

## TITLE:

# MODEL GENERATION DEVICE, MODEL GENERATION PROGRAM, AND MODEL GENERATION METHOD

## BACKGROUND

### Technical Field

**[0001]** The present invention relates to a model generation device, a model generation program, and a model generation method.

### Related Art

**[0002]** There is a variable air volume (VAV)-type air conditioning system as follows. In an air conditioning system, by controlling a supply air temperature and a total air supply amount to all air conditioning zones on an air conditioner side, and by controlling an air supply amount to each air conditioning zone by a VAV unit, the air in each air conditioning zone is conditioned (Patent Document 1).

### Prior-Art Documents

### Patent Documents

**[0003]** [Patent Document 1] Japanese Patent Laid-Open No. 2016-125688

## SUMMARY OF THE INVENTION

### Problems to Be Solved by the Invention

**[0004]** The above air conditioning system is a kind of control system in which the air in an air conditioning zone is taken as a control object. By grasping which of a plurality of states the control object is in, a user such as an administrator of the control system is able to deal with an abnormality or the like in the control system. Thus, it is desired that the user properly grasp which of the plurality of states the control object is in.

**[0005]** As an example, the user such as the administrator of the above air conditioning system monitors a state of the environment (air) of an air conditioning zone by monitoring a measured value (such as room temperature and airflow) of the indoor environment. However, it is difficult for the user to properly grasp a state (state subjectively felt by a resident of the air conditioning zone) of the environment of the air conditioning zone that the resident feels only by monitoring the measured value. As a result, the user such as the administrator is unable to discover an abnormality in the state of the environment of the air conditioning zone until a complaint or the like comes from the resident of the air conditioning zone, or the discovery may be delayed. As described above, in a conventional air conditioning system, since the user is unable to properly grasp the state of the environment of the air conditioning zone, a disadvantage may occur that the user is unable to deal with an abnormality in the state.

**[0006]** The present invention has been made in view of the above points, and an object thereof is to allow a user to properly grasp a state of a control object of a control system.

#### Means for Solving the Problems

**[0007]** In order to solve the above problems, a model generation device according to the present invention includes: a teacher data acquisition part, configured to acquire a plurality of teacher data that use a measured value related to which of a plurality of states a control object controlled by a control system is in as an explanatory variable and a state among the plurality of states at the time of the measured value as an objective variable; and a model generator, configured to generate, by statistical machine learning based on the plurality of teacher data, a model that uses the measured value newly measured as an input value and derives a probability of each of the plurality of states the control object is able to take at the time of the input value.

**[0008]** The model generation device may further include: a probability acquisition part, configured to input the measured value newly measured to the model and acquire the probability of each of the plurality of states derived by the model; and a notifier, configured to issue a

notification of at least a state with the highest probability among the plurality of states based on the probability of each of the plurality of states acquired by the probability acquisition part.

**[0009]** The model generation device may further include: a probability acquisition part, configured to input the measured value newly measured to the model and acquire the probability of each of the plurality of states derived by the model; and a notifier, configured to issue a notification of at least a portion of the probability of each of the plurality of states acquired by the probability acquisition part.

**[0010]** The model generation device may further include: a probability acquisition part, configured to input the measured value newly measured to the model and acquire the probability of each of the plurality of states derived by the model; and a notifier, configured to issue a notification that any of the probability of each of the plurality of states acquired by the probability acquisition part exceeds a predetermined value when the same occurs.

**[0011]** The model may be a model using the following equation (A) by a naive Bayes method.

$$P(y|x)=P(x|y)*P(y)/P(x).....(A)$$

x is the measured value, and y is any of the plurality of states.

**[0012]** P(y) may be user settable.

**[0013]** P(x|y) may be specified by using a histogram showing a distribution of P(x|y) for each measured value.

**[0014]** The teacher data acquisition part may be configured to specify a state of the control object as the objective variable based on information input by a user to the control system that controls the control object.

**[0015]** The control object may be air in an air conditioning zone. The control system may be an air conditioning system that controls the air. The teacher data acquisition part may be configured to take the objective variable of the teacher data when the user raises a set temperature of the air conditioning system as “cold” and take the objective variable of the teacher data when the user lowers the set temperature of the air conditioning system as “hot”.

**[0016]** A model generation method according to the present invention includes: a teacher data acquisition step, configured to acquire a plurality of teacher data that use a measured value related to which of a plurality of states a control object controlled by a control system is in as an explanatory variable and a state among the plurality of states at the time of the measured value as an objective variable; and a model generation step, configured to generate, by statistical machine learning based on the plurality of teacher data, a model that uses the measured value newly measured as an input value and derives a probability of each of the plurality of states the control object is able to take at the time of the input value.

