

THERMAL SENSATION MODEL GENERATING APPARATUS AND METHOD

Background

[0001] The present disclosure relates to a technology
5 of generating a thermal sensation model for estimating
occupants' thermal sensation for an assessment-target
space at a future date-and-time.

[0002] It is desirable to provide a technology of
10 accurately grasping an occupants' comfort level of an
indoor environment in the field of air-conditioning
control and operational management of an indoor
environment.

According to a known technology, occupants' thermal
sensation information is acquired on a basis of votes by
15 the occupants or the occupants' behaviors, images,
measured physiological quantities, or the like. A
learning model is constructed by learning the
relationship between the acquired thermal sensation
information and the index (hereinafter referred to as
20 living environment index) of the occupants' environment
at the time of occurrence of the thermal sensation
information. The trained model is used as an individual
thermal sensation model, and a target occupants' thermal
sensation for an arbitrary environment is estimated.
25 Examples of the occupants' thermal sensation information
include a whole-body thermal sensation scale such as
hot/cold, comfortability/satisfaction resulting from the
thermal environment, and the like. The living
environment index is a physical environment index such as
30 temperature or humidity, a PMV (Predicted Mean Vote) that
is an index calculated by using the physical environment

index, or the like.

[0003] Japanese Patent No. 2713532 discloses a method of substantially learning the relationship between occupants' thermal sensation information ("thermal sensation vote" in Japanese Patent No. 2713532) and the living environment index ("indoor temperature" in Japanese Patent No. 2713532).

Further, Tanaka (Tanaka Kitoshi, et al., "Study on the stock building renovation for Net-Zero Energy Building (Part 4) Study on air-conditioning control system considering individual thermal sensation", the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan, Technical papers of annual meeting, Vol. 10, pp. 213-216, 2017/9) discloses a method of learning the relationship between users' thermal sensation information ("discomfort vote" in Tanaka) and a users' living environment index ("PMV" in Tanaka).

[0004] The occupants' thermal sensation always changes affected by elements (hereinafter referred to as seasonal variation elements) that vary depending on seasons. Examples of the seasonal variation elements include clothing different depending on seasons, changes of metabolic rates, a room temperature of a bedroom at home in sleeping time, and the like (Kubo Hiroko, et al., "Seasonal Variations of Air Temperature for the Thermal Comfort", Journal of Human and Living Environment, Vol. 1, No. 1, pp. 51-57, 1994). Because of such reasons, if a trained model trained with past data is used to estimate future thermal sensation information after training, estimation errors may occur, which is a problem. It is desirable to increase estimation accuracy.

Summary

[0005] It is desirable to provide a thermal sensation model generating apparatus and method capable of obtaining an estimated result of occupants' thermal sensation close to the real thermal sensation.

[0006] According to the present disclosure, there is provided a thermal sensation model generating apparatus, including:

a data period manager module configured to store update timing information of a first model, the first model being a model of a relationship between a living environment index of an assessment-target space and occupants' thermal sensation for the assessment-target space, and

learning data period information;

a first model generating module configured to generate the first model at the update timing on a basis of the living environment index and the occupants' thermal sensation information in the learning data period;

a season-dependence manager module configured to obtain a characteristic quantity modified function on a basis of multiple first models and past outdoor thermal environment representative values, the multiple first models being generated in multiple learning data periods respectively, the past outdoor thermal environment representative values corresponding to the multiple learning data periods respectively, the characteristic quantity modified function indicating a relationship between a model characteristic quantity determining a form of a function of the first model and an outdoor

thermal environment representative value; and
a second model generating module configured to
determine a future learning data period to be
set for future date-and-time at which occupants' thermal
sensation is to be estimated,

calculate a model characteristic quantity
corresponding to an outdoor thermal environment
representative value in the future learning data period
on a basis of the characteristic quantity modified
function, and

generate a second model by modifying a latest
first model on a basis of the calculated model
characteristic quantity.

[0007] Further, according to the thermal sensation
model generating apparatus of an embodiment of the
present disclosure, the data period manager module is
configured to store overlapping period information in
addition to the update timing information and the
learning data period information, and

the multiple learning data periods are set such that
two contiguous learning data periods overlap one another
by a length of the overlapping period.

