition has been completed, the airflow control feasibility determination unit 41 determines that airflow control can be started and proceeds to step ST12. On the other hand, as a result of the determination made in step ST11, when generation of pattern data corresponding to a high-priority analysis condition has not been completed, the airflow control feasibility determination unit 41 returns to step ST11.

[0082] In step ST12, the airflow control unit 144 determines whether or not the timing of an airflow control execution period is right. When the airflow control unit 144 determines that the timing of the airflow control execution period is right, the airflow control unit 144 proceeds to step ST13. When the airflow control unit 144 determines that the timing of the airflow control execution period is not right, the airflow control unit 144 returns to step ST12. The airflow control execution period is, for example, a fixed period, such as an interval of five minutes.

[0083] When the airflow control unit 144 proceeds to a process of step ST13 to execute airflow control, the airflow analysis unit 142 continuously performs an airflow analysis for the other analysis conditions in order of priority from highest to lowest. When an airflow analysis is performed in parallel with airflow control, a result of an airflow analysis for an analysis condition for which a relatively low priority is set is also accumulated in the storage device 13 with the passage of time. A result of an airflow analysis based on a low-priority analysis condition can also be used early, and airflow control can be performed with higher accuracy.

[0084] In step ST13, the airflow control unit 144 acquires the air conditioning operating data 36 and the sensor data 37 from the storage device 13. The data acquired here is not limited to current data that is data acquired from the air-conditioning apparatus 2 and the sensor 3 at a time closest to the current time. The data acquired from the storage device 13 may be past data composed of the air conditioning operating data 36 and the sensor data 37 that were stored in the storage device 13 in the past.

[0085] In step ST14, the airflow control unit 144 selects, from among pieces of pattern data that have been generated by the pattern generation unit 143, a pattern that achieves a state closest to a predetermined target value. In step ST15, the operating state decision unit 42 decides on an operating state of the air-conditioning apparatus 2 with reference to a blowing condition of the air-conditioning apparatus 2 corresponding to the pattern selected in step ST14. In step ST16, the control command conversion unit 43 converts the operating state decided on in step ST15 into a control command to actually give an instruction to the air-conditioning apparatus 2, and transmits the control command to the air-conditioning apparatus 2.

[0086] In step ST17, the airflow control unit 144 determines whether or not an end condition has been met. When the end condition has been met, the airflow control unit 144 ends the process flow. On the other hand, as a result of the determination made in step ST17, when the end condition has not been met, the airflow control unit 144 returns to step ST12. The end condition is, for example, the stopping of the air-conditioning apparatus 2.

[0087] In this case, when an instruction to stop the operation of the air-conditioning apparatus 2 is input by the user or administrator, the controller 23 of the air-conditioning apparatus 2 stops the operation of the air-conditioning apparatus 2 and also transmits, to the air conditioning control device 1, a stop notification signal representing that the operation of the air-conditioning apparatus 2 has been stopped. The end condition may be not only the stopping of the air-conditioning apparatus 2, but also that a predetermined time period has been reached since the operation of the air-conditioning apparatus 2 was started. The predetermined time period is a time period taken for the operation of the air-conditioning apparatus 2 to enter into a stable state.

[0088] Next, operations performed by the airflow analysis unit 142, the pattern generation unit 143, and the airflow control unit 144 in step ST11 illustrated in FIG. 11 will be described with reference to FIG. 12. FIG. 12 is a flowchart illustrating an example of an operation procedure performed in step ST11 illustrated in FIG. 11. Here, a priority assigned to an analysis condition is expressed as an integer k. Furthermore, of priorities k ranked in a plurality of levels, the highest priority is 1. Here, k = 1 corresponds to the maximum priority of the essential condition illustrated in FIG. 7. Of the priorities k ranked in the plurality of levels, the minimum priority of the essential condition illustrated in FIG. 7 is kL.

[0089] When 1 representing the highest priority is set for a priority k of an analysis condition to be read out (step ST31), the airflow analysis unit 142 reads out the analysis condition to which the priority k = 1 is assigned from the storage device 13 and performs an airflow analysis (step ST32). Subsequently, the pattern generation unit 143 generates pattern data from an analysis result (step ST33).

[0090] Furthermore, the pattern generation unit 143 stores the generated pattern data in the storage device 13 (step ST34). The airflow control feasibility determination unit 41 determines whether or not the priority k coincides with the minimum priority kL (step ST35). As a result of the determination made in step ST35, when the priority k does not coincide with the minimum priority kL, the airflow control feasibility determination unit 41 sets, for a new priority k, a value obtained by adding 1 to the current priority k (step ST36), and returns to step ST32.

[0091] On the other hand, as a result of the determination made in step ST35, when the priority k coincides with the minimum priority kL, the airflow control feasibility determination unit 41 determines that airflow control can be executed (step ST37). Incidentally, in a case where there are two or more analysis conditions to which the same priority k is assigned, after steps ST32 to ST34 are performed for each of the two or more analysis conditions, the airflow control unit 144 proceeds to step ST35.

[0092] In this way, a high-priority airflow analysis is performed on a priority basis, and thus air conditioning control can be started at an early stage at which an airflow analysis for an analysis condition including a primary blowing condition is completed.

[0093] Next, the operation of the operating state decision unit 42 in step ST15 illustrated in FIG. 11 will be described. FIG. 13 is a flowchart illustrating an example of an operation procedure performed in step ST15 illustrated in FIG. 11. A pattern selection process performed by the operating state decision unit 42 will be described with reference to FIG. 13.

