

## **DISPLAY SYSTEM, DISPLAY METHOD, AND PROGRAM**

### **Technical Field**

[0001] The present disclosure generally relates to a display system, a display method, and a program, and more particularly relates to a display system including a controller for controlling a display device, a display method, and a program.

### **Background Art**

[0002] Patent Literature 1 discloses an air conditioner including an infrared sensor for detecting a temperature distribution in a room.

[0003] To detect an apparent temperature in a space surrounding a person by measuring an apparent temperature distribution in a room of a facility such as a single-family dwelling house or an office, either a large number of sensors or a dedicated sensor needs to be provided, thus causing a significant increase in cost.

### **Citation List**

#### **Patent Literature**

[0004] Patent Literature 1: JP 6678748 B2

### **Summary of Invention**

[0005] In view of the foregoing background, it is therefore an object of the present disclosure to provide a display system, a display method, and a program, all of which are configured or designed to estimate an apparent temperature distribution in a room using a sensor installed in a ventilator for ventilating the room.

[0006] To overcome the problem, a display system according to an aspect of the present disclosure includes an acquirer, an estimator, and a controller. The acquirer acquires a first detection value and a second detection value from a temperature sensor and a humidity sensor, respectively. The temperature sensor and the humidity sensor are both included in a ventilator that ventilates a room. The estimator estimates, based on the first detection value and the second detection value that are acquired by the acquirer, an apparent temperature distribution representing a distribution of apparent temperatures in a height direction in the room. The controller makes a

display device present the apparent temperature distribution estimated by the estimator.

[0007] A display method according to another aspect of the present disclosure includes an acquisition step, an estimation step, and a presentation step. The acquisition step includes acquiring a first detection value and a second detection value from a temperature sensor and a humidity sensor, respectively. The temperature sensor and the humidity sensor are both included in a ventilator that ventilates a room. The estimation step includes estimating, based on the first detection value and the second detection value that are acquired in the acquisition step, an apparent temperature distribution representing a distribution of apparent temperatures in a height direction in the room. The presentation step includes making a display device present the apparent temperature distribution estimated in the estimation step.

[0008] A program according to still another aspect of the present disclosure is designed to cause one or more processors to perform the display method described above.

## **Brief Description of Drawings**

[0009] FIG. 1 is a schematic representation illustrating an overall configuration for a display system according to an exemplary embodiment;

FIG. 2 schematically illustrates an indoor apparent temperature distribution estimated by an estimator included in the display system;

FIG. 3 schematically illustrates an on-screen image displayed on a display device provided for the display system; and

FIG. 4 is a flowchart showing the procedure of operation of the display system.

## **Description of Embodiments**

[0010] A preferred embodiment of the present disclosure will now be described in detail with reference to the accompanying drawings. In the following description of embodiments, constituent elements illustrated on multiple drawings and having the same feature will be designated by the same reference sign and description thereof will be omitted herein to avoid redundancy. Note that the embodiment to be described below is only an exemplary one of various embodiments of the present disclosure and should not be construed as limiting. Rather, the exemplary embodiment may be readily modified in various manners depending on a design choice or any other factor without departing from the scope of the present disclosure. The drawings to be referred to in the following description of embodiments are all schematic representations. Thus, the ratio of the dimensions (including thicknesses) of respective constituent elements

illustrated on the drawings does not always reflect their actual dimensional ratio.

[0011] (1) Overview

First, an overview of a display system 1 according to an exemplary embodiment will be described with reference to FIG. 1.

[0012] As shown in FIG. 1, the display system 1 according to this embodiment is designed to work in cooperation with a facility 5 in which a ventilator 2 is installed.

[0013] The display system 1 according to this embodiment acquires a first detection value and a second detection value from a temperature sensor 21 and a humidity sensor 22, respectively. The temperature sensor 21 and the humidity sensor 22 are both included in the ventilator 2 installed in the facility 5. The display system 1 estimates, based on the first detection value and the second detection value, an apparent temperature distribution in a height direction in a room 50 of the facility 5. Then, the display system 1 makes a display device 81 of a terminal device 8 present the apparent temperature distribution thus estimated.

[0014] (2) Details

Next, detailed configurations for the display system 1 according to this embodiment and the facility 5 and the terminal device 8 that work in cooperation with the display system 1 will be described with reference to FIGS. 1–3.

[0015] (2.1) Configuration for facility

First, details of the facility 5 will be described with reference to FIG. 1. As used herein, examples of the “facility” include dwelling facilities for use for housing purposes and non-dwelling facilities such as stores (tenants’ stores), offices, welfare facilities, educational institutions, hospitals, and factories. Examples of the non-dwelling facilities further include restaurants, amusement centers, hotels, inns, kindergartens, daycare facilities, and community centers. That is to say, the facility 5 may be a dwelling facility such as a multi-family dwelling house (i.e., a so-called “mansion” in Japan) or a non-dwelling facility such as an office building, whichever is appropriate. Alternatively, the facility 5 may also be a combination of a dwelling facility and a non-dwelling facility. For example, the facility 5 may include stores on lower floors thereof and dwelling units on upper floors thereof. In this embodiment, the facility 5 is supposed to be a single-family dwelling house as shown in FIG. 1.

[0016] As shown in FIG. 1, the facility 5 includes the ventilator 2, a communications interface 3, and a router 4.

[0017] The ventilator 2 may be, for example, a ceiling-mounted exhaust fan and performs at least one of normal ventilation or heat exchange ventilation. The ventilator 2 is provided through a ceiling 51 of a room 50 in the facility 5. The ventilator 2 according to this embodiment is an

exhaust fan of class 1 ventilation and is designed to supply and exhaust the air by mechanical power. The ventilator 2 includes the temperature sensor 21, the humidity sensor 22, a supply air duct 23, and an exhaust duct 24.

[0018] The temperature sensor 21 is a sensor for detecting, as a first detection value, the temperature (spatial temperature) of the air either inside or around the ventilator 2. As used herein, the phrase “inside the ventilator 2” also refers to inside the supply air duct 23 and inside the exhaust duct 24. The temperature sensor 21 according to this embodiment is provided inside the exhaust duct 24. The temperature sensor 21 may be implemented as, for example, an infrared sensor, a thermistor, or a thermocouple. The humidity sensor 22 is a sensor for detecting, as a second detection value, the humidity (spatial humidity) of the air either inside or around the ventilator 2. The humidity sensor 22 according to this embodiment is provided inside the exhaust duct 24. The humidity sensor 22 may be implemented as, for example, an electric humidity sensor. Optionally, the temperature sensor 21 and the humidity sensor 22 may also be implemented as an integrated temperature-humidity sensor.

