

DESCRIPTION

TITLE: DETERMINATION DEVICE, DETERMINATION METHOD, AND DETERMINATION PROGRAM

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CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the priority benefits of Japanese application no. 2023-112355, filed on July 7, 2023. The entity of the above-mentioned patent application is hereby incorporated by reference herein and made a part of this specification.

10

BACKGROUND

Technical Field

[0001] The disclosure relates to a determination device, a determination method, and a determination program.

15 Related Art

[0002] In recent years, as buildings have become larger, more and more air-conditioning equipment are being arranged in one building, which increases the burden of operation/management work. In such a situation, if a failure or malfunction occur in a building's air-conditioning equipment and the detection and processing of the abnormality is delayed, the indoor environment will deteriorate, energy will be wasted, leading to increased costs, so it is necessary to take immediate action.

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[0003] Conventionally, when it comes to air conditioning malfunctions or failures, it is mainly left for people to identify the discrepancy between set values and measured values and visually check the equipment, but in the case of equipment located within a tenant, it is

difficult for an administrator to enter for confirmation, so there is a need to identify the cause of the problem through methods other than visual inspection.

[0004] Thus, a technology has been proposed to distinguish an abnormal state in which failure or malfunction of air-conditioning equipment is thought to be occurring by setting failure conditions in advance, and using the simulation result of failure conditions and the simulation result of normal states to establish criteria capable of distinguishing between normal and abnormal states (See, for example, Patent Document 1).

Citation List

Patent Document

10 **[0005]** [Patent Document 1] Japanese Patent Laid-open No. 2004-234302 A

SUMMARY

Technical Problem

[0006] However, conventional technology has a problem in that it may not be possible to appropriately determine abnormal states of air-conditioning equipment other than failure conditions set in advance. For example, the problem with the conventional technology is that it detects failures only based on pre-assumed process failure conditions of air-conditioning equipment, and is unable to determine discrepancies between the set temperature and the measured temperature caused by insufficient capacity of the equipment to handle the load due to changes in internal load, difference in the surrounding environment, or the like.

Solution to Problem

[0007] In order to solve the above problems and achieve the objectives, the determination device of the disclosure includes: a collection unit that collects data related to an indoor

environment in which air-conditioning equipment is installed for each of specified multiple time periods; a characteristic value calculation unit that respectively performs a simulation of the indoor environment based on the data for each time period collected by the collection unit and respectively calculates a characteristic value from a simulation result for each time period; a difference calculation unit that respectively calculates, for corresponding times in the multiple time periods, a difference between the characteristic value for each time period calculated by the characteristic value calculation unit and a value contained in the data related to the indoor environment for each time period collected by the collection unit; and a determination unit that determines an abnormality of the air-conditioning equipment based on a distribution of the difference calculated by the difference calculation unit.

Effects

[0008] According to the disclosure, it is possible to appropriately determine abnormal states of air-conditioning equipment other than failure conditions set in advance.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a diagram showing an overview of an abnormality determination system including a determination device according to an embodiment.

FIG. 2 is a diagram showing an example of the configuration of a determination device according to an embodiment.

FIG. 3 is a diagram showing a specific example of data stored in a determination device according to the embodiment.

FIG. 4 is a diagram showing an example of target selection according to the embodiment.

FIG. 5 is a diagram showing a specific example of a processing performed by a

determination device according to the embodiment.

FIG. 6 is a diagram showing a specific example of an image output by a determination device according to the embodiment.

FIG. 7 is a flowchart showing an example of a processing procedure in a
5 determination device according to the embodiment.

FIG. 8 is a diagram showing an example of a hardware configuration.

DESCRIPTION OF THE EMBODIMENTS

[0010] Hereinafter, embodiments of a determination device, a determination method, and
10 a determination program according to the disclosure will be described in detail with reference to the accompanying drawings. The determination device, the determination method, and the determination program according to the disclosure are not limited to these embodiments.

[0011] [1. Introduction]

15 First, an overview of a system including a determination device 100 according to the embodiment will be described.

FIG. 1 is a diagram showing an overview of an abnormality determination system including a determination device according to an embodiment.

[0012] In the example of FIG. 1, the determination device 100 is connected to an air
20 conditioning system monitoring device 200 and a temperature sensor 300 by wire or wirelessly, and information is transmitted and received mutually. Moreover, the air conditioning system monitoring device 200 is connected to an air conditioning system 210 and an air conditioning system 220. In the example of FIG. 1, the air conditioning system monitoring device 200 is connected to two air conditioning systems, but the disclosure is

not limited thereto. The number of air conditioning systems may be increased or decreased as desired.