[0008] Further, the thermal sensation model generating
apparatus of an embodiment of the present disclosure
further includes:

an outdoor thermal environment information manager
module configured to store past outdoor thermal
environment information of a building having the
assessment-target space, in which

the season-dependence manager module is configured
to

acquire past outdoor thermal environment information corresponding to the multiple learning data periods respectively, from the outdoor thermal environment information manager module,

5 determine past outdoor thermal environment representative values corresponding to the multiple learning data periods respectively, and
 obtain the characteristic quantity modified function, and

10 the second model generating module is configured to
 acquire the past outdoor thermal environment information corresponding to the future learning data period from the outdoor thermal environment information manager module, and

15 determine an outdoor thermal environment representative value corresponding to the future learning data period.

[0009] Further, according to a thermal sensation model generating apparatus of an embodiment of the present disclosure, the second model generating module is
20 configured to modify the latest first model on a basis of
 a model characteristic quantity calculated on a basis of the characteristic quantity modified function, and

25 a model characteristic quantity of the latest first model.

 Further, according to a thermal sensation model generating apparatus of an embodiment of the present disclosure, the living environment index is a PMV
30 (Predicted Mean Vote), and

 occupants' thermal sensation is a percentage of

occupants who vote for dissatisfaction with a thermal environment.

[0010] Further, according to the present disclosure, there is provided a thermal sensation model generating method, including:

the first step of, with reference to a data period manager module configured to store

update timing information of a first model, the first model being a model of a relationship between a living environment index of an assessment-target space and occupants' thermal sensation for the assessment-target space, and

learning data period information,

generating the first model at the update timing on a basis of the living environment index and the occupants' thermal sensation information in the learning data period;

the second step of obtaining a characteristic quantity modified function on a basis of multiple first models and past outdoor thermal environment representative values, the multiple first models being generated in multiple learning data periods respectively, the past outdoor thermal environment representative values corresponding to the multiple learning data periods respectively, the characteristic quantity modified function indicating a relationship between a model characteristic quantity determining a form of a function of the first model and an outdoor thermal environment representative value; and

the third step of

determining a future learning data period to be

set for future date-and-time at which occupants' thermal sensation is to be estimated,

calculating a model characteristic quantity corresponding to an outdoor thermal environment

representative value in the future learning data period on a basis of the characteristic quantity modified function, and

generating a second model by modifying a latest first model on a basis of the calculated model characteristic quantity.

[0011] Further, according to a thermal sensation model generating method of an embodiment of the present disclosure, the data period manager module is configured to store overlapping period information in addition to the update timing information and the learning data period information, and

the multiple learning data periods are set such that two contiguous learning data periods overlap one another by a length of the overlapping period.

Further, according to a thermal sensation model generating method of an embodiment of the present disclosure, the second step includes

with reference to an outdoor thermal environment information manager module configured to store past outdoor thermal environment information of a building having the assessment-target space,

acquiring past outdoor thermal environment information corresponding to the multiple learning data periods respectively, from the outdoor thermal environment information manager module,

determining past outdoor thermal environment

representative values corresponding to the multiple learning data periods respectively, and

obtaining the characteristic quantity modified function, and

5 the third step includes

acquiring the past outdoor thermal environment information corresponding to the future learning data period from the outdoor thermal environment information manager module, and

10 determining an outdoor thermal environment representative value corresponding to the future learning data period.

Further, according to a thermal sensation model generating method of an embodiment of the present

15 disclosure, the third step includes modifying the latest first model on a basis of

a model characteristic quantity calculated on a basis of the characteristic quantity modified function, and

20 a model characteristic quantity of the latest first model.

[0012] According to the present disclosure, the data period manager module, the first model generating module, the season-dependence manager module, and the second
25 model generating module are provided. The first model is modified on a basis of the outdoor thermal environment status, on which the seasonal variation is reflected, to thereby generate the second model. As a result, an estimation error resulting from a seasonal variation
30 element may be reduced. As a result, according to the present disclosure, the estimated result of the

occupants' thermal sensation may be closer to the real thermal sensation.

[0013] Further, according to the present disclosure, the data period manager module stores the overlapping period information in addition to the update timing information and the learning data period information. The multiple learning data periods are set such that two contiguous learning data periods overlap one another by a length of the overlapping period. As a result, the model reliability may be further increased.