[0019] The supply air duct 23 is an air passage that connects the space outside the facility 5 to the indoor space of the room 50 in the facility 5 and is a duct for taking in the air outside the facility 5 and supplying the air into the room 50. The supply air duct 23 includes a first air inlet 231 arranged to face the room 50 and a second air inlet 232 provided outside the facility 5. The second air inlet 232 may be provided with, for example, a supply air fan.

[0020] The exhaust duct 24 is an air passage that connects the space outside the facility 5 to the indoor space of the room 50 in the facility 5 and is a duct for exhausting the air inside the room 50 to the outside of the facility 5. The exhaust duct 24 includes a first air outlet 241 arranged to face the room 50 and a second air outlet 242 provided outside the facility 5. The second air outlet 242 may be provided with, for example, an exhaust fan.

[0021] The communications interface 3 is connected to a network 6 such as the Internet via the router 4. The communications interface 3 transmits the first and second detection values detected by the temperature sensor 21 and the humidity sensor 22, respectively, to the display system 1 via the router 4 and the network 6. In addition, the communications interface 3 also transmits, to the display system 1, operating status information indicating whether the ventilator 2 is operating or not, i.e., whether the supply air fan and the exhaust fan of the ventilator 2 are running or not.

[0022] (2.2) Configuration for terminal device

Next, a configuration for the terminal device 8 will be described with reference to FIG. 1.

[0023] The terminal device 8 may be, for example, a desktop or laptop personal computer. The terminal device 8 is operated by a user such as a person living in the facility 5 or an employee of

a management company that manages the facility 5. The terminal device 8 is configured to be ready to communicate with the display system 1 via the network 6.

[0024] The display device 81 may be, for example, a liquid crystal display or an organic electroluminescent (EL) display. The display device 81 presents an apparent temperature distribution under the control of a controller 73 of a server 7 (to be described later).

[0025] (2.3) Configuration for display system

Next, details of the display system 1 will be described with reference to FIGS. 1–3.

[0026] The display system 1 according to this embodiment is implemented as a server 7. The server 7 includes, as a major constituent element, a computer system including one or more processors and one or more memories. The server 7 performs the functions of the acquirer 71, the estimator 72, the controller 73, the determiner 74, and the calculator 75 of the server 7 shown in FIG. 1 by making the one or more processors execute a program stored in the memory. The program may be stored in advance in the memory. Alternatively, the program may also be downloaded via a telecommunications line such as the Internet or distributed after having been stored in a non-transitory storage medium such as a memory card.

[0027] The server 7 includes the acquirer 71, the estimator 72, the controller 73, the determiner 74, and the calculator 75.

[0028] The acquirer 71 acquires the first detection value and the second detection value from the communications interface 3 via the network 6. Alternatively, the acquirer 71 may also be configured to be ready to communicate with the communications interface 3 directly not via the network 6.

[0029] The estimator 72 estimates, based on the first detection value and the second detection value that are acquired by the acquirer 71, an apparent temperature distribution representing the distribution of apparent temperatures in a height direction in the room 50. As used herein, the “apparent temperature” refers to a quantitative representation indicating the degree of a temperature that a human being feels like. According to the present disclosure, a net effective temperature (NET) is used as an index to the apparent temperature. The NET is described in, for example, a reference (“Meteorological Applications,” Volume 7, pp. 369–375, 2000). In the following description, the apparent temperature estimated by the estimator 72 will be hereinafter sometimes referred to as an “estimated apparent temperature.”

[0030] The estimator 72 according to this embodiment estimates an apparent temperature distribution in a space a3 (refer to FIG. 1) in the height direction from the ceiling 51 of the room 50 to its floor 52 (refer to FIG. 2). Note that the estimator 72 according to this embodiment estimates only an apparent temperature distribution in the height direction and supposes the

apparent temperature in the horizontal direction to be uniform. It will be described in detail later in the “(3) Display method” section specifically how the estimator 72 estimates the apparent temperature.

[0031] The determiner 74 determines whether a representative value derived from the apparent temperature distribution estimated by the estimator 72 falls outside of a preset range. In this embodiment, the preset range is a comfortable temperature range. As used herein, the “comfortable temperature range” refers to, for example, a temperature range that allows a human being to perform an activity comfortably. The comfortable temperature range varies from one person to another or from one season to another and may be set arbitrarily by a user such as a person living in the facility 5 or an employee of a management company of the facility 5. In this embodiment, the comfortable temperature range is set by a person living in the facility 5 as a range from 20°C to 24°C. Also, the representative value derived from the apparent temperature distribution refers to, for example, a maximum value, a minimum value, or an average value in the apparent temperature distribution. Alternatively, the representative value may also be a median. In the example shown in FIG. 2, the maximum value of the apparent temperature distribution is 25°C and the minimum value of the apparent temperature distribution is 20°C. The average value of the apparent temperature distribution is calculated based on the apparent temperature distribution and is 22.5°C in the example shown in FIG. 2.

[0032] In addition, the determiner 74 also determines whether an apparent temperature at an arbitrary point in the height direction in the room 50 in the apparent temperature distribution estimated by the estimator 72 falls outside of the comfortable temperature range. The arbitrary point in the height direction may be set arbitrarily by a user such as a person living in the facility 5 or an employee of a management company of the facility 5. In this embodiment, the apparent temperature distribution estimated by the estimator 72 is present only in the height direction, and therefore, the arbitrary point is set as a height above the floor 52. For example, in this embodiment, the arbitrary point is set by a person living in the facility 5 at a height of 1.2 meters above the floor 52.

[0033] When deciding that either the representative value derived from the apparent temperature distribution or the apparent temperature at an arbitrary point in the height direction in the room 50 fall outside of the comfortable temperature range, the determiner 74 notifies the controller 73 to that effect.