[0013] Moreover, the air conditioning system 210 includes an air conditioner 211, and a VAV (Variable Air Volume) 212 and a VAV 215 connected to the air conditioner 211. The

5 VAV 212 is connected to an indoor temperature sensor 213 and corresponds to air outlets 214-1 to 214-n. Similarly, the VAV 215 is connected to an indoor temperature sensor 216 and corresponds to air outlets 217-1 to 217-n. Further, the configuration of the air

conditioning system 220 from an air conditioner 221 forward is the same as that of the air conditioning system 210. Moreover, the configuration of the air conditioning system is

10 not limited to the configuration shown in FIG. 1, and the number of air conditioners and the number of VAVs may be increased or decreased as desired.

[0014] The determination device 100 is a server device that receives measured values of indoor temperature, supply air volume of VAV, radiation temperature of floor surface, etc.

from the air conditioning system monitoring device 200 and the temperature sensor 300,

15 and pre-stores the information as history data, and is realized by a PC (Personal Computer), a cloud system, etc.

[0015] The determination device 100 collects data related to an indoor environment in which air-conditioning equipment is installed for each of specified multiple time periods,

respectively performs a simulation of the indoor environment based on the data collected in

20 each time period, and respectively calculates a characteristic value from a simulation result for each time period. Moreover, for corresponding times in multiple time periods, the

determination device 100 respectively calculates a difference between the calculated characteristic value for each time period and a value contained in the data related to the indoor environment for each time period, and determines an abnormality of the air-

conditioning equipment based on a distribution of the difference calculated.

[0016] The determination device 100 first collects data related to the indoor environment in which air-conditioning equipment is installed for each of specified multiple time periods. For example, the determination device 100 collects data related to the indoor environment, such as the indoor temperature and VAV air volume, of a part of an object area in which a VAV is installed (hereinafter also referred to as the target) for each of specified multiple time periods (hereinafter also referred to as the evaluation object time period), such as July this year and July last year.

[0017] Next, the determination device 100 respectively performs a simulation of the indoor environment based on the collected data for each time period, and respectively calculates a characteristic value from the simulation result for each time period. For example, an input data set for CFD (Computational Fluid Dynamics) is created from the data for each time period/each target, and CFD is performed using the data to respectively calculate the characteristic value for each time period/each target.

[0018] Moreover, for corresponding times in the multiple time periods, the determination device 100 respectively calculates the difference between the calculated characteristic value for each time period and the value contained in the data related to the indoor environment for each time period. For example, the determination device 100 calculates the difference between the characteristic value and actual measured value of the indoor environment for each target for each date in each of July last year and July this year.

[0019] Thereafter, the determination device 100 determines the abnormality of the air-conditioning equipment based on a distribution of the difference calculated. For example, the determination device 100 statistically compares the data of difference for July last year with the data of difference for July this year for each target, and if there is a significant

difference between the data for the two time periods, determines that the VAV of the target is abnormal.

[0020] The air conditioning system monitoring device 200 monitors the control status of air-conditioning equipment such as the air conditioner 211 and the VAV 212 that belong to
5 each air conditioning system. Moreover, the air conditioning system monitoring device 200 transmits information related to the indoor environment, such as the supply air volume of each VAV and the temperature of each target, to the determination device 100.

[0021] The air conditioner 211 is air-conditioning equipment constituted by, for example, a cooling coil, a heating coil, and a blower, and its operation is monitored by the air
10 conditioning system monitoring device 200. Moreover, conditioned air blown out by the air conditioner 211 and the air conditioner 221 is supplied to each area via an air supply duct. The VAV 212 and the VAV 215 are air-conditioning equipment that controls the amount of conditioned air taken in to eliminate air conditioning load in each zone for the conditioned air supplied from the air conditioner 211. Moreover, the VAV 212 and the
15 VAV 215 adjust the amount of air supplied from each of the air outlets by controlling the opening degree of a damper.

[0022] The indoor temperature sensor 213, the indoor temperature sensor 216, and the temperature sensor 300 are measuring devices that measure nearby temperatures, and in addition to the indoor temperature, they also measure radiation temperatures of the walls,
20 ceiling, floor surfaces, and the like. Moreover, the temperature measured by each temperature sensor is transmitted to the determination device 100 along with the time of measurement, etc.