[0094] Here, for convenience of explanation, a case will be described where the following configuration and conditions are used. The air-conditioning apparatus 2 includes one indoor unit 22, and the number of air outlets provided in the indoor unit 22 is one. In the measurement data 136, the air conditioning operating data 36 includes data on an on-state or off-state of the air-conditioning apparatus 2, an operation mode representing a cooling operation or a heating operation, a preset temperature, a blowing air velocity, a vertical air direction, and a horizontal air direction. The sensor 3 is an infrared sensor, and the sensor data 37 includes data on a wall surface temperature, a ceiling surface temperature, and a floor surface temperature that are acquired from a thermal image provided by the infrared sensor.

[0095] Furthermore, of an analysis condition, a load condition includes a wall surface temperature, a ceiling surface temperature, and a floor surface temperature, and a blowing condition includes, at one air outlet provided in the indoor unit 22, a blowing air temperature, and vertical and horizontal directions of the airflow. Objects to be calculated through an airflow analysis are temperature and air velocity. As a target condition, upper limit values and lower limit values are set for air velocity and temperature in a plane at a predetermined height in a room that is an air-conditioned space.

[0096] In step ST21, the operating state decision unit 42 selects a current state pattern that is a pattern closely analogous to a current operating state as described below. The operating state decision unit 42 acquires, from the air conditioning operating data 36, an on-state or off-state of the air-conditioning apparatus 2, an operation mode, a blowing air velocity, a vertical air direction, and a horizontal air direction and selects a blowing condition that coincides with the acquired operating state of the air-conditioning apparatus 2 from among blowing conditions in analysis conditions.

[0097] Next, the operating state decision unit 42 acquires, from the sensor data 37, a wall surface temperature, a ceiling surface temperature, and a floor surface temperature and obtains, by subtracting the acquired floor surface temperature from the acquired ceiling surface temperature, a vertical temperature difference that is a temperature difference between the ceiling surface temperature and the floor surface temperature.

[0098] Furthermore, for load conditions in the analysis conditions as well, the operating state decision unit 42 obtains a vertical temperature difference by subtracting a floor temperature from a ceiling temperature and compares this vertical temperature difference and a wall temperature with respective values acquired from the sensor data 37 to decide on a closest load condition. Here, pattern data corresponding to an analysis condition including the blowing condition and the load condition that have been decided on is uniquely decided on. The operating state decision unit 42 regards the uniquely decided pattern data as a current state pattern that is a current indoor environment estimate.

[0099] In step ST22, the operating state decision unit 42 extracts, as described below, a candidate pattern that is a pattern serving as a candidate for an indoor environment estimate for a case where the blowing air velocity, the vertical air direction, and the horizontal air direction are changed from the current state pattern. The operating state decision unit 42 selects, with reference to the air conditioning operating data 36, a plurality of blowing conditions that coincide with one another in terms of the on-state or off-state of the air-conditioning apparatus 2 and the operation mode and that differ from one another in terms of the blowing air velocity, the vertical air direction, and the horizontal air direction.

[0100] Subsequently, the operating state decision unit 42 extracts, from the analysis condition list, a plurality of analysis conditions including a blowing condition that is the same as any blowing condition of the selected plurality of blowing conditions, and a load condition that is the same as the load condition decided on in step ST21. The operating state decision unit 42 regards a pattern corresponding to an extracted analysis condition as a candidate pattern. In some cases, one candidate pattern is extracted, or a plurality of candidate patterns are extracted.

[0101] In step ST23, the operating state decision unit 42 calculates an evaluation value for each of the current state pattern decided on in step ST21 and the candidate pattern decided on in step ST22. Here, an example of an evaluation value will be described. For variables of temperature and air velocity in pattern data, the respective percentages of areas included in a predetermined temperature range are calculated, and a value obtained by multiplying the percentages for the respective variables by a weighting factor and summing them up is regarded as an evaluation value.

[0102] A plurality of weighting factors are predetermined. In this case, the operating state decision unit 42 may determine whether the operating state of the air-conditioning apparatus 2 is a transient state or has reached a stable state to change, in response to the operating state, a weighting factor to be used. The transient state is a state in which the air-conditioning apparatus 2 is in a non-steady process, for example, immediately after the air-conditioning apparatus 2 is started. A determination of the operating state of the air-conditioning apparatus 2 is made, for example, in accordance with whether or not a time period that has elapsed since the air-conditioning apparatus 2 was started is greater than or equal to a predetermined threshold time period.

[0103] When the time period that has elapsed since the air-conditioning apparatus 2 was started is less than the threshold time period, the operating state decision unit 42 determines that the operating state of the air-conditioning apparatus 2 is the transient state. When the time period that has elapsed since the air-conditioning apparatus 2 was started is greater than or equal to the threshold time period, the operating state decision unit 42 determines that the operating state of the air-conditioning apparatus 2 is the stable state. When the weighting factor is changed in response to the operating state, immediately after the air-conditioning apparatus 2 is started, a higher priority is given to the rate at which a target value is reached, and, after the air-conditioning apparatus 2 is stabilized, a higher priority is given to comfort. Thus, airflow control responsive to the state of the air-conditioning apparatus 2 can be performed.

[0104] A determination of the operating state of the air-conditioning apparatus 2 is not limited to the above-described determination method. The operating state decision unit 42 may acquire information on an intake-air temperature and a preset temperature from the air-conditioning apparatus 2 and compare a temperature difference between the intake-air temperature and the preset temperature with a threshold temperature to determine the operating state of the air-conditioning apparatus 2.

[0105] When the temperature difference between the intake-air temperature and the preset temperature is greater than or equal to the threshold temperature, the operating state decision unit 42 determines that the operating state of the air-conditioning apparatus 2 is the transient state. When the temperature difference between the intake-air temperature and the preset temperature is less than the threshold temperature, the operating state decision unit 42 determines that the operating state of the air-conditioning apparatus 2 is the stable state.