Brief Description of Drawings

[0014] Fig. 1 is a diagram showing an example of an air-conditioning control system according to a first embodiment of the present disclosure;

Fig. 2 is a block diagram showing a configuration of a thermal sensation model generating apparatus according to the first embodiment of the present disclosure;

Fig. 3 is a flowchart illustrating operations of a living environment information retaining module, a thermal sensation information retaining module, and a data combining module of the thermal sensation model generating apparatus according to the first embodiment of the present disclosure;

Fig. 4 shows an example of thermal sensation vote information, vote date-and-time, and voter IDs according to the first embodiment of the present disclosure;

Fig. 5 shows an example of combination information according to the first embodiment of the present disclosure;

Fig. 6 is a flowchart illustrating an operation of a past model generating module of the thermal sensation

model generating apparatus according to the first embodiment of the present disclosure;

Fig. 7 is a diagram showing a relationship between a PMV, i.e., living environment index, and the number of voters for "hot";

Fig. 8 is a flowchart illustrating a modeling information generating method according to the first embodiment of the present disclosure;

Fig. 9 shows a relationship between PMV and PPD;

Fig. 10 shows an example of dissatisfied rate functions;

Fig. 11 is a flowchart illustrating an operation of a season-dependence manager module of the thermal sensation model generating apparatus according to the first embodiment of the present disclosure;

Fig. 12 is a flowchart illustrating an operation of determining a characteristic quantity modified function by a season-dependence manager module of the thermal sensation model generating apparatus according to the first embodiment of the present disclosure;

Fig. 13 is a diagram showing a model characteristic quantity according to the first embodiment of the present disclosure;

Fig. 14A and Fig. 14B illustrate a method of determining a characteristic quantity modified function according to the first embodiment of the present disclosure;

Fig. 15A and Fig. 15B illustrate another model characteristic quantity according to the first embodiment of the present disclosure;

Fig. 16 is a flowchart illustrating an operation of

a future model generating module of the thermal sensation model generating apparatus according to the first embodiment of the present disclosure;

Fig. 17A and Fig. 17B illustrate learning data periods of first and second embodiments of the present disclosure;

Fig. 18A and Fig. 18B show examples of mean variations of outdoor temperatures in certain periods; and

Fig. 19 shows an example of a configuration of a computer that realizes the thermal sensation model generating apparatus of the first and second embodiments of the present disclosure.

Detailed Description of Embodiments

[0015] [Principle of invention]

Since there is seasonal variations, it is necessary to support variations of the real thermal sensation at the time when data for training is collected. In view of the aforementioned circumstances, the present inventors focused on the point that a trained individual thermal sensation model (hereinafter referred to as past model) trained with past data is modified on a basis of an outdoor thermal environment status, on which seasonal variations are reflected, and the modified model is treated as a future model. Since the past model is modified on a basis of the outdoor thermal environment status, on which seasonal variations are reflected, it is possible to reflect an effect of a seasonal variance on the model.

[0016] An example of an outdoor thermal environment status, on which a seasonal variation is reflected, is an

outdoor air temperature. For example, a future model is generated from a trained past model by using an outdoor temperature mean value of a learning data period at the time of generating the past model, and by using a climatological normal outdoor temperature or an outdoor temperature forecast value of future, which is an estimation target of occupants' thermal sensation.

[0017] Further, the present inventors focused on the point that the reliability of a past model and a future model may not be maintained where data of a period, which includes a short-term variance such as two days or three days, is used. In order to take the seasonal variation. i.e., year-basis variance, into account, it is necessary to prepare, for the model training, data having a certain period length corresponding to the variance span. The period length is appropriately about one month. Further, the present inventors have conceived that an overlap method is effective in order to maintain the contiguousness of seasonal variations. According to the overlap method, a former period and a latter period overlap one another by a reliable period (two weeks, etc.).

[0018] [First embodiment]

Hereinafter, embodiments of the present disclosure will be described with reference to the drawings. In the first embodiment of the present disclosure, a basic method of generating a future model on a basis of a past model will be described.

The present embodiment relates to an example of generating a month-basis model of each month. A model parameter of a past model is modified by using a

characteristic quantity modified function on a basis of a climatological normal outdoor temperature of a data period month of the past model, and on a basis of a climatological normal outdoor temperature of a data period month of a future model including a predictive future. The past model is modified by using the characteristic quantity modified function to thereby obtain the future model.