[0023] [2. Configuration of the Determination Device 100]

Next, the configuration of the determination device 100 shown in FIG. 1 will be

described with reference to FIG. 2. FIG. 2 is a diagram showing an example of the configuration of a determination device according to an embodiment. As shown in FIG. 2, the determination device 100 according to the embodiment includes a communication unit 110, a control unit 120, and a storage unit 130.

5 **[0024]** The communication unit 110 is realized by, for example, a network interface card (NIC). The communication unit 110 is connected to each of the air conditioning system monitoring device 200 and the temperature sensor 300 by wired or wireless, and transmits and receives information thereto.

10 **[0025]** The storage unit 130 is realized by a storage device such as a RAM (Random Access Memory) or a hard disk. The storage unit 130 stores data and programs necessary for various processings by the control unit 120, but in particular, those closely related the disclosure include a history data storage unit 131, a characteristic value data storage unit 132, a difference data storage unit 133, and a determination data storage unit 134.

15 **[0026]** The history data storage unit 131 stores data related to past indoor environments, which is used in the determination processing to be described below. For example, the history data storage unit 131 stores data related to the indoor environment, such as the supply air temperature, VAV air volume, indoor temperature, radiation temperature of the floor surface, and the number of people indoor, at any time in the past, as time-series data for each date and time. The data related to the indoor environment may be previously
20 stored before the processing of the determination device 100 is performed.

[0027] The characteristic value data storage unit 132 stores the characteristic value calculated by a characteristic value calculation unit 122 to be described later. For example, the characteristic value data storage unit 132 stores, for each target selected, characteristic value such as the indoor temperature calculated by the characteristic value calculation unit

122 to be described below.

[0028] The difference data storage unit 133 stores the data of difference between the characteristic value and the actual measured value calculated by a difference calculation unit 123 to be described later. For example, the difference data storage unit 133 stores, for each target, the value of difference between the indoor temperature calculated as a characteristic value by simulation and the actual measured value of indoor temperature value stored in the history data storage unit 131 for each date.

[0029] The determination data storage unit 134 stores determination data generated by a determination unit 124 to be described later. For example, the determination data storage unit 134 stores the target whose air-conditioning equipment has been determined to be abnormal by the determination unit 124 to be described later, together with information about the VAV corresponding to the target (such as the location where it is installed).

[0030] Here, a specific example of the data stored in the history data storage unit 131 and the data stored in the difference data storage unit 133 will be described with reference to FIG. 3. FIG. 3 is a diagram showing a specific example of data stored in the determination device according to the embodiment. (A) of FIG. 3 shows the data stored in the history data storage unit 131, and (B) of FIG. 3 shows the data stored in the difference data storage unit 133.

[0031] In the example of (A) of FIG. 3, it is shown that for each date and time at regular intervals, such as “2022/07/01 9:00” and “2022/07/01 10:00”, actual measured values of the supply air temperature, VAV air volume, indoor temperature, etc. at the corresponding time are stored in association. In the example of (B) of FIG. 3, it is shown that for each target as the object of determination, such as “target 1,” the value of difference between the characteristic value and the actual measured value for the specified time periods, “23/07

(July 2023)” and “22/07 (July 2022),” are stored in sequence for each date, such as “07/01” and “07/02.”

[0032] Returning to the explanation of FIG. 2. The control unit 120 is realized by a central processing unit (CPU), a micro processing unit (MPU), or the like executing various programs stored in a storage device inside the determination device 100 using the RAM as a work region. Moreover, the control unit 120 is realized by an integrated circuit such as an application specific integrated circuit (ASIC) or a field programmable gate array (FPGA). The control unit 120 includes a collection unit 121, the characteristic value calculation unit 122, the difference calculation unit 123, and the determination unit 124, and may also include a display unit 125 as necessary.

[0033] The collection unit 121 collects data related to the indoor environment in which air-conditioning equipment is installed for each of specified multiple time periods. For example, the collection unit 121 refers to the information stored in the history data storage unit 131 and collects data such as the supply air temperature, VAV air volume, etc. for an externally selected target during each evaluation object time period. Here, the evaluation object time period may be any time period set from the outside, and two or more data time periods may be set. Moreover, since seasonal factors have a large impact on the indoor environment, it is desirable to set the evaluation object time period to a time period of the same season, such as the same month of the previous year.