[0034] The calculator 75 calculates the proportion of a period in which the representative value derived from the apparent temperature distribution estimated by the estimator 72 falls within a preset comfortable temperature range to an arbitrarily set period. As used herein, the “arbitrarily

set period” refers to a period to be set by a user such as a person living in the facility 5 or an employee of a management company of the facility 5. In the following description, the arbitrarily set period will be hereinafter sometimes referred to as an “evaluation period.” Examples of the evaluation period include one day, one week, one month, three months, and one year. In this embodiment, the evaluation period is set by a person living in the facility 5 at one week.

[0035] In addition, the calculator 75 also calculates the proportion of a period in which the apparent temperature at the arbitrary point in the height direction in the room 50 in the apparent temperature distribution estimated by the estimator 72 falls within the preset comfortable temperature range to the arbitrary set period (evaluation period).

[0036] The calculator 75 notifies the controller 73 of the proportions thus calculated.

[0037] The controller 73 makes the display device 81 of the terminal device 8 present the apparent temperature distribution estimated by the estimator 72. In addition, the controller 73 according to this embodiment makes, in response to the notification received from the determiner 74, the display device 81 display a notification image notifying the user that either the representative value derived from the apparent temperature distribution or the apparent temperature at the arbitrary point has fallen outside of the comfortable temperature range. Furthermore, the controller 73 according to this embodiment makes the display device 81 present the proportions calculated by the calculator 75. The controller 73 according to this embodiment controls the information displayed on the terminal device 8 via the network 6.

[0038] FIG. 3 illustrates an exemplary on-screen image G1 displayed on the display device 81 under the control of the controller 73. In an upper region R1 of the on-screen image G1, displayed is an image G2 representing the apparent temperature distribution in the room 50 that has been estimated by the estimator 72. The image G2 includes a temperature bar corresponding to the apparent temperature distribution. Optionally, the image G2 representing the apparent temperature distribution may also be superimposed on an image captured by shooting the room 50. As used herein, examples of the “image captured by shooting the room 50” include a moving picture, a still picture, and a stop-motion picture.

[0039] Meanwhile, a lower region R2 of the on-screen image G1 includes regions R21, R22, and R23.

[0040] In the region R21 defined on the left-hand side of the region R2, displayed is an image G3 indicating how the estimated apparent temperature changes with time. In FIG. 3, the solid curve L1 indicates how the apparent temperature at the arbitrary point in the room 50 changes with time. The numerical value L2 in FIG. 3 indicates the upper limit of the comfortable temperature range, and the numerical value L3 in FIG. 3 indicates the lower limit of the comfortable

temperature range. In the example shown in FIG. 3, an image G31 is displayed over a part, where the numerical value L2 indicating the upper limit of the comfortable temperature range is exceeded, of the solid curve L1 indicating how the estimated apparent temperature changes with time. The image G31 is a notification image notifying the user that the apparent temperature has exceeded the comfortable temperature range. The image G31 is displayed to attract the user's attention to that part, falling outside of the comfortable temperature range (i.e., the range from the numerical value L2 to the numerical value L3), of the solid curve L1 indicating how the estimated apparent temperature changes with time. Alternatively, the solid curve L1 may also indicate how the representative value (such as an average value) derived from the estimated apparent temperature distribution changes with time.

[0041] In the region R22 defined on the upper right part of the region R2, displayed is an image G4 indicating the proportion of the period in which the estimated apparent temperature falls within the comfortable temperature range to the evaluation period. In this embodiment, the image G4 indicates the proportion of that period in which the estimated apparent temperature falls within the comfortable temperature range to one week (as the evaluation period).

[0042] In the region R23 defined on the lower right part of the region R2, displayed is an image G5 indicating the beginning and end dates of the evaluation period.

### [0043] (3) Display method

Next, a display method (i.e., how the display system 1 operates) will be described with reference to FIGS. 1–4. FIG. 4 is a flowchart showing an exemplary display method according to this embodiment.

[0044] First, the acquirer 71 of the server 7 acquires the first detection value and the second detection value from the temperature sensor 21 and the humidity sensor 22, respectively, via the network 6 (in S1 shown in FIG. 4). Next, the estimator 72 estimates, based on the first detection value acquired by the acquirer 71, a spatial temperature in the space a1 (refer to FIG. 1) on the ceiling surface 511 of the room 50 (more specifically, right under the ceiling 51) (i.e., obtains an estimated spatial temperature [°C]). In this embodiment, the space a1 is a space located at a height of 1 meter or less under the ceiling surface 511. In addition, the estimator 72 also estimates, based on the second detection value acquired by the acquirer 71, a spatial humidity in the space a1 on the ceiling surface 511 of the room 50 (in S2 shown in FIG. 4). In this case, the position where the spatial temperature is estimated by the estimator 72 and the position where the spatial humidity is estimated by the estimator 72 are the same position. More specifically, the estimator 72 according to this embodiment estimates the spatial temperature and spatial humidity in the space a2 (refer to FIG. 1) where the straight-line distance as measured from the first air outlet 241

provided through the ceiling surface 511 is equal to or shorter than  $r1$  (refer to FIG. 1). The estimated spatial temperature calculated by the estimator 72 may be expressed by the following Equation (1) and the estimated spatial humidity calculated by the estimator 72 may be expressed by the following Equation (2):

[0045]

$$Tr = \alpha1 \times Ts + c1 \quad (1)$$

[0046]

$$Hr = \alpha2 \times Hs + c2 \quad (2)$$

[0047] In Equation (1),  $Tr$  is an estimated spatial temperature [ $^{\circ}\text{C}$ ] (in the space  $a2$ ),  $\alpha1$  is a coefficient,  $Ts$  is the first detection value [ $^{\circ}\text{C}$ ], and  $c1$  is a coefficient. For example,  $\alpha1$  may be 0.95 and  $c1$  may be 0.2. In Equation (2),  $Hr$  is an estimated humidity [%] (in the space  $a2$ ),  $\alpha2$  is a coefficient,  $Hs$  is the second detection value [%], and  $c2$  is a coefficient. For example,  $\alpha2$  may be 1.05 and  $c2$  may be 5.0.