[0019] In the present embodiment, for the purpose of simplification, as shown in Fig. 1, for example, in an occupant-voting air-conditioning control system, there are two occupants in one target air-conditioning zone being. An occupant-voting air-conditioning control system is disclosed in, for example, "Yasuhito Omagari, et. al., "Feasibility Study on Environmental Control using Thermal Sensation Vote", Air-Conditioning and Sanitary Engineers of Japan, Technical papers of annual meeting, Vol. 3, pp. 41-44, September 2016".

[0020] Fig. 1 shows occupants 100, an assessment-target space 101 (occupants are in the space), an air-conditioning controller apparatus (controller) 102 that receives thermal sensation votes, a temperature sensor 103 that measures a room temperature of the assessment-target space 101, a humidity sensor 104 that measures a humidity of the assessment-target space 101, an indoor unit 105, and an outdoor unit 106. The air-conditioning controller apparatus 102 controls an air-conditioning apparatus (including the indoor unit 105 and the outdoor unit 106) such that the room temperature measured by the temperature sensor 103 is the same as the room temperature set value and the humidity measured by the

humidity sensor 104 is the same as the humidity set value.

[0021] Fig. 2 is a block diagram showing a configuration of a thermal sensation model generating apparatus of the present embodiment. The thermal sensation model generating apparatus includes the past model generating unit 1 and the future model generating unit 2.

[0022] The past model generating unit 1 includes the data collecting module 10, the data period manager module 14, the past model generating module 15 (first model generating module), and the past model storing manager module 16. The data period manager module 14 stores update timing information of an individual thermal sensation model and learning data period information, the individual thermal sensation model being a model of a relationship between a living environment index of the assessment-target space 101 and occupants' thermal sensation for the assessment-target space 101. The past model generating module 15 (first model generating module) generates the past model (first model) at the update timing on a basis of the living environment index and the occupants' thermal sensation information in the learning data period. The past model storing manager module 16 stores the past model generated by the past model generating module 15.

[0023] The data collecting module 10 includes the living environment information retaining module 11, the thermal sensation information retaining module 12, and the data combining module 13. The living environment information retaining module 11 calculates a living environment index based on thermal environment

information. The thermal sensation information retaining module 12 acquires thermal sensation information voted by occupants in an assessment-target space. The data combining module 13 extracts the calculated living environment index from the thermal environment information at the measured date-and-time corresponding to the thermal sensation information generated date-and-time. The data combining module 13 generates combination information by combining the thermal sensation information and the living environment index.

[0024] The future model generating unit 2 includes the outdoor thermal environment information manager module 20, the season-dependence manager module 21, and the future model generating module 22 (second model generating module). The outdoor thermal environment information manager module 20 stores past outdoor thermal environment information of a building having the assessment-target space. The season-dependence manager module 21 obtains a characteristic quantity modified function on a basis of multiple past models and past outdoor thermal environment representative values, the multiple past models being generated in multiple learning data periods respectively, the past outdoor thermal environment representative values corresponding to the multiple learning data periods respectively, the characteristic quantity modified function indicating a relationship between a model characteristic quantity determining a form of a function of the past model and an outdoor thermal environment representative value. The future model generating module 22 (second model generating module) determines a future learning data period to be set for

future date-and-time at which occupants' thermal sensation is to be estimated, calculates a model characteristic quantity corresponding to an outdoor thermal environment representative value in the future learning data period on a basis of the characteristic quantity modified function, and generates a future model (second model) by modifying a latest past model on a basis of the calculated model characteristic quantity.

[0025] Fig. 3 is a flowchart illustrating operations of the living environment information retaining module 11, the thermal sensation information retaining module 12, and the data combining module 13.

The living environment information retaining module 11 receives thermal environment information (thermal environment measured values such as temperature measured value or humidity measured value) from environment measuring devices (the temperature sensor 103 and the humidity sensor 104, etc.) provided at the assessment-target space 101, for example, and calculates a living environment index. Further, the living environment information retaining module 11 stores the measured date-and-time of the thermal environment measured value and the living environment index in association with each other as living environment information (measured date-and-time and living environment index) (Fig. 3, Step S100).

[0026] The living environment information retaining module 11 has mathematical formulae and parameter values required to calculate a living environment index, type information of a thermal environment measured value used for calculation, and the like, which are preset by an

indoor environment assessment/control, etc. solution provider or a facilities manager.