[0034] The above-mentioned target will be described with reference to FIG 4. FIG. 4 is a diagram showing an example of target selection according to the embodiment. In the example of FIG. 4, first, the entire floor is divided into four VAV control areas 1 to 4. Indoor temperature sensors (1) to (4) are installed in each of the VAV control areas. Moreover, in addition to the VAV control areas, the entire floor is divided into 3 x 10 squares

as an object area for the simulation result of CFD used by the characteristic value calculation unit 122 to be described later.

[0035] Under the above-mentioned circumstances, for each of the VAV control areas, an arbitrary square within the area is selected as a target and associated with the indoor temperature sensor. For example, for the “VAV control area 1,” the square including the “temperature sensor (1)” is selected as the “target 1” and associated with the “temperature sensor (1).” Similarly, targets 2 to 4 are selected for each of the VAV control areas 2 to 4 and associated with the corresponding indoor temperature sensors.

[0036] In other words, as a target, an arbitrary square within each of the VAV control areas as the object of abnormality determination is selected, and associated with the corresponding indoor temperature sensor. As a result, the determination device 100 is able to perform simulation and determination processing for each target (for each VAV corresponding to the target) using the actual measured value of the temperature sensor associated with each target.

[0037] The indoor temperature sensor may be the same as that used for VAV control, or a separate temperature sensor installed for measuring the indoor environment may be used. Moreover, the selection of the target may be set externally taking into consideration the usage status of the object floor, or the square closest to the indoor temperature sensor may be automatically set. Further, while FIG. 4 shows an example of selecting an object for one floor, the disclosure is not limited thereto. It is possible to set each floor of the entire building as the object for selection, or to set only one air conditioning system as the target for selection.

[0038] Returning to the explanation of FIG 2, the characteristic value calculation unit 122 respectively performs a simulation of the indoor environment based on the data for each

time period collected by the collection unit 121, and respectively calculates the characteristic value from the simulation result for each time period. Moreover, the characteristic value calculation unit 122 may use the data for each time period collected by the collection unit 121 to perform a simulation using computational fluid dynamics for one
5 or more of the following: indoor temperature distribution, indoor air volume distribution, indoor air speed distribution, indoor pollutant (e.g., carbon dioxide) concentration distribution, and indoor humidity distribution.

[0039] For example, the characteristic value calculation unit 122 first creates data of boundary conditions to be used in the calculations by CFD from the data notified by the
10 collection unit 121 described above. Thereafter, the characteristic value calculation unit 122, for example, uses the created data set to calculate the indoor temperature distribution by CFD, and stores the data obtained by aggregating the calculated temperature in units of targets as the characteristic value in the characteristic value data storage unit 132.

[0040] Moreover, as a method of aggregation, the characteristic value calculation unit 122
15 may calculate the average value of the CFD results within the target, or use the maximum value. Further, the object of a CFD simulation is not limited to the indoor temperature distribution, but elements that represent the indoor environment, such as indoor air volume, air speed, CO₂, and humidity, may also be used.

[0041] Here, the CFD used by the characteristic value calculation unit 122 will be
20 described. In the embodiment, in CFD, simulation is performed by inputting information that affects the space (supply air temperature, air volume, radiation temperature, etc.) as boundary conditions, and visualizes conditions such as air volume, wind speed, CO₂, humidity, and temperature distribution. Moreover, information that affects the space (supply air temperature, air volume, radiation temperature, etc.) is input into CFD as

boundary conditions, such that reproducible results may be obtained by combining multiple conditions while taking into account these factors which cause interference.

[0042] Moreover, in CFD, simulation is performed by inputting boundary conditions into an indoor model. Thus, when the boundary conditions are similar, simulation results will also be similar, and the differences between the actual result and the simulation result will also be similar. Thus, by statistically comparing the differences between the actual result and the simulation result for two time periods with similar boundary conditions and analyzing the distribution of the difference, the determination device 100 is capable of determining that an abnormality has occurred in the equipment of the corresponding air conditioning system or the equipment in the corresponding indoor area.

[0043] For corresponding times in multiple time periods, the difference calculation unit 123 respectively calculates the difference between the characteristic value for each time period calculated by the characteristic value calculation unit 122 and the value contained in the data related to the indoor environment for each time period collected by the collection unit 121. For example, the difference calculation unit 123 refers to information stored in the history data storage unit 131 and the characteristic value data storage unit 132, calculates the difference between the characteristic value and the actual measured value at the same time in the evaluation object time period, and stores it in the difference data storage unit 133.