[0106] Furthermore, the above-described method of calculating an evaluation value is an example, and an evaluation value may be calculated by using another calculation method. Furthermore, an object to be evaluated is not limited to temperature and may be air velocity or may be an element other than temperature and air velocity. For example, assuming that an object to be evaluated is a pattern, for example, of vertical temperature differences at a plurality of positions in the room obtained from an airflow analysis result, a calculated value for the pattern is stored in the storage device 13, and this calculated value may be regarded as an evaluation value.

[0107] Furthermore, in some cases, an analysis result of an airflow analysis, or pattern data completely coincides with an actual condition, but an error can sometimes be included. Thus, the operating state decision unit 42 may correct the analysis result or pattern data by using a measurement value or values of one or both of the air conditioning operating data and the sensor data and may use the corrected analysis result or pattern data. For example, a sensor 3 is provided that measures an intake-air temperature, which is a temperature of air sucked into the air inlet of the air-conditioning apparatus 2, and the operating state decision unit 42 acquires information on a measurement value from the sensor 3 provided at the air inlet.

[0108] Subsequently, the operating state decision unit 42 acquires, from an analysis result or pattern data, information on temperature corresponding to the intake-air temperature and corrects the analysis result or pattern data by using a difference value between the temperature acquired from the analysis result or pattern data and the measurement value. When the analysis result or pattern data is corrected, this correction is reflected in airflow control to be actually executed inside the room, and the temperature in the room is corrected. Thus, an error caused by a difference between an analysis condition and an actual condition is corrected, and airflow control can be performed with high accuracy.

[0109] In step ST24, the operating state decision unit 42 decides on an operating state of the air-conditioning apparatus 2 as described below. When all of evaluation values of a plurality of candidate patterns calculated in step ST23 are below the evaluation value of the current state pattern, the operating state decision unit 42 does not change the operating state. When there is a candidate pattern whose evaluation value is higher than the evaluation value of the current state pattern, the operating state decision unit 42 decides on, as a target value of the operating state of the air-conditioning apparatus 2, an operating state of the air-conditioning apparatus 2 corresponding to a blowing condition corresponding to the candidate pattern.

[0110] When there is a plurality of candidate patterns whose evaluation values are higher than the evaluation value of the current state pattern, the operating state decision unit 42 selects a candidate pattern whose evaluation value is the highest and decides on, as a target value of the operating state of the air-conditioning apparatus 2, an operating state of the air-conditioning apparatus 2 corresponding to a blowing condition corresponding to the selected candidate pattern.

[0111] In this way, the air conditioning control device 1 accumulates, as pattern data, a result obtained by performing an airflow analysis for the airflow analysis model generated in accordance with the apparatus and space information and the analysis condition list. Furthermore, in performing airflow control, the air conditioning control device 1 selects, in accordance with the measurement data, a pattern that meets a target condition from among pieces of pattern data to execute airflow control.

[0112] Priorities are assigned to respective analysis conditions in the analysis condition list, and the air conditioning control device 1 performs an airflow analysis for the analysis conditions in order of priority from highest to lowest and thus can start airflow control at an early stage at which an airflow analysis for a high-priority condition is completed. Furthermore, when the air conditioning control device 1 continuously performs an airflow analysis for a low-priority analysis condition after airflow control is started, various pieces of pattern data are gradually accumulated, and thus the accuracy of airflow control can be improved.

[0113] Incidentally, in Embodiment 1, the model generation unit 141 may perform machine learning by using the measurement data 136 accumulated in the storage device 13 to update the airflow analysis model 133 so that the airflow analysis model 133 matches an air-conditioned space. Thus, the accuracy of airflow analysis is further improved.

[0114] The air conditioning control device 1 according to Embodiment 1 includes the storage device 13 that stores a plurality of analysis conditions to which respective priorities are assigned, and a result of an airflow analysis for each of the analysis conditions, and the arithmetic device 14 that controls the air-conditioning apparatus 2. The arithmetic device 14 includes the airflow analysis unit 142, the airflow control feasibility determination unit 41, and the operating state decision unit 42. The airflow analysis unit 142 performs the airflow analysis for the plurality of analysis conditions in order of priority from highest to lowest.

[0115] The airflow control feasibility determination unit 41 determines, in accordance with a generation state of an analysis result provided by the airflow analysis unit 142, whether or not airflow control can be started for the air-conditioning apparatus 2. When the airflow control feasibility determination unit 41 determines that the airflow control can be started, the operating state decision unit 42 decides on an operating state of the air-conditioning apparatus 2 in accordance with an analysis result provided by the airflow analysis unit 142.

[0116] In Embodiment 1, priorities are assigned to a respective plurality of analysis conditions, an airflow analysis is performed for the analysis conditions in order of priority from highest to lowest, and thus airflow control can be started at an early stage at which an airflow analysis for a high-priority analysis condition is completed. Appropriate airflow control is performed early after the air-conditioning apparatus 2 is started, thus making it possible to provide a comfortable environment to the user early. Airflow control appropriate to an air-conditioned space is performed earlier, thus keeping the operating frequency of the compressor 51 from being wastefully changed to enable energy savings to be achieved.

[0117] In the related art, in a case where the number of analysis conditions for which an analysis is to be performed is large, it is conceivable that the number of analysis conditions is reduced to reduce the period of time of airflow analysis, and that analysis conditions that are lacking are compensated for by using a method, such as interpolation processing. In some methods of reducing the number of analysis conditions, however, an analysis condition corresponding to an operating state that is used very often is deleted, and the deleted analysis condition is compensated for by interpolation processing. In this case, the accuracy of airflow analysis is likely to deteriorate.