[0027] In response to an information send request from the data combining module 13, the living environment information retaining module 11 sends living environment information (measured date-and-time and living environment index) to the data combining module 13 (Fig. 3, Step S101).

[0028] The living environment index is a thermal environment index of a living environment. The living environment index is a physical environment index such as air temperature or humidity measured in an air-conditioning environment typically. Alternatively, the living environment index is an index (for example, SET (Standard new Effective Temperature), PMV (Predicted Mean Vote), etc.) typically calculated by using a physical environment index. In the present embodiment, the living environment index is PMV, which is the international standard. The six elements (air temperature T_a [$^{\circ}\text{C}$], humidity H [%], mean radiant temperature T_r [$^{\circ}\text{C}$], air velocity v [m/s], metabolic rate M [met], and clothing insulation I_{cl} [clo]) typically required to calculate PMV have the following values. In short, the air temperature T_a [$^{\circ}\text{C}$] and the humidity H [%] are the air temperature measured value and the humidity measured value of a target building. The mean radiant temperature T_r is the same as the air temperature T_a . The air velocity v is 0.1 [m/s], the metabolic rate M is 1.0 [met], and the clothing insulation I_{cl} is 0.8 [clo]. In this example, a PMV is obtained under such a condition. Other information required to calculate a PMV is preset with

reference to the international standard and the like together with the PMV mathematical formula.

[0029] Now, a PMV calculation method will be described.

The ISO-7730 international standard defines the PMV calculation method. So a PMV is calculated by using the standard calculation method. PMV is obtained by using the following Formula (1) to Formula (3). ANSI/ASHRAE Standard 55-2010, etc. discloses a calculation program.

$$PMV = Q(M) \times L \dots (1)$$

$$Q(M) = 0.303 \exp^{-0.036M+0.028} \dots (2)$$

$$L = M - (C + R + E_d + E_s) - (C_{re} + E_{re}) \dots (3)$$

[0030] M is metabolic rate [met], L is human body heat load L [W/m²], C is convective heat loss quantity [W/m²], R is radiative heat loss quantity [W/m²], E_d is transepidermal water loss quantity [W/m²], E_s is sweating evaporative heat loss quantity [W/m²], C_{re} is respiratory sensible heat loss quantity [W/m²], and E_{re} is respiratory latent heat loss quantity [W/m²].

[0031] The following Formula (4) to Formula (6) are convergence-calculated to thereby calculate a convective heat loss quantity C and a radiative heat loss quantity R. t_{cl} is clothing outer surface temperature [°C].

$$C = f_{cl} \times h_c \times (t_{cl} - T_a) \dots (4)$$

$$R = 3.96 \times 10^{-8} \times f_{cl} \times \{(t_{cl} + 273.15)^4 - (T_r + 273.15)^4\} \dots (5)$$

$$t_{cl} = t_s - 0.155 \times I_{cl} \times (C + R) \dots (6)$$

[0032] In Formula (4) to Formula (6), I_{cl} is clothing insulation [clo]. f_{cl} is clothing area increase factor. Where I_{cl} < 0.78 is satisfied, f_{cl} = 1 + 1.29 × I_{cl} is satisfied. Where I_{cl} ≥ 0.78 is satisfied, f_{cl} = 1.05 + 0.645 × I_{cl} is satisfied. T_r is mean radiant

temperature [$^{\circ}\text{C}$]. t_s is mean skin temperature [$^{\circ}\text{C}$], and is obtained by using the next formula. W is mechanical work quantity [W/m^2] (normally 0).

$$t_s = 35.7 - 0.028 \times (M - W) \dots (7)$$

[0033] Further, h_c is human body convective heat transfer coefficient [$\text{W}/(\text{m}^2 \cdot ^{\circ}\text{C})$], and is the larger one of $2.38 \times |t_{cl} - t_a|^{0.25}$ or $12.1 \times v^{0.5}$. v is air velocity [m/s].