[0044] Here, the difference calculation unit 123 calculates, for each target, the difference between the characteristic value of the target and the actual measured value of the temperature sensor associated with the target. Moreover, the difference calculation unit 123 may, for example, calculate the difference for each date (07/01...) of the evaluation object time period (July this year: July last year) (see (B) of FIG. 3), or may calculate the

difference for each arbitrary time on each date (07/01 9:00...).

[0045] In other words, the interval for calculating the difference may be changed according to the evaluation object time period. For example, if the evaluation object time period is one month, the difference may be calculated for each day, and if the evaluation
5 object time period is one day, the difference may be calculated for each hour. Moreover, when calculating the difference for each day, for example, the difference calculation unit 123 may calculate the average value of the difference for each hour on that date as the difference for that date.

[0046] The determination unit 124 determines the abnormality of the air-conditioning
10 equipment based on the distribution of the difference calculated by the difference calculation unit 123. For example, the determination unit 124 refers to the information stored in the difference data storage unit 133 and statistically compares multiple pieces of difference data for the evaluation object time period to determine whether or not there is a significant difference. Moreover, the determination unit 124 determines that the VAV in the VAV
15 control area corresponding to the target determined to have a significant difference is abnormal, and stores information such as the installation area of the VAV determined to be abnormal in the determination data storage unit 134.

[0047] Moreover, based on the distribution of the difference calculated by the difference calculation unit 123, the determination unit 124 may determine the abnormality of the air-
20 conditioning equipment by using a corresponding test method depending on whether the difference has equal variance or unequal variance.

[0048] For example, the determination unit 124 first determines equal variance or unequal variance by conducting an F-test on the distribution of two pieces of difference data for the evaluation object time period. Next, for example, if the difference has equal variance, the

determination unit 124 conducts a t-test so as to determine whether or not there is a significant difference between the average of the two evaluation object time periods. On the other hand, if the difference has unequal variance, a Welch's t-test is conducted so as to determine whether or not there is a significant difference between the average of the two evaluation object time periods. Thereafter, the determination unit 124 determines that the VAV in the VAV control area corresponding to the target determined to have a significant difference is abnormal, in the same manner as in the above-described processing.

[0049] The display unit 125 displays an image related to the area in which the air-conditioning equipment determined to be abnormal by the determination unit 124 is arranged. For example, the display unit 125 refers to the information stored in the determination data storage unit 134, aggregates the installation areas of VAVs that have been determined to be abnormal, and displays a list image in which each control area of the VAV installed on each floor, classified into either an area assumed to be normal or an area assumed to have malfunction.

[0050] [3. Implementation example]

Here, a specific example of the processing performed by the determination device 100 will be described with reference to FIG. 5. FIG. 5 is a diagram showing a specific example of a processing performed by a determination device according to the embodiment. FIG. 5 shows an example in which a CFD simulation is performed for the indoor temperature distribution. First, the determination device 100 specifies two time periods, "July last year" and "July this year", as the evaluation object time periods, and selects targets 1 to 4.

[0051] Moreover, the collection unit 121 collects history data for each of the targets 1 to 4 at each date/each time in July last year, and history data for each of the targets 1 to 4 at

each date/each time in July this year. Thereafter, the characteristic value calculation unit 122 performs a simulation of temperature distribution by CFD using data sets created from the corresponding history data for each of each date/each time in July last year and each date/each time in July this year.

5 **[0052]** Moreover, the characteristic value calculation unit 122 calculates an average value of the temperature in units of targets from the simulation result, and sets it as the characteristic value. By the above processing, the characteristic value of the targets 1 to 4 have been calculated for each of the each date/each time in July last year and for each date/each time in July this year.

10 **[0053]** Next, the difference calculation unit 123 calculates the difference between each calculated characteristic value and the actual measured value corresponding to the characteristic value. For example, if the characteristic value is “10 o’clock on July 1st last year, target 1: 26°C,” the actual measured value corresponds to “10 o’clock on July 1st last year, the measured value of the temperature sensor corresponding to target 1: 25.5°C”, and
15 the difference: “0.5°C”. Thereafter, the difference calculation unit 123 calculates an average value for each date of the calculated differences, and sets it as the difference for each date. In other words, by summarizing the difference calculated for each time by date, the differences for each of the target 1 to 4 are calculated for each of each date in July last year (1st to 31st) and for each date in July this year (1st to 31st).