**[0017]** A model generation program according to the present invention causes a computer to execute: a teacher data acquisition step, configured to acquire a plurality of teacher data that use a measured value related to which of a plurality of states a control object controlled by a control system is in as an explanatory variable and a state among the plurality of states at the time of the measured value as an objective variable; and a model generation step, configured to generate, by statistical machine learning based on the plurality of teacher data, a model that uses the measured value newly measured as an input value and derives a probability of each of the plurality of states the control object is able to take at the time of the input value.

#### Effects of the Invention

**[0018]** According to the present invention, a user is able to properly grasp a state of a control object of a control system.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0019]** FIG. 1 is a hardware configuration diagram of a model generation device and an air conditioning system according to an embodiment of the present invention.

FIG. 2 is a configuration diagram of a model generation device.

FIG. 3 illustrates a configuration example of time series data and teacher data.

FIG. 4 illustrates a configuration example of time series data and teacher data.

FIG. 5 is a graph of probability distribution of  $P(x|y)$  with respect to room temperature.

FIG. 6 is a graph of probability distribution of  $P(x|y)$  with respect to supply air temperature.

FIG. 7 is a graph of probability distribution of  $P(x|y)$  with respect to air supply amount.

FIG. 8 is a table showing each value of  $P(x|y)$  derived by a model.

FIG. 9 illustrates a notification image displayed on a display device.

FIG. 10 illustrates a notification image displayed on a display device.

## DESCRIPTION OF THE EMBODIMENTS

**[0020]** Hereinafter, an embodiment of the present invention will be described with reference to the drawings.

**[0021]** As shown in FIG. 1, a model generation device 50 of the present embodiment is configured as a monitoring device monitoring an air conditioning system 10. Hereinafter, the model generation device 50 will be described after description of the air conditioning system 10.

**[0022]** The air conditioning system 10 is configured as a VAV air conditioning system in which the air in an air conditioning zone Z1 and the air in an air conditioning zone Z2 (more specifically, room temperature T1 and room temperature T2 to be described later) are taken as a control object and are individually controlled.

**[0023]** The air conditioning system 10 includes an air conditioner 11, an air supply duct 12, VAV units 13A and 13B, a supply air temperature sensor 14, airflow meters 15A and 15B, room temperature sensors 16A and 16B, air conditioning operation panels 17A and 17B, VAV controllers 18A and 18B, and an air conditioner controller 19.

**[0024]** The air conditioner 11 is configured to supply conditioned air being cooled or heated air. The air supply duct 12 constitutes a flow path of the conditioned air supplied from the air conditioner 11 to the air conditioning zones Z1 and Z2 respectively via the VAV units 13A and 13B. The VAV units 13A and 13B control an air supply amount of the conditioned air to the air conditioning zones Z1 and Z2, respectively. Each of the VAV units 13A and 13B includes a

damper and an actuator controlling an opening degree of the damper. The air supply amount of the conditioned air is controlled by the opening degree of the damper.

**[0025]** The supply air temperature sensor 14 measures, as a supply air temperature  $T_{sa}$ , a temperature of the conditioned air from the air conditioner 11. The airflow meters 15A and 15B respectively measure, as an air supply amount  $Q_1$  and an air supply amount  $Q_2$ , a flow rate of the conditioned air to the air conditioning zones  $Z_1$  and  $Z_2$ , respectively. The air supply amounts  $Q_1$  and  $Q_2$  are represented by a ratio to a maximum air supply amount of the air conditioning zone  $Z_1$  or  $Z_2$ . The air supply amounts  $Q_1$  and  $Q_2$  may be represented by flow rate ( $m^3/h$ ). The room temperature sensors 16A and 16B respectively measure the room temperature  $T_1$  of the air conditioning zone  $Z_1$  and the room temperature  $T_2$  of the air conditioning zone  $Z_2$ .

**[0026]** The air conditioning operation panel 17A is operated by a user  $U_1$  present in the air conditioning zone  $Z_1$ . By the operation performed by the user  $U_1$  (for example, a tenant resident as a tenant of air conditioning zone  $Z_1$ ), the air conditioning operation panel 17A receives input of a set temperature  $SP_1$  being a target temperature of the room temperature  $T_1$  of the air conditioning zone  $Z_1$ . The air conditioning operation panel 17B is operated by a user  $U_2$  (for example, a tenant resident as a tenant of air conditioning zone  $Z_2$ ) present in the air conditioning zone  $Z_2$ . By the operation performed by the user  $U_2$ , the air conditioning operation panel 17B receives input of a set temperature  $SP_2$  being a target temperature of the room temperature  $T_2$  of the air conditioning zone  $Z_2$ .

**[0027]** Each of the VAV controllers 18A and 18B is configured to include various computers such as a programmable logic controller (PLC).