[0034] The transepidermal water loss quantity E_d is obtained by using the next formula.

$$E_d = 3.05 \times (5.73 - 0.007 \times M - p_a) \dots (8)$$

The sweating evaporative heat loss quantity E_s is obtained by using the next formula.

$$E_s = 0.42 \times (M - 58.15) \dots (9)$$

[0035] The respiratory sensible heat loss quantity C_{re} is obtained by using the next formula.

$$C_{re} = 0.0014 \times M \times (34 - T_a) \dots (10)$$

The respiratory latent heat loss quantity E_{re} is obtained by using the next formula. p_a is vapor pressure.

$$E_{re} = 0.0173 \times M \times (5.87 - p_a) \dots (11)$$

[0036] In this manner, the living environment information retaining module 11 is capable of calculating a PMV as the living environment index. In the present embodiment, the thermal environment measured value is measured every minute and sent to the living environment information retaining module 11. The living environment information retaining module 11 calculates a PMV every minute. Where an air-conditioning controller apparatus or a building maintenance central monitor system stores thermal environment measured values at regular intervals, the living environment information retaining module 11

may acquire the thermal environment measured value from such an air-conditioning controller apparatus or a central monitor system.

[0037] Meanwhile, the thermal sensation information retaining module 12 receives thermal sensation information of occupants in the assessment-target space 101. The thermal sensation information retaining module 12 stores the thermal sensation information in association with the generated date-and-time of the thermal sensation information and information of the occupants who voted the thermal sensation information (Fig. 3, Step S102).

[0038] In response to an information send request from the data combining module 13, the thermal sensation information retaining module 12 sends the thermal sensation information, the generated date-and-time information, and the occupant information to the data combining module 13 (Fig. 3, Step S103).

[0039] The thermal sensation information is a quantity indicating sensations of occupants corresponding to the living environment index. The thermal sensation information indicates information such as a whole-body thermal sensation scale such as hot/cold or comfortability/satisfaction resulting from a thermal environment. The thermal sensation information also includes indices such as the number of dissatisfied occupants in the target space or the percentage of dissatisfied occupants calculated on a basis of the number of dissatisfied occupants. Smartphones, PCs (personal computers), and the like may be as necessary used as input terminals that input the thermal sensation

information.

[0040] In the present embodiment, the thermal sensation vote information (hot/cold) from occupants is the thermal sensation information. Each occupant votes his/her thermal sensation vote such as hot or cold at will via an input terminal. Fig. 4 shows an example of the thermal sensation vote information, the vote date-and-time (generated date-and-time information), and voter IDs (occupant information). The example of Fig. 4 shows "hot" and "cold".

[0041] An occupant may input the voter ID and the thermal sensation vote and send them to the thermal sensation information retaining module 12. Alternatively, where each occupant uses an own input terminal, a terminal ID may be used as a voter ID and sent to the thermal sensation information retaining module 12.

Further, the input terminal may send the vote date-and-time to the thermal sensation information retaining module 12. Alternatively, the vote date-and-time may be the date-and-time at which the thermal sensation information retaining module 12 receives thermal sensation vote information.

[0042] Next, the data combining module 13 receives the living environment index from the living environment information retaining module 11, and receives the thermal sensation information from the thermal sensation information retaining module 12. Then the data combining module 13 extracts the living environment index at the measured date-and-time corresponding to the thermal sensation information generated date-and-time. The data combining module 13 stores combination information

(generated date-and-time information, occupant ID, thermal sensation information, and living environment index) which is a combination of the thermal sensation information and the living environment index (Fig. 3, Step S104).

[0043] In response to an information send request from the past model generating module 15, the data combining module 13 sends the combination information to the past model generating module 15 (Fig. 3, Step S105).

[0044] Fig. 5 shows an example of the combination information, which is a combination of the thermal sensation information generated date-and-time information (vote date-and-time information), the occupant ID (voter ID), the thermal sensation information, and the living environment index (PMV).

In extracting the living environment index at the measured date-and-time corresponding to the thermal sensation information generated date-and-time, in some cases, the thermal sensation information generated time interval is different from the thermal environment measured value measuring time interval. For example, the resolution of the thermal sensation information generated date-and-time (vote date-and-time) is every minute, for example, and the resolution of the thermal environment measured value measured date-and-time is every ten minutes, for example. In such a case, a solution provider or a facilities manager may predetermine a rule for extraction.

[0045] For example, the resolution of the thermal sensation information generated date-and-time (vote date-and-time) is every minute, and the thermal environment

measured value is measured every ten minutes. In such a case, the measured date-and-time, which is closest to the thermal sensation information generated date-and-time, is treated as the measured date-and-time corresponding to the thermal sensation information generated date-and-time.