[0048] Next, the estimator 72 estimates an apparent temperature (NET) in the space  $a2$  which forms part of the space  $a1$  under the ceiling surface 511 and where the straight-line distance from the first air outlet 241 is equal to or shorter than  $r1$  (in S3 shown in FIG. 4). The estimated apparent temperature in the space  $a2$  may be expressed by the following Equation (3):

[0049]

$$STr = 37 - \frac{37 - Tr}{0.68 - 0.0014Hr + \frac{1}{1.76 + 1.4V^{0.75}}} - 0.29Tr(1 - 0.01Hr) \quad (3)$$

[0050] In Equation (3),  $STr$  is the estimated apparent temperature (in the space  $a2$ ), and  $V$  is an air speed [m/s].  $V$  is an air speed in the room 50. The indoor air speed is equal to or less than as small as approximately 0.3 [m/s] and does not affect the estimated apparent temperature (NET value) significantly even if the indoor air speed is supposed to be constant. Thus, in this embodiment,  $V$  is supposed to be 0.1 [m/s].

[0051] Next, the estimator 72 estimates, by the following Equations (4) and (5), the apparent temperature on a predetermined height basis in the space  $a3$  including the space  $a2$  in the room 50, thereby estimating an apparent temperature distribution in the height direction in the room 50 (in S4 shown in FIG. 4).

[0052]

$$T(h) = \alpha 3 \times h + c3 \quad (4)$$

[0053]

$$c3 = ST_r - Lrf \times \alpha 3 \quad (5)$$

[0054] In Equation (4),  $h$  is a height [m] above the floor,  $T(h)$  is an estimated apparent temperature at the height  $h$  [m] above the floor,  $\alpha 3$  is a coefficient, and  $c3$  is a coefficient. For example,  $\alpha 3$  may be 0.5 and  $c3$  may be 0.2. In Equation (5),  $Lrf$  is the height [m] of the ceiling 51. The estimated apparent temperature at the ceiling 51 calculated by Equation (5) by substituting  $h$  for  $Lrf$  substantially agrees with  $ST_r$  calculated by Equation (3).

[0055] Next, the controller 73 makes the display device 81 (refer to FIG. 3) of the terminal device 8 (refer to FIG. 3) present the apparent temperature distribution estimated by the estimator 72 (in S5 shown in FIG. 4).

[0056] (4) Advantages

As described above, a server 7 according to this embodiment includes an acquirer 71, an estimator 72, and a controller 73. The estimator 72 estimates, based on first and second detection values respectively detected by a temperature sensor 21 and a humidity sensor 22 both included in a ventilator 2, an apparent temperature distribution in a height direction in a room 50. The estimator 72 according to this embodiment may estimate the apparent temperature distribution based on the first and second detection values respectively detected by the temperature sensor 21 and humidity sensor 22 both included in the ventilator 2, thus eliminating the need to provide a lot of sensors or a dedicated sensor for the purpose of measuring the apparent temperature distribution. In addition, the controller 73 according to this embodiment makes a display device 81 of a terminal device 8 present the apparent temperature distribution, estimated by the estimator 72, in the height direction in the room 50. This allows a user such as a person living in the facility 5 or an employee of a management company of the facility 5 to learn the apparent temperature distribution in the room 50 that has been estimated by the estimator 72. Then, the user such as the occupant or the employee may take an appropriate action such as changing the thermal environment according to the apparent temperature distribution. In addition, the estimator 72 according to this embodiment may estimate the apparent temperature distribution in the room 50 based on only the detection values obtained by the temperature sensor 21 and humidity sensor 22 both included in the ventilator 2. This enables estimating the apparent temperature in an environment surrounding the person (user) even without installing a lot of sensors or a dedicated sensor.

[0057] Furthermore, the estimator 72 according to this embodiment estimates, based on the first

detection value and the second detection value, a spatial temperature and a spatial humidity, respectively, in the space a1 on the ceiling surface 511 of the room 50. The estimator 72 estimates, based on the spatial temperature and spatial humidity thus estimated, an apparent temperature distribution in the height direction in the room 50. The spatial temperature and spatial humidity in the space a1 are a spatial temperature and a spatial humidity in the room 50. On the other hand, the first detection value provided by the temperature sensor 21 and the second detection value provided by the humidity sensor 22 are respectively a spatial temperature and a spatial humidity in either the space inside the ventilator 2 or the space surrounding the ventilator 2. This enables estimating the apparent temperature distribution more accurately than in a situation where the apparent temperature distribution in the room 50 is estimated by directly using the first and second detection values provided by the temperature sensor 21 and humidity sensor 22, respectively. Estimating the spatial temperature and spatial humidity in the space a1 in the room 50 eliminates the need to install a temperature-humidity sensor separately in the room 50, thus cutting down the cost effectively.

[0058] Furthermore, the estimated temperature in the space a1 and the estimated humidity in the space a1 are estimated at an identical position by the estimator 72 according to this embodiment. Besides, the estimator 72 according to this embodiment estimates the spatial temperature and spatial humidity in the space a2 which forms part of the space a1 and where the straight-line distance from the first air outlet 241 provided through the ceiling surface 511 is equal to or shorter than  $r1$ . This improves the accuracy of the spatial temperature and spatial humidity estimated, because the air is constantly exchanged in the vicinity of the first air inlet 231 or the first air outlet 241. The estimator 72 estimates the apparent temperature distribution based on the spatial temperature and spatial humidity in the space a2 where the straight-line distance from the first air inlet 231 or the first air outlet 241 is equal to or shorter than 1 meter, for example, thus improving the accuracy of the apparent temperature distribution estimated.

[0059] Furthermore, the server 7 according to this embodiment further includes a determiner 74 that determines whether a representative value derived from the apparent temperature distribution falls outside of a preset comfortable temperature range (preset range). The controller 73 makes, when the determiner 74 decides that the representative value fall outside of the comfortable temperature range, the display device 81 display an image G31 (notification image) notifying a user that the representative value falls outside of the comfortable temperature range. Displaying the notification image on the display device 81 tells a user such as a person who lives in the facility 5 or an employee of a management company of the facility 5 that the representative value falls outside of the comfortable temperature range. The representative value is any one of a maximum

value in the apparent temperature distribution, a minimum value in the apparent temperature distribution, or an average value obtained from the apparent temperature distribution. This enables determining, under a broader condition, whether the representative value derived from the apparent temperature distribution falls outside of the comfortable temperature range.