**[0028]** The set temperature  $SP_1$  input to the air conditioning operation panel 17A is set in the VAV controller 18A. Based on a deviation between the set temperature  $SP_1$  and the room temperature  $T_1$  measured by the room temperature sensor 16A, the VAV controller 18A calculates a required air supply amount for the room temperature  $T_1$  to reach the set temperature  $SP_1$ . The VAV controller 18A, while transmitting the required air supply amount to the air conditioner

controller 19, controls the opening degree of the damper of the VAV unit 13A so as to secure the required air supply amount. The VAV controller 18A controls the opening degree of the damper based on a deviation between the air supply amount Q1 measured by the airflow meter 15A and the required air supply amount. The VAV controller 18A supplies, on a regular basis (for example, every 10 minutes), the set temperature SP1, the air supply amount Q1 and the room temperature T1 at that time to the model generation device 50 via the air conditioner controller 19.

**[0029]** Similarly, the VAV controller 18B transmits to the air conditioner controller 19 a required air supply amount calculated based on a deviation between the set temperature SP2 and the room temperature T2. Further, the VAV controller 18B controls the opening degree of the damper of the VAV unit 13B based on a deviation between the air supply amount Q2 and the required air supply amount so as to secure the required air supply amount. The VAV controller 18B supplies, on a regular basis (for example, every 10 minutes), the set temperature SP2, the air supply amount Q2 and the room temperature T2 at that time to the model generation device 50 via the air conditioner controller 19.

**[0030]** The air conditioner controller 19 is configured to include various computers such as a PLC and a personal computer. The air conditioner controller 19 controls the air conditioner 11 so that a temperature (here, supply air temperature Tsa measured by supply air temperature sensor 14) of the conditioned air supplied from the air conditioner 11 matches a preset supply air temperature set value SPsa. The supply air temperature set value SPsa is changed periodically according to a predetermined schedule. Further, the air conditioner controller 19 controls the air conditioner 11 so as to blow the conditioned air at an air supply amount that secures the required air supply amount from each of the VAV controllers 18A and 18B. The air conditioner controller 19 supplies, on a regular basis (for example, every 10 minutes), the supply air temperature Tsa at that time to the model generation device 50.

**[0031]** The model generation device 50 is configured as a monitoring device monitoring the air conditioning system 10. The model generation device 50 generates models M1 and M2 to be

described later. The model generation device 50 is composed of various computers such as a personal computer, a server computer, and a PLC. As shown in FIG. 1, the model generation device 50 includes a processor 51 such as a central processing unit (CPU), a random access memory (RAM) 52 functioning as a main memory of the processor 51, and a storage 53 storing a model generation program executed by the processor 51 and teacher data or the like to be described later. The storage 53 is composed of a non-volatile storage such as a hard disk and a solid state drive (SSD). The model generation device 50 further includes an operation device 54 including a keyboard, a mouse, a touch sensor or the like, and a display device 55 displaying various images. The model generation device 50 further includes a communication module (not shown) communicating with the air conditioner controller 19 by wire or wirelessly.

**[0032]** By executing the model generation program stored in the storage 53, the processor 51 acts as an information collector 51A, a teacher data acquisition part 51B, a model generator 51C, a probability acquisition part 51D, and a notifier 51E shown in FIG. 2.

**[0033]** The information collector 51A collects the room temperatures T1 and T2, the supply air temperature Tsa, the air supply amounts Q1 and Q2 and the set temperatures SP1 and SP2 supplied on a regular basis from the air conditioner controller 19 and from the VAV controllers 18A and 18B via the air conditioner controller 19, and sequentially stores the same in the storage 53. The information collector 51A sequentially stores these information in the storage 53 in association with time information indicating a time at which the information is supplied. At this time, the information collector 51A stores the information in the storage 53 separately for the air conditioning zone Z1 and the air conditioning zone Z2. Accordingly, these information are stored as time series data of the air conditioning zones Z1 and Z2 as shown in FIG. 3 and FIG. 4 in the storage 53. In the time series data of the air conditioning zone Z1, the room temperature T1, the supply air temperature Tsa, the air supply amount Q1 and the set temperature SP1 are associated with each time. In the time series data of the air conditioning zone Z2, the room

temperature T2, the supply air temperature Tsa, the air supply amount Q2 and the set temperature SP2 are associated with each time.

**[0034]** The teacher data acquisition part 51B shown in FIG. 2 acquires teacher data D1 and teacher data D2 based on the time series data of each of the air conditioning zones Z1 and Z2 stored in the storage 53. As shown on the right side of FIG. 3, the teacher data D1 regarding the air conditioning zone Z1 is data that use each measured value of the room temperature T1, the supply air temperature Tsa and the air supply amount Q1 as an explanatory variable, and a state of air (control object of air conditioning system 10) in the air conditioning zone Z1 affected by the each measured value as an objective variable (label). The state of air as the objective variable is a subjective state felt by the user U1 with respect to this air (particularly room temperature T1). Examples of the state include “cold”, “hot”, and “others”. Similarly, as shown on the right side of FIG. 4, the teacher data D2 regarding the air conditioning zone Z2 is data that use each measured value of the room temperature T2, the supply air temperature Tsa and the air supply amount Q2 as an explanatory variable, and the state of air (control object of air conditioning system 10) in the air conditioning zone Z2 affected by the each measured value as an objective variable (label). Each record corresponding to one line shown in FIG. 3 and FIG. 4 is one piece of the teacher data D1 or D2.