20 **[0054]** Thereafter, the determination unit 124 conducts an F-test on each of the targets 1 to 4 using the difference data for July last year and July this year as respective population, and determines whether the difference has equal variance or unequal variance. If the difference has have equal variance, a t-test is conducted, whereas if it has unequal variance, the Welch's t-test is conducted to determine whether or not there is a significant difference.

[0055] Next, for a target that is determined to have a significant difference, the display unit 125 outputs the determination result to the outside by displaying an image indicating that a change has occurred in the state of the VAV corresponding to the target and that a fault may have occurred (abnormal state).

5 **[0056]** Through the series of processings described above, the determination device 100 may determine a change in the state (abnormality) of the air-conditioning equipment by statistically comparing the differences between the simulation result and the actual measured value for July last year and July this year, which have similar boundary conditions.

[0057] Next, a specific example of an image displayed by the display unit 125 related to
10 a VAV in which a fault may have occurred will be described with reference to FIG. 6. FIG. 6 is a diagram showing a specific example of an image output by a determination device according to the embodiment. The example of FIG. 6 shows the possibility of fault occurrence in “VAV1 to VAV10” installed on each of the “first to 20th floors” of the building in which the VAV as the object of determination is located.

15 **[0058]** In the table of FIG. 6, a VAV floor marked with “○” indicates a VAV control area where the air-conditioning equipment is assumed to be in a normal state, and a VAV floor marked with an “X” indicates a VAV control area where the air-conditioning equipment is assumed to have malfunction. For users involved in the equipment management and operation of the building, the display unit 125 of the determination device 100 may display
20 a list such as the example of Figure 6, allowing them to understand the determination result of abnormal state of the air-conditioning equipment by units of VAV control areas.

[0059] [4. Processing procedure by the determination device]

Next, an example of a processing procedure performed by the determination device 100 according to the embodiment will be described with reference to FIG. 7. FIG. 7 is a

flowchart showing an example of a processing procedure in a determination device according to the embodiment.

[0060] First, the determination device 100 specifies a time period of the object of determination (evaluation object time period) (step S101). Next, the determination device
5 100 selects a location (target) of the object of determination (Step S102). Next, the collection unit 121 collects information related to the indoor environment for the specified time period and the selected location (step S103).

[0061] Moreover, the characteristic value calculation unit 122 creates an input data set for CFD based on the collected information (step S104). Next, the characteristic value
10 calculation unit 122 performs CFD using the generated data set and calculates the characteristic value (step S105). Thereafter, the difference calculation unit 123 calculates the difference between the characteristic value calculated by performing CFD and the actual measured value corresponding to the characteristic value collected in S103 (step S106).

[0062] Next, the determination unit 124 determines whether the difference calculated for
15 each evaluation object time period has equal variance or unequal variance (step S107). If the calculated difference has equal variance (step S107; Yes), the determination unit 124 conducts a t-test, which is a test corresponding to equal variance (step S108). On the other hand, if the calculated difference has unequal variance (step S107; No), the determination unit 124 conducts the Welch's t-test, which is a test corresponding to unequal variance (step
20 S109).

[0063] Moreover, after the processing of S108 or the processing of S109, the display unit 125 displays the determination result of the abnormal state of the air-conditioning equipment based on the implementation of the test (step S110), and the determination device 100 ends the process.

[0064] [5. Effects of the embodiment]

As described above, the determination device 100 according to the embodiment includes the collection unit 121, the characteristic value calculation unit 122, the difference calculation unit 123, and the determination unit 124. The collection unit 121 collects data
5 related to the indoor environment in which air-conditioning equipment is installed for each of specified multiple time periods. The characteristic value calculation unit 122 respectively performs a simulation of the indoor environment based on the data for each time period collected by the collection unit 121, and respectively calculates the characteristic value from the simulation result for each time period.

10 **[0065]** For corresponding times in multiple time periods, the difference calculation unit 123 respectively calculates the difference between the characteristic value for each time period calculated by the characteristic value calculation unit 122 and the value contained in the data related to the indoor environment for each time period collected by the collection unit 121. The determination unit 124 determines the abnormality of the air-conditioning
15 equipment based on the distribution of the difference calculated by the difference calculation unit 123.