Alternatively, the thermal sensation information generated date-and-time is rounded up on ten-minute basis, and the rounded date-and-time is treated as the measured date-and-time corresponding to the thermal sensation information generated date-and-time. Such rules for extraction may be predetermined.

[0046] For example, the thermal environment measured value is measured every ten minutes, i.e., 14:50, 15:00, 15:10, and so on. In such a case, the measured date-and-time 15:00 (the closest date-and-time) or 15:10 (15:03 is rounded up on ten-minute basis) corresponds to the thermal sensation information generated date-and-time 15:03.

[0047] The living environment information retaining module 11, the thermal sensation information retaining module 12, and the data combining module 13 executes the processing of Fig. 3 again and again, and the data combining module 13 thereby stores the combination information.

[0048] Next, the data period manager module 14 has data period management information preset by an indoor environment assessment/control, etc. solution provider or a facilities manager. The data period management information is used to determine the update timing and the learning data period of the individual thermal sensation model (past model).

In response to the information send request from the past model generating module 15 or the future model generating module 22, the data period manager module 14 sends the data period management information.

5 [0049] In the present embodiment, the data period management information includes the update timing information and the learning data period length information of the individual thermal sensation model. Specifically, the update timing of the individual thermal sensation model is 0:00 of the 1st day of every month (1st day of X month, X is arbitrary month). The learning data period length of the individual thermal sensation model is one month from the previous update timing to the present update timing. In other words, the update timing of the individual thermal sensation model is the 1st day of every month. Then the learning data period for updating the individual thermal sensation model has the start date-and-time (the 1st day of the previous month, 0:00) and the end date-and-time (the last day of the previous month, 23:59).

15 [0050] It is only necessary to determine the update timing and the learning data period of the individual thermal sensation model from the data period management information. So, as a matter of course, alternatively, the data period management information may include the update start date-and-time and the learning data period length (every 14 days, every 168 hours, etc.) starting back from the update start date-and-time.

25 [0051] Fig. 6 is a flowchart illustrating an operation of the past model generating module 15. The past model generating module 15 acquires the data period management

information from the data period manager module 14, and recognizes that it is the update timing of the individual thermal sensation model on a basis of the data period management information (Fig. 6, Step S200, YES). Then
5 the past model generating module 15 determines the start date-and-time and the end date-and-time of the learning data period corresponding to the present model updating (Fig. 6, Step S201).

[0052] The past model generating module 15 acquires
10 the combination information of the determined learning data period from the data combining module 13 (Fig. 6, Step S202). The past model generating module 15 generates the input-and-output data (modeling information) for identifying the individual thermal
15 sensation model by using the acquired combination information (Fig. 6, Step S203). The past model generating module 15 identifies the individual thermal sensation model by using the generated modeling information, and updates the individual thermal sensation
20 model as the latest past model (Fig. 6, Step S204).

[0053] Further, the past model generating module 15 sends the modeling result of the latest past model and the learning data period information, which is used for modeling, to the past model storing manager module 16
25 (Fig. 6, Step S205).

The past model generating module 15 executes the processing of Fig. 6 every model update timing.

[0054] In the present embodiment, as described above, the update timing of the individual thermal sensation
30 model is 0:00 of the 1st day of every month. For example, the individual thermal sensation model is updated at

1/March/2018 0:00. In such a case, the learning data period is from 1/February/2018 0:00 to 28/February/2018 23:59. Further, where the individual thermal sensation model is updated at 1/August/2019 0:00, then the learning data period is from 1/July/2018 0:00 to 31/July/2018 23:59.

[0055] Further, in the present embodiment, the modeling information includes the living environment index (PMV) and the Predicted Percentage of Votes for "hot" PPVh. The basic function of the individual thermal sensation model is a function of the Predicted Percentage of Dissatisfied PPD. The PPD is also the international standard, and ISO-7730 discloses the formula that uses the PMV.

[0056] Next, the modeling information generating method of Step S203 will be described. As described above, the past model generating module 15 generates the modeling information on a basis of the combination information.

The Predicted Percentage of Votes for "hot" PPVh using an arbitrary PMV is calculated by using the next formula, where the number of voters for "hot" using the arbitrary PMV is N, and the number of occupants in the assessment-target space is N_all.

$$PPVh = N/N_all \dots (12)$$

[0057] The number of occupants in the assessment-target space N_all is preset by an indoor environment assessment/control, etc. solution provider or a facilities manager.