[0060] Furthermore, the determiner 74 according to this embodiment determines whether an apparent temperature at an arbitrary point in the height direction in the room 50 falls outside of the comfortable temperature range. Displaying a notification image on the display device 81 tells a user such as a person who lives in the facility 5 or an employee of a management company of the facility 5 that the apparent temperature at the arbitrary point falls outside of the comfortable temperature range.

[0061] Furthermore, the server 7 according to this embodiment further includes a calculator 75 that calculates the proportion of a period in which the representative value derived from the apparent temperature distribution falls within a preset comfortable temperature range to an arbitrarily set period (evaluation period). The controller 73 makes the display device 81 present the proportion. This allows a user such as an employee of a management company of the facility 5 to learn the proportion of a period in which the representative value falls within the comfortable temperature range to the evaluation period. If the evaluation period is one day, for example, then the data thus collected may be used effectively as an index for preventing the onset of an acute disease such as heat stroke. On the other hand, if the evaluation period is about three months, for example, then the data thus collected may be used as data to choose the best ventilator 2 on a season-by-season basis. Furthermore, if the evaluation period is about one year, for example, then the data thus collected may be used as data to demonstrate the air conditioning capability of a property (facility 5) itself or present an advantageous feature of the property when luring a tenant.

[0062] Furthermore, the calculator 75 according to this embodiment calculates the proportion of a period in which an apparent temperature at an arbitrary point falls within the comfortable temperature range to the evaluation period. This allows a user such as an employee of a management company of the facility 5 to learn the proportion of a period in which the apparent temperature at the arbitrary point falls within the comfortable temperature range to the evaluation period.

[0063] Furthermore, the estimator 72 according to this embodiment estimates the apparent temperature distribution in the height direction in the room 50 by the above-described Equations (1) to (5). This allows the estimator 72 according to this embodiment to estimate the apparent temperature distribution by analysis formulae and eliminates the need for a complicated algorithm that premises the use of, for example, a cloud computing system involving machine learning, thus

enabling cutting down the cost of the display system.

[0064] (Variations)

Note that the embodiment described above is only an exemplary one of various embodiments of the present disclosure and should not be construed as limiting. Rather, the exemplary embodiment may be readily modified in various manners depending on a design choice or any other factor without departing from the scope of the present disclosure.

[0065] Also, the functions of the display system 1 according to the exemplary embodiment described above may also be implemented as, for example, a display method, a (computer) program, or a non-transitory storage medium on which the program is stored. A display method according to an aspect includes an acquisition step, an estimation step, and a presentation step. The acquisition step includes acquiring a first detection value and a second detection value from a temperature sensor 21 and a humidity sensor 22, respectively. The temperature sensor 21 and the humidity sensor 22 are both included in a ventilator 2 that ventilates a room 50. The estimation step includes estimating, based on the first detection value and the second detection value that are acquired in the acquisition step, an apparent temperature distribution representing a distribution of apparent temperatures in a height direction in the room 50. The presentation step includes making a display device 81 present the apparent temperature distribution estimated in the estimation step. A program according to another aspect is designed to cause one or more processors to perform the display method described above.

[0066] The display system 1 according to the present disclosure may include, for example, a computer system. The computer system may include a processor and a memory as principal hardware components thereof. The functions of the display system 1 according to the present disclosure may be performed by making the processor execute a program stored in the memory of the computer system. The program may be stored in advance in the memory of the computer system. Alternatively, the program may also be downloaded through a telecommunications line or be distributed after having been recorded in some non-transitory storage medium such as a memory card, an optical disc, or a hard disk drive, any of which is readable for the computer system. The processor of the computer system may be made up of a single or a plurality of electronic circuits including a semiconductor integrated circuit (IC) or a large-scale integrated circuit (LSI). As used herein, the “integrated circuit” such as an IC or an LSI is called by a different name depending on the degree of integration thereof. Examples of the integrated circuits include a system LSI, a very-large-scale integrated circuit (VLSI), and an ultra-large-scale integrated circuit (ULSI). Optionally, a field-programmable gate array (FPGA) to be programmed after an LSI has been fabricated or a reconfigurable logic device allowing the

connections or circuit sections inside of an LSI to be reconfigured may also be adopted as the processor. Those electronic circuits may be either integrated together on a single chip or distributed on multiple chips, whichever is appropriate. Those multiple chips may be aggregated together in a single device or distributed in multiple devices without limitation. As used herein, the “computer system” includes a microcontroller including one or more processors and one or more memories. Thus, the microcontroller may also be implemented as a single or a plurality of electronic circuits including a semiconductor integrated circuit or a large-scale integrated circuit.

[0067] Next, variations of the exemplary embodiment will be enumerated one after another. Note that the variations to be described below may be adopted in combination as appropriate.

[0068] In the exemplary embodiment described above, at least some functions of the display system 1 are aggregated together in a single device (i.e., the server 7). However, this is not an essential configuration for the display system 1. Alternatively, the constituent elements of the display system 1 may also be distributed in multiple devices ( housings).

[0069] For example, some functions of the display system 1 may be provided for, for example, the terminal device 8 or any device (housing) other than the server 7. Also, the display system 1 does not have to be provided outside the facility 5 (such as a single-family dwelling house) but may be provided inside the facility 5. In other words, the display system 1 may be provided in a local environment inside the facility 5. Optionally, at least some functions of the display system 1 may also be implemented as a cloud computing system, for example.

[0070] The display system 1 only needs to include at least the acquirer 71, the estimator 72, and the controller 73.

[0071] The display system 1 may include not only the server 7 but also the terminal device 8 as well.

[0072] In the exemplary embodiment described above, the display system 1 is supposed to be introduced into a single-family dwelling house as an example. However, this is only an example and should not be construed as limiting. Alternatively, the display system 1 may also be introduced into any of various other types of facilities 5 including a multi-family dwelling house (such as a so-called “mansion” in Japan) and an office.

[0073] The terminal device 8 may also be a mobile telecommunications device such as a smartphone or a tablet computer and the display device 81 may be implemented as a touchscreen panel display. The terminal device 8 does not have to be provided outside the facility 5 (such as a single-family dwelling house) but may also be provided inside the facility 5.

[0074] In the exemplary embodiment described above, the estimator 72 estimates the apparent temperature distribution using linear equations as Equations (1), (2), (4), and (5) as an example.