**[0035]** When the user U1 feels “cold” about the air in the air conditioning zone Z1, it is conceivable that the user U1 operates the air conditioning operation panel 17A and raises the set temperature SP1. When the user U1 feels “hot” about the air in the air conditioning zone Z1, it is conceivable that the user U1 operates the air conditioning operation panel 17A and lowers the set temperature SP1. The same applies to the set temperature SP2.

**[0036]** From the above, as shown in FIG. 3 and FIG. 4, the teacher data acquisition part 51B labels the teacher data immediately before a rise of the set temperature SP1 or SP2 with “cold” as an objective variable. The teacher data acquisition part 51B labels the teacher data immediately before a drop of the set temperature SP1 or SP2 with “hot” as an objective variable. The teacher

data acquisition part 51B labels the other teacher data (that is, teacher data in which set temperature SP1 or SP2 undergoes no change before and after) with “others” as an objective variable. A reason is that it is difficult to grasp how the user U1 or U2 feels.

**[0037]** The model generator 51C generates the model M1 for the air conditioning zone Z1 by statistical machine learning according to the teacher data D1. In the model M1, a newly measured value (room temperature T1, supply air temperature Tsa, and air supply amount Q1) is used as an input value, and a probability of each of states (“cold”, “hot”, and “others” felt by user U1) the air may take at the time of the input value is derived and output. The model generator 51C generates the model M2 for the air conditioning zone Z2 by statistical machine learning according to the teacher data D2. In the model M2, a newly measured value (room temperature T2, supply air temperature Tsa, and air supply amount Q2) is used as an input value, and a probability of each of states (“cold”, “hot”, and “others” felt by user U2) the air may take at the time of the input value is derived and output. The models M1 and M2 are also collectively referred to as a model M.

**[0038]** In the generated model M, each probability is calculated by a naive Bayes method using the following equation (1).

$$P(y|x)=P(x|y)*P(y)/P(x).....(1)$$

Here, x is a measured value, and y indicates any of “cold”, “hot”, and “others”. P(y) is a probability that a state becomes y, and is also called a prior probability. P(x) is a probability that a measured value becomes x, and is also called a marginal likelihood. P(x|y) is a conditional probability that a value measured when a state is y becomes x, and is a likelihood. P(y|x) is a probability that a state when a measured value is x becomes y, and is a posterior probability. The above equation (1) is prepared for each air conditioning zone.

**[0039]** Since P(x) is independent of an objective variable, there is no need to obtain a specific numerical value thereof. Here, as described later, each P(x|y)\*P(y) is normalized so that the sum

of each  $P(y|x)$  of all  $y$  (that is, “cold”, “hot”, and “others”) is 100%. By this normalization,  $P(x)$  is taken into consideration.

**[0040]**  $P(y)$  is usually obtained by a constituent ratio of “cold”, “hot”, and “others”. However, since “cold” and “hot” are used only when a change occurs in the set temperature SP1 or SP2, the constituent ratio thereof is very likely to deviate from an actual situation. Accordingly,  $P(y)$  may be set on the user side. The user operates the operation device 54 and sets appropriate  $P(y)$ . Here,  $P(y)$  is equal in each state, that is,  $P(\text{cold})=P(\text{hot})=P(\text{others})=1/3$ .

**[0041]**  $P(x|y)$  is defined by statistical machine learning. Here, by statistical machine learning, the model generator 51C approximates a set of teacher data by an appropriate probability distribution in the form of a histogram showing the probability (likelihood) of each measured value as shown in FIG. 5 to FIG. 7. This approximated probability distribution indicates  $P(x|y)$ . The probability distribution is defined for each model and for each measured value. FIG. 5 shows a probability distribution of the room temperature T1 used in the model M1. FIG. 6 shows a probability distribution of the supply air temperature Tsa used in the model M1. FIG. 7 shows a probability distribution of the air supply amount Q1 used in the model M1. The probability distribution is stored in the storage 53 for reference.

**[0042]** After generation of the models M1 and M2, the probability acquisition part 51D of FIG. 2 acquires the room temperature T1, the supply air temperature Tsa and the air supply amount Q1 supplied from the air conditioner controller 19 or from the VAV controller 18A via the air conditioner controller 19 and measured by the room temperature sensor 16A and so on. The probability acquisition part 51D inputs the acquired information to the model M1, and acquires the probability of each of “cold”, “hot”, and “others” being a state of air in the air conditioning zone Z1 at the time of the input value that is output by the model M1 in response to the input.

**[0043]** Hereinafter, an operation of the model M1 will be described assuming that the input values input to the model M1 include the room temperature  $T1=26.0\text{ }^{\circ}\text{C}$ ,  $Tsa=14.0\text{ }^{\circ}\text{C}$ , and the air supply amount  $Q1=40\%$ .