[0118] On the other hand, for a plurality of analysis conditions, the air conditioning control device 1 according to Embodiment 1 does not reduce the number of analysis conditions but performs an airflow analysis for a high-priority analysis condition on a priority basis and starts airflow control in accordance with an analysis result. Since an airflow analysis for a high-priority analysis condition is performed, the accuracy of airflow analysis is kept from being impaired.

[0119] Furthermore, in Embodiment 1, after airflow control is started, the airflow analysis unit 142 performs an airflow analysis for a low-priority analysis condition in parallel with the airflow control, and thus many analysis results are accumulated in the storage device 13 with the passage of time. Thus, the air conditioning control device 1 can perform finely-tuned airflow control for the user with high accuracy by using analysis results for many analysis conditions accumulated in the storage device 13.

[0120] Additionally, in Embodiment 1, instead of storing and managing a result of an airflow analysis without doing anything to the result, the storage device 13 stores and manages pattern data representing a distribution of an environment in the air-conditioned space. Thus, data size of an analysis result is compressed, enabling a reduction in the storage capacity of the storage device 13. Even in a case where there are many analysis conditions, the necessary storage capacity can be reduced. As a result, in Embodiment 1, calculation loads and the storage capacity are reduced, and airflow control taking into account a distribution of a thermal environment in the air-conditioned space can be started early.

List of Reference Signst

[0121]

1: air conditioning control device,
2: air-conditioning apparatus,
3, 3-1 to 3-n: sensor,
4: network,
11: reception device,
12: transmission device,
13: storage device,
14: arithmetic device,
21: outdoor unit,
22: indoor unit,
23: controller,
36: air conditioning operating data,
37: sensor data,
41: airflow control feasibility determination unit,
42: operating state decision unit,
43: control command conversion unit,
50: refrigerant circuit,
51: compressor,
52: four-way valve,
53: heat source side heat exchanger,
54: expansion device,
55: load side heat exchanger,
56: refrigerant pipe,
57: outdoor fan,
58: indoor fan,
59: air direction adjustment unit,
61: horizontal flap,
62: vertical flap,
80: processing circuit,

81: processor,
82: memory,
83: bus,
131: analysis condition list,
132: apparatus and space information,
133: airflow analysis model,
134: pattern data,
135: target condition,
136: measurement data,
141: model generation unit,
142: airflow analysis unit,
143: pattern generation unit,
144: airflow control unit

Claims

1. An air conditioning control device comprising:

a storage device configured to store a plurality of analysis conditions to which respective priorities are assigned, and a result of an airflow analysis for each of the analysis conditions; and
an arithmetic device configured to control an air-conditioning apparatus,
wherein the arithmetic device includes
an airflow analysis unit configured to perform the airflow analysis for the plurality of analysis conditions in order of priority from highest to lowest,
an airflow control feasibility determination unit configured to determine, in accordance with a generation state of an analysis result provided by the airflow analysis unit, whether or not airflow control can be started for the air-conditioning apparatus, and
an operating state decision unit configured to, when the airflow control feasibility determination unit determines that the airflow control can be started, decide on an operating state of the air-conditioning apparatus in accordance with an analysis result provided by the airflow analysis unit.

2. The air conditioning control device of claim 1, wherein, when the airflow analysis for, of the plurality of analysis conditions, an analysis condition to which a predetermined priority is assigned is completed, the airflow control feasibility determination unit is configured to determine that the airflow control can be started.

3. The air conditioning control device of claim 1 or 2,

wherein the storage device is configured to store operating data representing an operating state of the air-conditioning apparatus, and
wherein, for priorities to be assigned to the analysis conditions, of past operating states of the air-conditioning apparatus, as a frequency of occurrence of an operating state increases, a priority to be assigned to an analysis condition corresponding to the operating state is set higher.

4. The air conditioning control device of claim 1 or 2, wherein, for priorities to be assigned to the analysis conditions, when an operating state of the air-conditioning apparatus is a blowing condition, the blowing condition is divided into a plurality of ranges, a highest priority is set for a typical blowing condition in each divided range.

5. The air conditioning control device of any one of claims 1 to 4, wherein, after the airflow control feasibility determination unit determines that airflow control can be started, the airflow analysis unit is configured to continuously perform airflow analyses based on the analysis conditions in the order of priority.

6. The air conditioning control device of any one of claims 1 to 5,

wherein the storage device is configured to store operating data representing an operating state of the air-

conditioning apparatus, and sensor data, which is a measurement value of a sensor configured to measure at least an environment in an air-conditioned space, and
wherein, when deciding on, as an operating state of the air-conditioning apparatus, a blowing condition closest to a predetermined target condition in accordance with the analysis result, the operating state decision unit is configured to correct the analysis result by using one or both of a current operating state of the air-conditioning apparatus and the sensor data.

7. The air conditioning control device of any one of claims 1 to 5,
wherein, when deciding on, as an operating state of the air-conditioning apparatus, a blowing condition closest to a predetermined target condition in accordance with the analysis result, the operating state decision unit is configured to calculate an evaluation value of the blowing condition by using a factor that differs according to whether an operating state of the air-conditioning apparatus is a transient state or a stable state and is configured to decide on, as a current operating state of the air-conditioning apparatus, a blowing condition whose calculated evaluation value is highest. 1

8. The air conditioning control device of any one of claims 1 to 7,

wherein the arithmetic device includes a pattern generation unit configured to generate, from an analysis result provided by the airflow analysis unit, pattern data representing, with variables fewer in number than the analysis result, a tendency of a distribution of an environment in an air-conditioned space, and
wherein the operating state decision unit is configured to decide on an operating state of the air-conditioning apparatus in accordance with the pattern data generated by the pattern generation unit.