[0066] As a result, the determination device 100 achieves the following effect: it is able to automatically determine the air-conditioning equipment that has a high probability of failure/malfunction in the air conditioning system based on data related to the air
20 conditioning environment accumulated in advance, thereby appropriately determining an abnormal state in the air-conditioning equipment other than failure conditions set in advance.

[0067] Moreover, since for the determination device 100, there is no need to set normal/abnormal conditions in advance, it is possible to reduce the burden on the operations manager and the like and to allow the air conditioning system to be maintained and managed

efficiently. Further, the determination device 100 can prevent deterioration of the indoor environment and reduce energy consumption by appropriately determining abnormalities in air-conditioning equipment and promptly responding to air-conditioning equipment in which a failure/malfunction has occurred.

5 **[0068]** Further, the characteristic value calculation unit 122 of the determination device 100 uses the data for each time period collected by the collection unit 121 to perform a simulation using computational fluid dynamics for one or more of the indoor temperature distribution, the indoor air volume distribution, the indoor air speed distribution, the indoor pollutant (e.g., carbon dioxide) concentration distribution, and the indoor humidity
10 distribution. As a result, the determination device 100 performs CFD, which may obtain reproducible result by inputting information related to the indoor environment as boundary conditions, on indices that represent the indoor environment, such as the indoor temperature distribution and the indoor wind speed distribution, thereby achieving the effect of being able to determine a change in the state of the air-conditioning equipment by comparing the
15 distribution of the difference between the simulation result and the actual measured value.

[0069] Moreover, based on the distribution of the difference calculated by the difference calculation unit 123, the determination unit 124 of the determination device 100 determines the abnormality of the air-conditioning equipment by using a corresponding test method depending on whether the difference has equal variance or unequal variance. As a result,
20 the determination device 100 has the effect of being able to determine a change in the state of the air-conditioning equipment by determining whether or not there is a significant difference based on the distribution of the difference for each data time period as the object of determination using an appropriate test method.

[0070] Further, the determination device 100 includes the display unit 125. The display

unit 125 displays an image related to the area in which the air-conditioning equipment determined to be abnormal by the determination unit 124 is arranged. As a result, the determination device 100 has the effect that it is possible to easily determine whether the state of each air-conditioning equipment arranged on each floor is normal or abnormal.

5 **[0071]** [6. Hardware Configuration]

The determination device 100 according to the embodiment described above is realized by, for example, a computer 1000 having a configuration as shown in FIG. 8. FIG. 8 is a diagram showing an example of a hardware configuration. The computer 1000 includes a CPU 1100, a RAM 1200, a ROM 1300, an auxiliary storage device 1400, a
10 communication I/F (interface) 1500, and an input/output I/F (interface) 1600, all connected via a bus 1800.

[0072] The CPU 1100 operates based on a program stored in the ROM 1300 or the auxiliary storage device 1400, and controls each unit. The ROM 1300 stores a boot program executed by the CPU 1100 when the computer 1000 is started, a programs that
15 depends on the hardware of the computer 1000, or the like.

[0073] The auxiliary storage device 1400 stores the program executed by the CPU 1100, and data used by the program. The communication I/F 1500 receives data from other devices via a predetermined communication network and sends the data to the CPU 1100, and transmits data generated by the CPU 1100 to other devices via the predetermined
20 communication network.

[0074] The CPU 1100 controls output devices such as a display or a printer, and an input/output device 1700 such as a keyboard, a mouse or the like, via the input/output I/F 1600. The CPU 1100 obtains data from the input/output device 1700 via the input/output I/F 1600. Moreover, the CPU 1100 outputs the generated data to the input/output device

1700 via the input/output I/F 1600.

[0075] For example, when the computer 1000 functions as the determination device 100 according to the embodiment, the CPU 1100 of the computer 1000 executes a program loaded onto the RAM 1200 to realize the functions of the control unit 120.

5 **[0076]** [7. Other]

Of the processings described in the above embodiments, all or part of the processings described as being performed automatically may be performed manually. Alternatively, all or part of the processings described as being performed manually may be performed automatically by known methods. Moreover, the information including the
10 processing procedures, specific names, various data, and parameters shown in the above documents and drawings may be changed as desired unless otherwise specified. For example, the various information shown in each drawing is not limited to the information shown in the drawings.