**[0044]** With reference to the probability distribution shown in FIG. 5, the model M1 acquires  $P(x|y)$  corresponding to a value (including 26.0 °C) closest to the room temperature T1 of 26.0 °C, that is,  $P(x|cold)$ ,  $P(x|hot)$ , and  $P(x|others)$  (see dotted line portion A). With reference to the probability distribution shown in FIG. 6, the model M1 acquires  $P(x|y)$  corresponding to a value (including 14.0 °C) closest to Tsa of 14.0 °C, that is,  $P(x|cold)$ ,  $P(x|hot)$ , and  $P(x|others)$  (see dotted line portion B). With reference to the probability distribution shown in FIG. 7, the model M1 acquires  $P(x|y)$  corresponding to a value (including 40%) closest to the air supply amount Q1 of 40%, that is,  $P(x|cold)$ ,  $P(x|hot)$ , and  $P(x|others)$  (see dotted line portion C). In this way, with reference to a probability distribution showing a distribution of the probability (likelihood) of each measured value, the model M1 acquires  $P(x|y)$  corresponding to a measured value (including one having the same value as the input value) closest to the input value in the probability distribution.

**[0045]**  $P(x|y)$  for each input value and for each state of air in the air conditioning zone Z1 acquired in this way is shown in FIG. 8. In the model M1, regarding each of “cold”, “hot”, and “others” being the state of air, three  $P(x|y)$  for each measured value are multiplied to calculate  $P(x|y)$  of “cold”, “hot”, and “others” of the entire model M1 to which three measured values are input, that is,  $P(x|cold)$ ,  $P(x|hot)$ , and  $P(x|others)$  of the entire model M1. In the model M1,  $P(x1|cold)$  ( $x1=[26.0\text{ °C}, 14.0\text{ °C}, 40\%]$ , the same applies hereinafter) of the entire model M1 is calculated to be  $P(T1=26.0\text{ °C}|cold)*P(Tsa=14.0\text{ °C}|cold)*P(Q1=40\%|cold)=0.011*0.274*0.073=0.00022$ . Similarly, in the model M1,  $P(x1|hot)$  and  $P(x1|others)$  of the entire model M1 are calculated.

**[0046]** In the model M1, by substituting each of the calculated  $P(x1|cold)$ ,  $P(x1|hot)$ , and  $P(x1|others)$  for  $P(x|y)$  in the above (1),  $P(y|x)$  for each state y, that is,  $P(cold|x1)$ ,  $P(hot|x1)$ , and  $P(others|x1)$  are calculated. Here, as described above,  $P(y)$  is set to 1/3, which is the same in each state.  $P(x)$  is considered by normalizing each of  $P(x1|cold)*P(cold)$ ,  $P(x1|hot)*P(hot)$  and  $P(x1|others)*P(others)$  so that the sum of  $P(cold|x1)$ ,  $P(hot|x1)$ , and  $P(others|x1)$  is 100%.

**[0047]** In the model M1,  $P(\text{cold}|x1)$ ,  $P(\text{hot}|x1)$ , and  $P(\text{others}|x1)$  are calculated by the following equations. However, due to normalization of  $P(x1|y)*P(y)$ ,  $P(x1)=P(x1|\text{cold})*P(\text{cold})+P(x1|\text{hot})*P(\text{hot})+P(x1|\text{others})*P(\text{others})]/100$ .

$$\bullet P(\text{cold}|x1)=P(x1|\text{cold})*P(\text{cold})/P(x1)=1\%$$

$$\bullet P(\text{hot}|x1)=P(x1|\text{hot})*P(\text{hot})/P(x1)=75\%$$

$$\bullet P(\text{others}|x1)=P(x1|\text{others})*P(\text{others})/P(x1)=24\%$$

**[0048]** The model M1 outputs each probability calculated to the probability acquisition part 51D. In this way, in the model M1, when a measured value (in the above, room temperature  $T1=26.0\text{ }^{\circ}\text{C}$ , supply air temperature  $Tsa=14.0\text{ }^{\circ}\text{C}$ , and air supply amount  $Q1=40\%$ ) newly measured is input, the probability of each of “cold”, “hot”, and “others” that the state of air in the air conditioning zone Z1 at the time of this measured value may take is calculated and output to the probability acquisition part 51D.

**[0049]** The probability acquisition part 51D of FIG. 2 acquires the room temperature  $T2$ , the supply air temperature  $Tsa$  and the air supply amount  $Q2$  supplied from the air conditioner controller 19 or from the VAV controller 18B via the air conditioner controller 19 and measured by the room temperature sensor 16B and so on. The probability acquisition part 51D inputs the acquired information to the model M2, and acquires the probability of each of “cold”, “hot”, and “others” being a state of air in the air conditioning zone Z2 at the time of the input value that is output by the model M2 in response to the input. The operation of the model M2 conforms to the operation of the model M1 described above.