However, this is only an example and should not be construed as limiting. Alternatively, the estimator 72 may estimate the apparent temperatures by analysis formulae other than linear equations. For example, the estimator 72 may also estimate the apparent temperatures by approximation expressions according to the indoor environment such as a high-order polynomial, a logarithmic function, or an exponential function. For instance, in a facility in which both floor heating and a heater are operating, the temperature becomes relatively high around the ceiling and floor in a room. In that case, the apparent temperature distribution may be approximated using a quadratic function, a hyperbola, or a trigonometric function, for example. If an approximation expression for estimating the apparent temperatures is an analysis formula, then an algorithm may be implemented easily. Optionally, the approximation expression for estimating the apparent temperatures may also be obtained by, for example, performing a regression analysis when the facility 5 is designed. The regression analysis may be performed based on, for example, a result of temperature and humidity simulations by air current simulation and statistic software. Alternatively, the approximation expression may also be obtained by statistical processing based on the results of environmental measurement to be performed after the facility 5 has been constructed.

[0075] In the exemplary embodiment described above, the ventilator 2 is supposed to be a ventilator of class 1 ventilation. Alternatively, the ventilator 2 may also be a ventilator of class 2 ventilation or a ventilator of class 3 ventilation. If the ventilator 2 is a ventilator of class 2 ventilation, the ventilator 2 uses mechanical power only for the purpose of supplying the air, and there is no need to provide any fan for the exhaust duct 24. On the other hand, if the ventilator 2 is a ventilator of class 3 ventilation, the ventilator 2 uses mechanical power only for the purpose of exhausting the air, and there is no need to provide any fan for the supply air duct 23.

[0076] The temperature sensor 21 and the humidity sensor 22 may also be provided inside the supply air duct 23. In that case, the estimator 72 preferably estimates, based on the first detection value and the second detection value, the spatial temperature and the spatial humidity in the space a2 where the straight-line distance from the first air inlet 231 is equal to or shorter than r1 and then estimates the apparent temperature distribution.

[0077] The notification image does not have to be the image G31 shown in FIG. 3. Alternatively, the notification image may also be an image in which a part, falling outside of the comfortable temperature range (i.e., the range from the numerical value L2 to the numerical value L3), of the solid curve L1 is flickered. Still alternatively, the notification image may also be an image in which the part, falling outside of the comfortable temperature range, of the solid curve L1 is circled in red. Yet alternatively, the notification image may also be an image in which the

part, falling outside of the comfortable temperature range, of the solid curve L1 is displayed in a different color. Yet alternatively, the notification image may also be an image representing a character string notifying the user that the apparent temperature has fallen outside of the comfortable temperature range.

[0078] If the determiner 74 has decided that either a representative value derived from the apparent temperature distribution or an apparent temperature at an arbitrary point have fallen outside of the comfortable temperature range, then the controller 73 may control a loudspeaker included in the terminal device 8, for example, to make the loudspeaker sound an alarm.

[0079] The determiner 74 may determine whether a representative value derived from the apparent temperature distribution or an apparent temperature at an arbitrary point falls outside of the comfortable temperature range. If the determiner 74 has decided that the apparent temperature have fallen outside of the comfortable temperature range, then the controller 73 may make the display device 81 display a notification image notifying the user that the apparent temperature has fallen outside of the comfortable temperature range.

[0080] (Recapitulation)

As can be seen from the foregoing description, a display system (1) according to a first aspect includes an acquirer (71), an estimator (72), and a controller (73). The acquirer (71) acquires a first detection value and a second detection value from a temperature sensor (21) and a humidity sensor (22), respectively. The temperature sensor (21) and the humidity sensor (22) are both included in a ventilator (2) that ventilates a room (50). The estimator (72) estimates, based on the first detection value and the second detection value that are acquired by the acquirer (71), an apparent temperature distribution representing a distribution of apparent temperatures in a height direction in the room (50). The controller (73) makes a display device (81) present the apparent temperature distribution estimated by the estimator (72).

[0081] This aspect allows the display system (1) to estimate, based on first and second detection values provided respectively by a temperature sensor (21) and a humidity sensor (22) both included in a ventilator (2), an apparent temperature distribution in a height direction in a room (50) and make a display device (81) present the apparent temperature distribution thus estimated. This eliminates the need to provide a lot of sensors or a dedicated sensor for the purpose of measuring the apparent temperature distribution, thus enabling cutting down the cost of the display system (1).

[0082] In a display system (1) according to a second aspect, which may be implemented in conjunction with the first aspect, the estimator (72) estimates, based on the first detection value and the second detection value, a spatial temperature on a ceiling surface (511) of the room (50)

and a spatial humidity on the ceiling surface (511) of the room (50), respectively. The estimator (72) thereby estimates, based on the spatial temperature and spatial humidity thus estimated, the apparent temperature distribution in the height direction in the room (50).

[0083] According to this aspect, the estimator (72) estimates a spatial temperature and a spatial humidity on the ceiling surface (511) and then estimates the apparent temperature distribution, thus improving the accuracy of the apparent temperature distribution estimated.

[0084] In a display system (1) according to a third aspect, which may be implemented in conjunction with the second aspect, at least one of an air inlet (first air inlet 231) or an air outlet (first air outlet 241) of the ventilator (2) is provided through the ceiling surface (511). The spatial temperature and the spatial humidity are estimated by the estimator (72) at an identical position. The identical position is a position where a straight-line distance measured from either the air inlet (first air inlet 231) or the air outlet (first air outlet 241) provided through the ceiling surface (511) is equal to or shorter than a predetermined distance (straight-line distance  $r_1$ ).

[0085] This aspect improves the accuracy of the spatial temperature and spatial humidity estimated, because the air is constantly exchanged in the vicinity of the air inlet (first air inlet 231) or air outlet (first air outlet 241) of the ventilator (2). The estimator (72) estimates the apparent temperature distribution based on the spatial temperature and spatial humidity at a position where the straight-line distance from the air inlet (first air inlet 231) or air outlet (first air outlet 241) is equal to or shorter than 1 meter, for example, thus improving the accuracy of the apparent temperature distribution estimated.

[0086] A display system (1) according to a fourth aspect, which may be implemented in conjunction with any one of the first to third aspects, further includes a determiner (74). The determiner (74) determines whether a representative value derived from the apparent temperature distribution falls outside of a preset range. The controller (73) makes, when the determiner (74) decides that the representative value fall outside of the preset range, the display device (81) display a notification image notifying a user that the representative value falls outside of the preset range.