9. The air conditioning control device of claim 8,
wherein the pattern data is represented by a frequency distribution based on any one or more of temperature, humidity, air velocity, and comfort index in the air-conditioned space in the analysis result.

10. The air conditioning control device of claim 8 or 9,
wherein the airflow control feasibility determination unit is configured to determine, in accordance with a generation state of the pattern data provided by the pattern generation unit, whether or not airflow control can be started.

FIG. 1

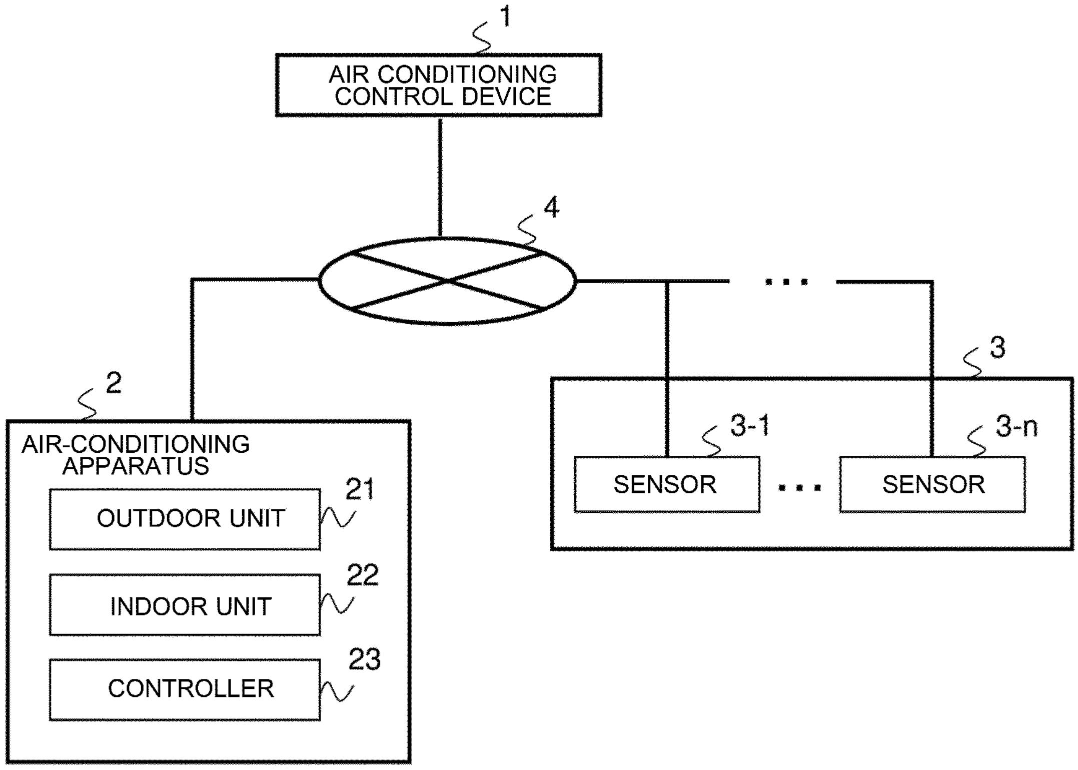

1
AIR CONDITIONING CONTROL DEVICE
4
3
2
AIR-CONDITIONING APPARATUS
OUTDOOR UNIT
21
INDOOR UNIT
22
CONTROLLER
23
3-1
SENSOR
...
3-n
SENSOR
...