**[0050]** Based on the probability of each of “cold”, “hot”, and “others” acquired by the probability acquisition part 51D, the notifier 51E notifies the user of a state with the highest probability among “cold”, “hot”, and “others”. For example, the notifier 51E generates, for example, an image of FIG. 9 and displays the same on the display device 55. The image of FIG. 9 shows each state in which the state with the highest probability among the probabilities output from the model M1 is taken as the state of air in the air conditioning zone Z1 and the state with

the highest probability among the probabilities output from the model M2 is taken as the state of air in the air conditioning zone Z2. For the room temperature and the set temperature in FIG. 9, for example, the room temperatures T1 and T2 supplied from the VAV controllers 18A and 18B via the air conditioner controller 19 and the set temperatures SP1 and SP2 are used.

**[0051]** The probability acquisition part 51D may acquire the probability of each state of the air conditioning zones Z1 and Z2 by utilizing the models M1 and M2 every time the room temperatures T1 and T2, the supply air temperature Tsa, and the air supply amounts Q1 and Q2 are acquired on a regular basis. Then, every time the probability acquisition part 51D acquires the probability, the notifier 51E may update the state of air in the air conditioning zones Z1 and Z2 displayed on the display device 55. Accordingly, the latest state of air is displayed on the display device 55.

**[0052]** As described above, the notifier 51E may display on the display device 55 an image showing a displacement of each probability acquired on a regular basis by the probability acquisition part 51D. Specifically, as shown in FIG. 10, the notifier 51E may display on the display device 55 a graph of time changes (time series data) in the room temperature T1 and the set temperature SP1 of the air conditioning zone Z1 and a graph of time changes (time series data) in the probability of each of “cold” and “hot” output from the model M1 in association with a time axis. As shown in FIG. 10, the probability of “cold” before the set temperature SP1 rises, that is, before the user U1 feels cold and raises the set temperature SP1, is high. The probability of “hot” before the set temperature SP1 drops, that is, before the user U1 feels hot and lowers the set temperature SP1, is high. Hence, the probability output by the model M1 properly reflects “cold” and “hot” felt by the user U1, that is, the state of air in the air conditioning zone Z1. The notifier 51E may display the same image as in FIG. 10 for the air conditioning zone Z2.

**[0053]** In the case where any of the probabilities of “cold”, “hot”, and “others” (particularly any of the probabilities of “cold” and “hot”) acquired by the probability acquisition part 51D exceeds a predetermined value, the notifier 51E may issue a notification of the same. For

example, the notifier 51E may monitor each probability acquired by the probability acquisition part 51D, and if the probability of “cold” for the air conditioning zone Z1 exceeds the predetermined value, the notifier 51E may display on the display device 55 a message image indicating “it is likely to be cold in the air conditioning zone Z1” or the like.

**[0054]** The notifier 51E may perform the above notification by outputting a warning sound from a speaker or the like, or by lighting a warning lamp or the like.

**[0055]** An administrator of the air conditioning system 10 performs predetermined work in response to the above notification. For example, if an air conditioning zone having a high probability of being “cold” or “hot” has a set temperature set to “automatic”, the administrator changes the set temperature. A change of setting is performed by operation of the operation device 54 of the model generation device 50. The set temperature after change that is input to the model generation device 50 is set in the VAV controller 18A or 18B via the air conditioner controller 19. For example, in the case where there is an air conditioning zone having a high probability of being “cold” or “hot”, the administrator may change various settings (such as supply air temperature set value SPsa, and damper opening degree of VAV unit 13A or 13B) of the air conditioning system 10. This change is also performed by operation of the operation device 54. If the state having a high probability of being “cold” or “hot” occurs frequently, the administrator of the air conditioning system 10 may perform maintenance of the entire air conditioning system 10.

**[0056]** As described above, in this embodiment, the models M1 and M2 are generated by statistical machine learning from the teacher data D1 or D2 that use the measured value such as the room temperature T1 as the explanatory variable and the state of air in the air conditioning zone Z1 as the objective variable. The models M1 and M2 derive the probability of each state (“cold”, “hot”, and “others”) the air in each of the air conditioning zones Z1 and Z2 may take with respect to the measured value as an input value. By confirming this probability or the information output from the model generation device based on this probability, a user as the

administrator of the air conditioning system 10 is able to grasp the probability of the state of air in each of the air conditioning zones Z1 and Z2 and is able to properly grasp the state of air.

**[0057]** In the above, a case where there are two air conditioning zones has been illustrated. However, in a VAV-type air conditioning system applied to a large-scale building, the number of air conditioning zones becomes huge. In this case, it is difficult for the administrator to grasp the state of air in each air conditioning zone every time. As in this embodiment, by generating a model for each air conditioning zone, calculating the probability of the state of each air conditioning zone, and performing notification by the notifier 51E, a monitoring burden on the administrator is reduced.