[0087] According to this aspect, displaying a notification image when the representative value derived from the apparent temperature distribution falls outside of a preset range tells a user such as a person who is monitoring the display device (81) or an occupant that the representative value has fallen outside of the preset range.

[0088] In a display system (1) according to a fifth aspect, which may be implemented in conjunction with the fourth aspect, the representative value is any one of a maximum value, a minimum value, or an average value of the apparent temperature distribution.

[0089] According to this aspect, displaying a notification image when any one of a maximum

value, a minimum value, or an average value of the apparent temperature distribution falls outside of a preset range tells a user such as a person who is monitoring the display device (81) or an occupant that the maximum value, minimum value, or average value of the apparent temperature distribution has fallen outside of the preset range.

[0090] A display system (1) according to a sixth aspect, which may be implemented in conjunction with any one of the first to third aspects, further includes a determiner (74). The determiner (74) determines whether an apparent temperature at an arbitrary point in the height direction in the room (50) in the apparent temperature distribution falls outside of a preset range. The controller (73) makes, when the determiner (74) decides that the apparent temperature at the arbitrary point fall outside of the preset range, the display device (81) display a notification image notifying a user that the apparent temperature at the arbitrary point falls outside of the preset range.

[0091] According to this aspect, displaying a notification image when an apparent temperature at an arbitrary point in the height direction in the apparent temperature distribution falls outside of a preset range tells a user such as a person who is monitoring the display device (81) or an occupant that the apparent temperature at the arbitrary point has fallen outside of the preset range.

[0092] A display system (1) according to a seventh aspect, which may be implemented in conjunction with any one of the first to sixth aspects, further includes a calculator (75). The calculator (75) calculates a proportion of a period in which the representative value derived from the apparent temperature distribution falls within a preset range to an arbitrarily set period. The controller (73) makes the display device (81) present the proportion.

[0093] This aspect allows a user such as the monitoring person to learn the proportion of a period in which the representative value falls within a preset range to an arbitrarily set period. If the arbitrarily set period is one day, for example, then the data thus collected may be used effectively as an index for preventing the onset of an acute disease such as heat stroke. On the other hand, if the arbitrarily set period is about three months, for example, then the data thus collected may be used as data to choose the best ventilator (2) on a season-by-season basis. Furthermore, if the arbitrarily set period is about one year, for example, then the data thus collected may be used as data to demonstrate the air conditioning capability of a property (facility) or present an advantageous feature of the property when luring a tenant.

[0094] A display system (1) according to an eighth aspect, which may be implemented in conjunction with any one of the first to sixth aspects, further includes a calculator (75). The calculator (75) calculates a proportion of a period in which an apparent temperature at an arbitrary point in the height direction in the room (50) in the apparent temperature distribution falls within a preset range to an arbitrarily set period. The controller (73) makes the display device (81)

present the proportion.

[0095] This aspect allows a user such as the monitoring person to learn the proportion of a period in which an apparent temperature at an arbitrary point falls within a preset range to an arbitrarily set period. If the arbitrarily set period is one day, for example, then the data thus collected may be used effectively as an index for preventing the onset of an acute disease such as heat stroke. On the other hand, if the arbitrarily set period is about three months, for example, then the data thus collected may be used as data to choose the best ventilator (2) on a season-by-season basis. Furthermore, if the arbitrarily set period is about one year, for example, then the data thus collected may be used as data to demonstrate the air conditioning capability of a property (facility) or present an advantageous feature of the property when luring a tenant.

[0096] In a display system (1) according to a ninth aspect, which may be implemented in conjunction with any one of the first to eighth aspects, the estimator (72) estimates the apparent temperature distribution by the following Equations (1) to (5):

[0097]

$$Tr = \alpha 1 \times Ts + c1 \quad (1)$$

[0098]

$$Hr = \alpha 2 \times Hs + c2 \quad (2)$$

[0099]

$$STr = 37 - \frac{37 - Tr}{0.68 - 0.0014Hr + \frac{1}{1.76 + 1.4V^{0.75}} - 0.29Tr(1 - 0.01Hr)} \quad (3)$$

[0100]

$$T(h) = \alpha 3 \times h + c3 \quad (4)$$

[0101]

$$c3 = STr - Lrf \times \alpha 3 \quad (5)$$

[0102] where  $\alpha 1$ ,  $\alpha 2$ ,  $\alpha 3$ ,  $c1$ ,  $c2$ , and  $c3$  are respective coefficients;

$h$  is a height [m] above a floor;

$Lrf$  is a height [m] of a ceiling;

$V$  is an air speed [m/s];

$T_s$  is the first detection value [ $^{\circ}\text{C}$ ] provided by the temperature sensor (21);

$T_r$  is an estimated temperature [ $^{\circ}\text{C}$ ] in a space (a2);

$ST_r$  is an apparent temperature [ $^{\circ}\text{C}$ ] in the space (a2);

$T(h)$  is an apparent temperature [ $^{\circ}\text{C}$ ] at the height  $h$  above the floor;

$H_s$  is the second detection value [%] provided by the humidity sensor (22); and

$H_r$  is an estimated humidity [%] in the space (a2).

[0103] This aspect allows the estimator (72) to estimate the apparent temperature distribution by analysis formulae and eliminates the need for a complicated algorithm that premises the use of, for example, a cloud computing system involving machine learning, thus enabling cutting down the cost.

[0104] Note that the constituent elements according to the second to ninth aspects are not essential constituent elements for the display system (1) but may be omitted as appropriate.

[0105] A display method according to a tenth aspect includes an acquisition step, an estimation step, and a presentation step. The acquisition step includes acquiring a first detection value and a second detection value from a temperature sensor (21) and a humidity sensor (22), respectively. The temperature sensor (21) and the humidity sensor (22) are both included in a ventilator (2) that ventilates a room (50). The estimation step includes estimating, based on the first detection value and the second detection value that are acquired in the acquisition step, an apparent temperature distribution representing a distribution of apparent temperatures in a height direction in the room (50). The presentation step includes making a display device (81) present the apparent temperature distribution estimated in the estimation step.