FIG. 2

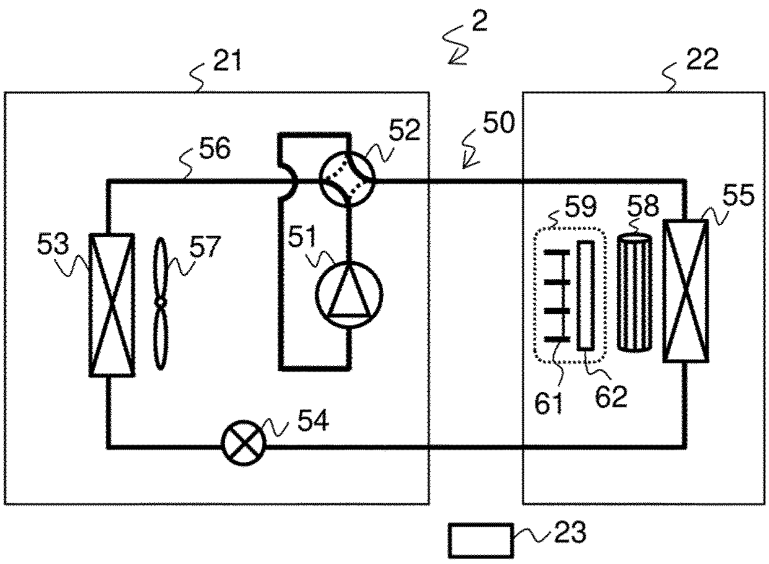

2
21
22
56
52
50
59
58
55
53
57
51
61
62
54
23

FIG. 3

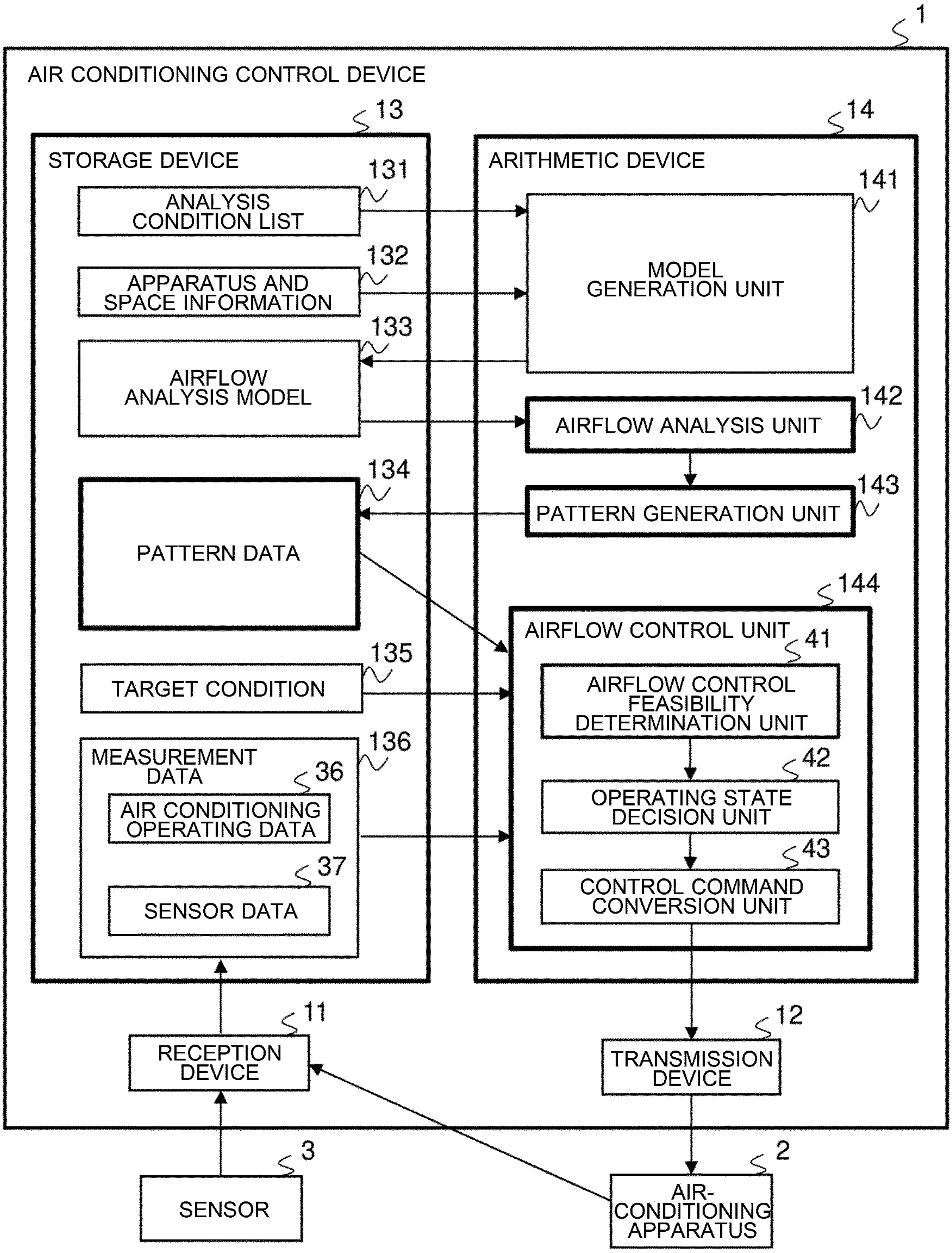

1
AIR CONDITIONING CONTROL DEVICE
13
STORAGE DEVICE
131
ANALYSIS CONDITION LIST
132
APPARATUS AND SPACE INFORMATION
133
AIRFLOW ANALYSIS MODEL
134
PATTERN DATA
135
TARGET CONDITION
136
MEASUREMENT DATA
36
AIR CONDITIONING OPERATING DATA
37
SENSOR DATA
14
ARITHMETIC DEVICE
141
MODEL GENERATION UNIT
142
AIRFLOW ANALYSIS UNIT
143
PATTERN GENERATION UNIT
144
AIRFLOW CONTROL UNIT
41
AIRFLOW CONTROL FEASIBILITY DETERMINATION UNIT
42
OPERATING STATE DECISION UNIT
43
CONTROL COMMAND CONVERSION UNIT
11
RECEPTION DEVICE
12
TRANSMISSION DEVICE
3
SENSOR
2
AIR-CONDITIONING APPARATUS

FIG. 4

ANALYSIS CONDITION No.	PATTERN NAME	OPERATION MODE	PRIORITY	LOAD CONDITION	BLOWING CONDITION	PATTERN GENERATION STATE
1	pattern001	HEATING	2	H1	U1	INCOMPLETION
2	pattern002	HEATING	2	H1	U2	INCOMPLETION
3	pattern003	HEATING	1	H1	U3	COMPLETION
4	pattern004	HEATING	2	H1	U4	INCOMPLETION
5	pattern005	HEATING	2	H2	U1	INCOMPLETION
6	pattern006	HEATING	1	H2	U2	COMPLETION
...	...	...	...	...	...	...

FIG. 5

BLOWING CONDITION	STATE OF COM-PRESSOR	BLOWING AIR VELOCITY	VERTICAL AIR DIRECTION	HORIZONTAL AIR DIRECTION
U1	ON	6	30°	−45°
U2	ON	6	40°	−22.5°
U3	ON	6	50°	0
U4	ON	6	60°	22.5°
...	...	...	...	...

FIG. 6

LOAD CONDITION	WALL TEM-PERATURE [°C]	CEILING TEM-PERATURE [°C]	FLOOR TEM-PERATURE [°C]
H1	$Tw = 15$	$Tc = 25$	$Tf = 15$
H2	$Tw = 15$	$25 < Tc < 30$	$Tf = 15$
H3	$Tw = 15$	$25 < Tc < 30$	$15 < Tf < 20$
H4	$Tw = 15$	$25 < Tc < 30$	$10 < Tf < 15$
...	...	...	...