**[0058]** Since the way the users U1 and U2 feel “cold” or “hot” is affected by personal temperature sensitivity, it is difficult for the administrator to deal with “cold” or “hot” only by monitoring a measured value such as room temperature. In this embodiment, teacher data in which an objective variable (label) with respect to the measured value when a change is made in the set temperature by the users U1 and U2 is “cold” or “hot” is used in machine learning. Accordingly, each probability output by the models M1 and M2 is able to reflect a situation that is difficult to grasp from the personal temperature sensitivity of the users U1 and U2, that is, the measured value, and the administrator is able to properly grasp the state of air in the air conditioning zones Z1 and Z2 (here, user’s subjective state).

**[0059]** Conventionally, the administrator has not been able to grasp that the air in the air conditioning zone Z1 or Z2 is in a bad condition until a complaint or the like comes from the user U1 or U2 present in the air conditioning zone Z1 or Z2. In this embodiment, by the models M1 and M2, the administrator is able to grasp and deal with a bad condition of air in the air conditioning zone Z1 or Z2 before a complaint or the like occurs. The administrator is also able to deal with an originally undesired state (state in which user U1 or U2 endures) in which no complaint occurs.

**[0060]** When there is a complaint from the user U1 or U2, teacher data that use the content (“cold” or “hot”) of the complaint as an objective variable and a measured value at the time of the complaint as an explanatory variable may be used for the above machine learning. However, since the complaint does not occur frequently, the amount of the teacher data based on the complaint is usually small. Even if it is intended to perform machine learning only by the teacher data, it is difficult to secure a sufficient amount of teacher data for the machine learning. In this embodiment, when a change occurs in the set temperature SP1 or SP2, the objective variable is set by focusing on the fact that it can be presumed that the user U1 or U2 may feel “cold” or “hot”, and the change occurs more frequently than the above complaint. Hence, it is easy to obtain a required amount of teacher data for machine learning.

**[0061]** In this embodiment, since the models M1 and M2 are models using “ $P(y|x)=P(x|y)*P(y)/P(x)$ ” being the above equation (1) by the naive Bayes method, each probability output has good accuracy. By enabling P(y) in the above equation (1) to be set by a user such as an administrator, a model corresponding to the situation of each air conditioning system 10 may be obtained. P(y) may be different between the model M1 and the model M2. When P(cold) is increased, the probability of “cold” output by the model M1 or M2 is increased (the same applies to “hot” and “others”). In this embodiment, P(x|y) is specified by using a histogram (see FIG. 5 to FIG. 7) showing the distribution of P(x|y) for each measured value. In this embodiment, since the distribution of P(x|y) for each measured value is not a normal distribution, specification accuracy of P(x|y) is good by use of the histogram.

**[0062]** (Modifications)

Various modifications can be made to the above embodiment. The modifications are listed below. However, at least some of the following modifications can be combined as appropriate.

**[0063]** (Modification 1)

A measured value contained in the teacher data D1 and D2 and input to the models M1 and M2 is arbitrarily selected. The measured value may be a measured value related to which of a plurality

of states (“cold”, “hot”, and “others”) the air conditioning zone Z1 or Z2 is in. For example, humidity or the like may be adopted as the measured value. Examples of the measured value include a physical quantity fed back by feedback control. However, an operation amount being another physical quantity used in this feedback control is also treated here as a kind of measured value. That is, the measured value is a concept including an operation amount.

**[0064]** (Modification 2)

The model generation device 50 may be a device generating a model for a control system other than the air conditioning system 10. The teacher data acquisition part 51B may acquire a plurality of teacher data that use a measured value (including a value obtained by taking a moving average) related to which of a plurality of states a control object controlled by a control system is in as an explanatory variable and a state among the plurality of states at the time of the measured value as an objective variable. The model generator 51C may generate, by statistical machine learning based on a plurality of teacher data, a model that uses a newly measured value as an input value and derives a probability of each of the plurality of states the control object may take at the time of the input value. Other control systems may include a control system used in various plants. Other control systems may include a heating system in which a steel material is heated by a heating furnace. In this case, the control object is a temperature inside the heating furnace. The measured value is process data such as flame intensity of a burner that heats the heating furnace. The state that the control object may take is any of “high”, “low”, and “suitable temperature” in temperature, and may be labeled by the administrator when the teacher data are generated.

**[0065]** The teacher data acquisition part 51B may, based on the information (for example, set temperature SP1 or SP2 input by the user, and information input by a user that discriminates between “high”, “low”, and “suitable temperature” in the heating system) input by the user to the control system that controls the control object, specify the state (for example, “cold”, “hot”, and “others” described above, or “high”, “low”, and “suitable temperature” described above) of the

control object as the objective variable of the teacher data. Accordingly, a model is generated that outputs the above probability reflecting the user's feeling.