[0077] Further, each component of each device shown in the figures is merely a functional
15 concept, and does not necessarily have to be physically configured as shown in the drawings. In other words, the specific form of distribution/integration of each device is not limited to that shown in the drawing, and all or part of it may be functionally or physically distributed/integrated in arbitrary units depending on various loads, usage conditions, etc.

[0078] The above-mentioned components include those that may be easily thought of by
20 a person skilled in the art, those that are substantially the same, and those that are within the so-called equivalent range. Further, the above-described embodiments may be appropriately combined as long as the processing contents are not contradictory.

[0079] Further, the above-mentioned “unit (section, module, part)” may be read as “means” or “circuit”, etc. For example, the control unit may be interpreted as a control means or a

control circuit.

[0080] Some of the embodiments of the disclosure have been described in detail above with reference to the drawings, by they are merely examples, and the disclosure may be implemented in other forms that incorporate various modifications and improvements based on the knowledge of those skilled in the art, including the embodiments described in the SUMMARY.

[Reference Signs List]

[0081] 100 Determination device

110 Communication unit

10 120 Control unit

121 Collection unit

122 Characteristic value calculation unit

123 Difference calculation unit

124 Determination unit

15 125 Display unit

130 Storage unit

131 History data storage unit

132 Characteristic value data storage unit

133 Difference data storage unit

20 134 Determination data storage unit

200 Air conditioning system monitoring device

210, 220 Air conditioning system

211, 221 Air conditioner

212, 215 VAV

213, 216 Indoor temperature sensor

214-1 to 214-n, 217-1 to 217-n Air outlet

300 Temperature sensor

CLAIMS

Claim 1: A determination device, comprising:

a collection unit that collects data related to an indoor environment in which air-

5 conditioning equipment is installed for each of specified multiple time periods;

a characteristic value calculation unit that respectively performs a simulation of the indoor environment based on the data for each time period collected by the collection unit and respectively calculates a characteristic value from a simulation result for each time period;

10 a difference calculation unit that respectively calculates, for corresponding times in the multiple time periods, a difference between the characteristic value for each time period calculated by the characteristic value calculation unit and a value contained in the data related to the indoor environment for each time period collected by the collection unit; and

15 a determination unit that determines an abnormality of the air-conditioning equipment based on a distribution of the difference calculated by the difference calculation unit.

Claim 2: The determination device according to claim 1,

20 wherein the characteristic value calculation unit performs a simulation by computational fluid dynamics of one or more of indoor temperature distribution, indoor air volume distribution, indoor air speed distribution, indoor pollutant concentration distribution, and indoor humidity distribution, using the data for each time period collected by the collection unit.

Claim 3: The determination device according to claim 1,

wherein based on the distribution of the difference calculated by the difference calculation unit, the determination unit determines an abnormality of the air-conditioning equipment using a corresponding test method depending on whether the difference has an equal variance or an unequal variance.

Claim 4: The determination device according to claim 1, further comprising:

a display unit that displays an image related to an area in which the air-conditioning equipment determined to be abnormal by the determination unit is arranged.

Claim 5: A determination method executed by a determination device, comprising:

a collection process of collecting data related to an indoor environment in which air-conditioning equipment is installed for each of specified multiple time periods;

a characteristic value calculation process of respectively performing a simulation of the indoor environment based on the data for each time period collected by the collection process and respectively calculating a characteristic value from a simulation result for each time period;

a difference calculation process of respectively calculating, for each corresponding time in the multiple time periods, a difference between the characteristic value for each time period calculated in the characteristic value calculation process and a value contained in the data related to the indoor environment for each time period collected

in the collection process; and

a determination process of determining an abnormality of the air-conditioning equipment based on a distribution of the difference calculated by the difference calculation process.

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Claim 6: A determination program, causing a computer to execute:

a collection procedure of collecting data related to an indoor environment in which air-conditioning equipment is installed for each of specified multiple time periods;

10 a characteristic value calculation procedure of respectively performing a simulation of the indoor environment based on the data for each time period collected by the collection procedure and respectively calculating a characteristic value from a simulation result for each time period;

15 a difference calculation procedure of respectively calculating, for each corresponding time in the multiple time periods, a difference between the characteristic value for each time period calculated by the characteristic value calculation procedure and a value contained in the data related to the indoor environment for each time period collected by the collection procedure; and

20 a determination procedure of determining an abnormality of the air-conditioning equipment based on a distribution of the difference calculated by the difference calculation procedure.