FIG. 7

SETTING OF CONDITIONS	MAXIMUM PRIORITY	MINIMUM PRIORITY
ESSENTIAL CONDITION	1	3
ADDITIONAL CONDITION	4	10

FIG. 8

TEMPERATURE DIVISION [°C]	pattern001	pattern002	pattern003	···
	OCCURRENCE RATE [%]	OCCURRENCE RATE [%]	OCCURRENCE RATE [%]	···
20～21	1.53	0.22	18.17	···
21～22	1.48	2.38	18.76	···
22～23	2.70	2.70	19.29	···
23～24	5.93	2.52	19.76	···
24～25	44.43	5.26	20.38	···
25～26	29.25	20.22	20.80	···
26～27	9.70	40.16	21.20	···
27～28	2.02	12.13	21.71	···
28～29	0.13	4.85	22.26	···
29～30	0.00	4.45	22.69	···

FIG. 9

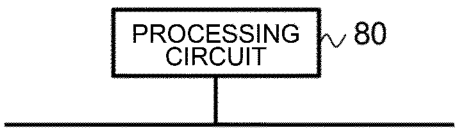


FIG. 10

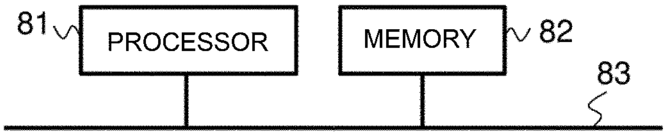


FIG. 11

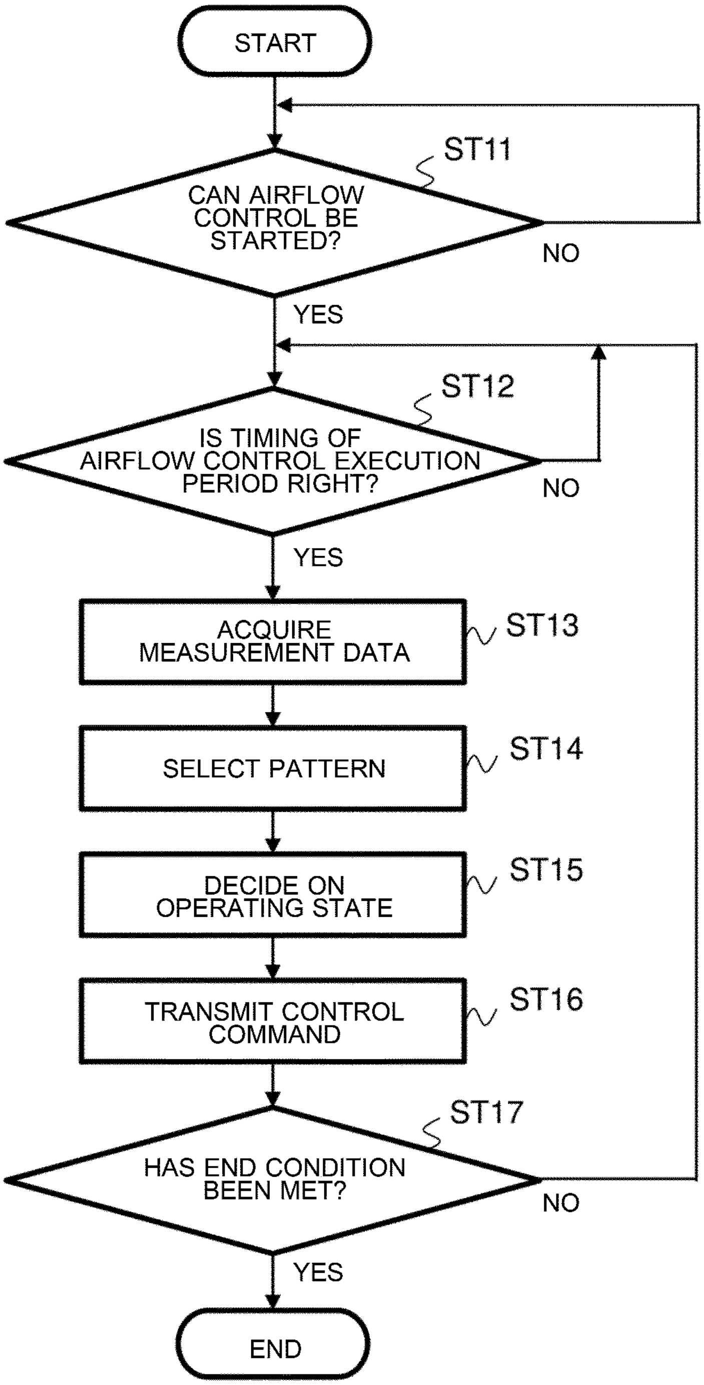

START
ST11
CAN AIRFLOW CONTROL BE STARTED?
NO
YES
ST12
IS TIMING OF AIRFLOW CONTROL EXECUTION PERIOD RIGHT?
NO
YES
ACQUIRE MEASUREMENT DATA
ST13
SELECT PATTERN
ST14
DECIDE ON OPERATING STATE
ST15
TRANSMIT CONTROL COMMAND
ST16
ST17
HAS END CONDITION BEEN MET?
NO
YES
END