**[0066]** (Modification 3)

The model generation device 50 has an arbitrary hardware configuration. At least some of the parts 51A to 51E may be composed of one or more logic circuits. Examples of the logic circuit include an application specific integrated circuit (ASIC) and a field programmable gate array (FPGA). Various data stored in the storage 53 may be stored in another storage provided outside the model generation device 50. The model generation program may be stored in a non-transitory storage medium other than the storage 53. The devices and systems herein may be one device in which various components are housed in one housing, or may be a combination of a plurality of devices in which various components are respectively housed in a plurality of housings separated from each other.

**[0067]** (Scope of present invention)

Although the present invention has been described above with reference to embodiments and modifications, the present invention is not limited to the above embodiments and modifications. For example, the present invention includes various modifications to the above embodiments and modifications that can be understood by those skilled in the art within the technical ideas of the present invention. Each configuration mentioned in the above embodiments and modifications can be appropriately combined as long as there is no contradiction.

Description of Reference Numerals

**[0068]** 10: air conditioning system; 11: air conditioner; 12: air supply duct; 13A, 13B: VAV unit; 14: supply air temperature sensor; 15A, 15B: airflow meter; 16A, 16B: room temperature sensor; 17A, 17B: air conditioning operation panel; 18A, 18B: VAV controller; 19: air conditioner controller; 50: model generation device; 51: processor; 51A: information collection part; 51B: teacher data acquisition part; 51C: model generator; 51D: probability acquisition part; 51E:

notifier; 53: storage; 54: operation device; 55: display device; M1, M2: model; U1, U2: user; Z1, Z2: air conditioning zone.

## CLAIMS

### [Claim 1]

A model generation device, comprising:

a teacher data acquisition part, configured to acquire a plurality of teacher data that use a measured value related to which of a plurality of states a control object controlled by a control system is in as an explanatory variable and a state among the plurality of states at the time of the measured value as an objective variable; and

a model generator, configured to generate, by statistical machine learning based on the plurality of teacher data, a model that uses the measured value newly measured as an input value and derives a probability of each of the plurality of states the control object is able to take at the time of the input value.

### [Claim 2]

The model generation device according to claim 1, further comprising:

a probability acquisition part, configured to input the measured value newly measured to the model and acquire the probability of each of the plurality of states derived by the model; and

a notifier, configured to issue a notification of at least a state with the highest probability among the plurality of states based on the probability of each of the plurality of states acquired by the probability acquisition part.

### [Claim 3]

The model generation device according to claim 1 or 2, further comprising:

a probability acquisition part, configured to input the measured value newly measured to the model and acquire the probability of each of the plurality of states derived by the model; and

a notifier, configured to issue a notification of at least a portion of the probability of each of the plurality of states acquired by the probability acquisition part.

### [Claim 4]

The model generation device according to any one of claims 1 to 3, further comprising:

a probability acquisition part, configured to input the measured value newly measured to the model and acquire the probability of each of the plurality of states derived by the model; and

a notifier, configured to issue a notification that any of the probability of each of the plurality of states acquired by the probability acquisition part exceeds a predetermined value when the same occurs.

[Claim 5]

The model generation device according to any one of claims 1 to 4, wherein the model is a model using equation (A) by a naive Bayes method:

$$P(y|x)=P(x|y)*P(y)/P(x).....(A)$$

wherein x is the measured value, and y is any of the plurality of states.

[Claim 6]

The model generation device according to claim 5, wherein

P(y) is user settable.

[Claim 7]

The model generation device according to claim 5 or 6, wherein

P(x|y) is specified by using a histogram showing a distribution of P(x|y) for each measured value.

[Claim 8]

The model generation device according to any one of claims 1 to 7, wherein

the teacher data acquisition part is configured to specify a state of the control object as the objective variable based on information input by a user to the control system that controls the control object.

[Claim 9]

The model generation device according to claim 8, wherein

the control object is air in an air conditioning zone;

the control system is an air conditioning system that controls the air;

the teacher data acquisition part is configured to take the objective variable of the teacher data when the user raises a set temperature of the air conditioning system as “cold” and take the objective variable of the teacher data when the user lowers the set temperature of the air conditioning system as “hot”.

[Claim 10]

A model generation method, comprising:

a teacher data acquisition step, configured to acquire a plurality of teacher data that use a measured value related to which of a plurality of states a control object controlled by a control system is in as an explanatory variable and a state among the plurality of states at the time of the measured value as an objective variable; and

a model generation step, configured to generate, by statistical machine learning based on the plurality of teacher data, a model that uses the measured value newly measured as an input value and derives a probability of each of the plurality of states the control object is able to take at the time of the input value.

[Claim 11]

A model generation program, causing a computer to execute:

a teacher data acquisition step, configured to acquire a plurality of teacher data that use a measured value related to which of a plurality of states a control object controlled by a control system is in as an explanatory variable and a state among the plurality of states at the time of the measured value as an objective variable; and

a model generation step, configured to generate, by statistical machine learning based on the plurality of teacher data, a model that uses the measured value newly measured as an input value and derives a probability of each of the plurality of states the control object is able to take at the time of the input value.