[0106] This aspect enables estimating, based on first and second detection values provided respectively by a temperature sensor (21) and a humidity sensor (22) both included in a ventilator (2), an apparent temperature distribution in a height direction in a room (50) and making a display device (81) present the apparent temperature distribution thus estimated. This eliminates the need to provide a lot of sensors or a dedicated sensor for the purpose of measuring the apparent temperature distribution, thus enabling cutting down the cost.

[0107] A program according to an eleventh aspect is designed to cause one or more processors to perform the display method according to the tenth aspect.

[0108] This aspect enables estimating, based on first and second detection values provided respectively by a temperature sensor (21) and a humidity sensor (22) both included in a ventilator (2), an apparent temperature distribution in a height direction in a room (50) and making a display device (81) present the apparent temperature distribution thus estimated. This eliminates the need to provide a lot of sensors or a dedicated sensor for the purpose of measuring the apparent

temperature distribution, thus enabling cutting down the cost.

## Reference Signs List

|        |     |                                                 |
|--------|-----|-------------------------------------------------|
| [0109] | 1   | Display System                                  |
|        | 2   | Ventilator                                      |
|        | 21  | Temperature Sensor                              |
|        | 22  | Humidity Sensor                                 |
|        | 231 | First Air Inlet (Air Inlet)                     |
|        | 241 | First Air Outlet (Air Outlet)                   |
|        | 50  | Room                                            |
|        | 51  | Ceiling                                         |
|        | 511 | Ceiling Surface                                 |
|        | 71  | Acquirer                                        |
|        | 72  | Estimator                                       |
|        | 73  | Controller                                      |
|        | 74  | Determiner                                      |
|        | 75  | Calculator                                      |
|        | 81  | Display Device                                  |
|        | G31 | Image (Notification Image)                      |
|        | r1  | Straight-Line Distance (Predetermined Distance) |

## CLAIMS

1. A display system comprising:
  - an acquirer configured to acquire a first detection value and a second detection value from a temperature sensor and a humidity sensor, respectively, the temperature sensor and the humidity sensor being both included in a ventilator configured to ventilate a room;
  - an estimator configured to estimate, based on the first detection value and the second detection value that are acquired by the acquirer, an apparent temperature distribution representing a distribution of apparent temperatures in a height direction in the room; and
  - a controller configured to make a display device present the apparent temperature distribution estimated by the estimator.
2. The display system of claim 1, wherein
  - the estimator is configured to estimate, based on the first detection value and the second detection value, a spatial temperature on a ceiling surface of the room and a spatial humidity on the ceiling surface of the room, respectively, and thereby estimate, based on the spatial temperature and spatial humidity thus estimated, the apparent temperature distribution in the height direction in the room.
3. The display system of claim 2, wherein
  - at least one of an air inlet or an air outlet of the ventilator is provided through the ceiling surface,
  - the spatial temperature and the spatial humidity are estimated by the estimator at an identical position, and
  - the identical position is a position where a straight-line distance measured from either the air inlet or the air outlet provided through the ceiling surface is equal to or shorter than a predetermined distance.
4. The display system of any one of claims 1 to 3, further comprising a determiner configured to determine whether a representative value derived from the apparent temperature distribution falls outside of a preset range, wherein
  - the controller is configured to, when the determiner decides that the representative value

fall outside of the preset range, make the display device display a notification image notifying a user that the representative value falls outside of the preset range.

5. The display system of claim 4, wherein  
the representative value is any one of a maximum value, a minimum value, or an average value of the apparent temperature distribution.

6. The display system of any one of claims 1 to 3, further comprising a determiner configured to determine whether an apparent temperature at an arbitrary point in the height direction in the room in the apparent temperature distribution falls outside of a preset range, wherein

the controller is configured to, when the determiner decides that the apparent temperature at the arbitrary point fall outside of the preset range, make the display device display a notification image notifying a user that the apparent temperature at the arbitrary point falls outside of the preset range.

7. The display system of any one of claims 1 to 6, further comprising a calculator configured to calculate a proportion of a period in which the representative value derived from the apparent temperature distribution falls within a preset range to an arbitrarily set period, wherein

the controller is configured to make the display device present the proportion.

8. The display system of any one of claims 1 to 6, further comprising a calculator configured to calculate a proportion of a period in which an apparent temperature at an arbitrary point in the height direction in the room in the apparent temperature distribution falls within a preset range to an arbitrarily set period, wherein

the controller is configured to make the display device present the proportion.

9. The display system of any one of claims 1 to 8, wherein  
the estimator is configured to estimate the apparent temperature distribution by the following Equations (1) to (5):

$$Tr = \alpha 1 \times Ts + c1 \quad (1)$$

$$Hr = \alpha 2 \times Hs + c2 \quad (2)$$

$$STr = 37 - \frac{37 - Tr}{0.68 - 0.0014Hr + \frac{1}{1.76 + 1.4V^{0.75}}} - 0.29Tr(1 - 0.01Hr) \quad (3)$$

$$T(h) = \alpha 3 \times h + c3 \quad (4)$$

$$c3 = STr - Lrf \times \alpha 3 \quad (5)$$

where  $\alpha 1$ ,  $\alpha 2$ ,  $\alpha 3$ ,  $c1$ ,  $c2$ , and  $c3$  are respective coefficients;

$h$  is a height [m] above a floor;

$Lrf$  is a height [m] of a ceiling;

$V$  is an air speed [m/s];

$Ts$  is the first detection value [°C] provided by the temperature sensor;

$Tr$  is an estimated spatial temperature [°C] on a ceiling surface;

$STr$  is an apparent temperature [°C] in the room;

$T(h)$  is an apparent temperature [°C] at the height  $h$  above the floor;

$Hs$  is the second detection value [%] provided by the humidity sensor; and

$Hr$  is an estimated humidity [%] on the ceiling surface.

10. A display method comprising:

an acquisition step including acquiring a first detection value and a second detection value from a temperature sensor and a humidity sensor, respectively, the temperature sensor and the humidity sensor being both included in a ventilator configured to ventilate a room;

an estimation step including estimating, based on the first detection value and the second detection value that are acquired in the acquisition step, an apparent temperature distribution representing a distribution of apparent temperatures in a height direction in the room; and

a presentation step including making a display device present the apparent temperature distribution estimated in the estimation step.

11. A program designed to cause one or more processors to perform the display method of claim 10.