FIG. 12

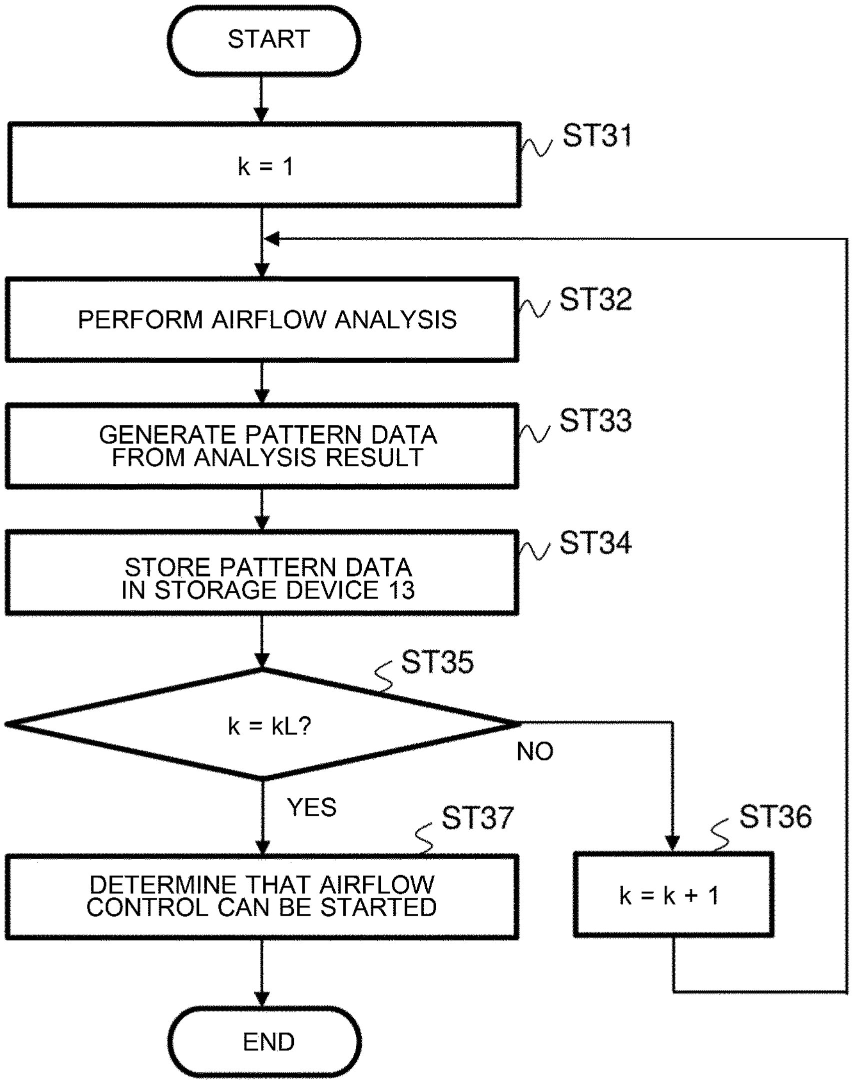
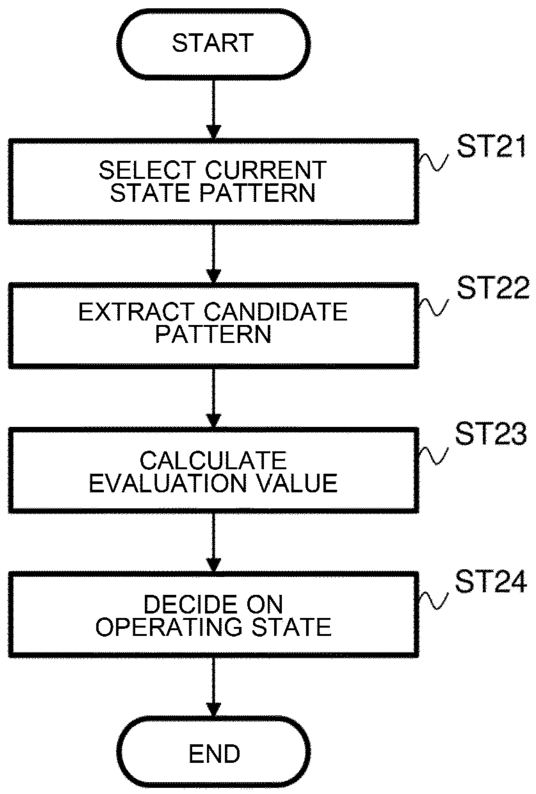

START
k = 1
ST31
PERFORM AIRFLOW ANALYSIS
ST32
GENERATE PATTERN DATA FROM ANALYSIS RESULT
ST33
STORE PATTERN DATA IN STORAGE DEVICE 13
ST34
ST35
k = kL?
NO
YES
ST37
ST36
DETERMINE THAT AIRFLOW CONTROL CAN BE STARTED
k = k + 1
END

FIG. 13


START
SELECT CURRENT STATE PATTERN
ST21
EXTRACT CANDIDATE PATTERN
ST22
CALCULATE EVALUATION VALUE
ST23
DECIDE ON OPERATING STATE
ST24
END

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2020/039495

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl. F24F11/63(2018.01)i, F24F11/64(2018.01)i
FI: F24F11/64, F24F11/63

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)
Int. Cl. F24F11/63, F24F11/64

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 A	WO 2019/235109 A1 (MITSUBISHI ELECTRIC CORP.) 12 December 2019 (2019-12-12), paragraphs [0011]-[0090], fig. 1-6	1-2, 4-10 3
A	JP 2016-061447 A (TOSHIBA CORP.) 25 April 2016 (2016-04-25), paragraphs [0008]-[0052], fig. 1-9	1-10
A	JP 2012-063055 A (TAISEI CORP.) 29 March 2012 (2012-03-29), paragraphs [0033]-[0059], fig. 1-8	1-10

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

* Special categories of cited documents:
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"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30.11.2020	08.12.2020

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2020/039495

Patent Documents referred to in the Report	Publication Date	Patent Family	Publication Date
WO 2019/235109 A1	12.12.2019	(Family: none)	
JP 2016-061447 A	25.04.2016	(Family: none)	
JP 2012-063055 A	29.03.2012	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2016061447 A **[0006]**