Here, in Formula (12), the number of voters N may be the number of voters calculated in consideration of

physiological validity for thermal sensation. This calculation method is based on the following principle. A voter votes for "hot" with an arbitrary PMV. The same voter senses hotter with another PMV that is hotter than that environment (i.e., the aforementioned arbitrary PMV).

[0058] Specifically, the PMV, on which each voter votes for the first time when the PMV is low (hotness is low), is referred to as a latch start point $PMV_{start}(m)$ (m is positive integer, and $m = 1$ to 4 in the present embodiment). In the PMV range larger than the latch start point $PMV_{start}(m)$, the number of occupants is calculated while the "hot" voting status is maintained. According to this calculation method, as shown in Fig. 7, the number of voters for "hot" is increased as the environment becomes hotter, which means that the physiological validity becomes high. Hereinafter, this method will be referred to as "vote latch method". An example of generating modeling information by using the vote latch method will be described.

[0059] Fig. 8 is a flowchart illustrating the vote latch method including calculating the Predicted Percentage of Votes PPV_h on a basis of the calculated number of voters and generating the modeling information.

The past model generating module 15 extracts only the "hot" voting information from the combination information acquired in Step S202 (Fig. 8, Step S300). The past model generating module 15 obtains the number of voters (the number of occupants who vote for "hot") N_{vote} , who have different voter IDs, included in the extracted information (Fig. 8, Step S301). Where the data example of Fig. 5 is the combination information of the learning

data period, the number of voters who vote for "hot" is obtained as follows. $N_vote = 4$.

[0060] Next, the past model generating module 15 sets the default value "1" for the variable m (m is positive integer equal to or smaller than N_vote) for counting the number of voters (Fig. 8, Step S302).

The past model generating module 15 obtains the latch start point $PMVstart(m)$, which is the smallest PMV value on which the m -th voter votes for "hot" (Fig. 8, Step S303).

[0061] The past model generating module 15 determines whether or not the processing of Step S303 is done for all the voters who vote for "hot", i.e., $m = N_vote$ is satisfied (Fig. 8, Step S304). Where the variable m is smaller than N_vote ($m < N_vote$), the past model generating module 15 increments the variable m ($m = m+1$) since the processing is not finished (Fig. 8, Step S305).

In such a manner, the past model generating module 15 executes the processing of Step S303 for each voter who votes for "hot".

[0062] The past model generating module 15 finishes the processing of Step S303 for all the voters who vote for "hot", i.e., $m = N_vote$ is satisfied (Step S304, YES).

Then the past model generating module 15 generates the modeling information on a basis of an arbitrary PMV and the Predicted Percentage of Votes for "hot" $PPVh$ corresponding to the PMV (Fig. 8, Step S306).

[0063] $V_latch(m)$ is the voted or non-voted status of a voter $P(m)$ on an arbitrary PMV. Where $PMV < PMVstart(m)$ is satisfied, $V_latch(m) = 0$ (non-voted) is satisfied. Where $PMVstart(m) \leq PMV$ is satisfied,

V_latch(m) = 1 (voted) is satisfied.

In this case, the Predicted Percentage of Votes for "hot" PPVh with respect to the arbitrary PMV is obtained by using the next formula.

5 [0064] [Math 1]

$$\text{PPVh} = \{ \sum_{m=1}^{N_{\text{vote}}} V_{\text{latch}}(m) \} / N_{\text{all}} \quad \dots (13)$$

[0065] In such a manner, calculation of the Predicted Percentage of Votes for "hot" PPVh is finished.

10 Generation of the modeling information based on the PMV of the learning data period and the Predicted Percentage of Votes for "hot" PPVh of the learning data period is finished. In the data example of Fig. 5, the vertical axis of Fig. 7 is divided by the number of voters who vote for "hot" to thereby obtain the Predicted Percentage of Votes for "hot", which is the modeling information. The modeling information may be generated at fixed intervals of the PMV, or may be data of only the increase points of the PPVh.

15 [0066] Next, the method of identifying the individual thermal sensation model of Step S204 will be described. As described above, in the present embodiment, the Predicted Percentage of Dissatisfied PPD is the basic function of the individual thermal sensation model. The following relational expression shows the PPD, which is the function of the PMV.

$$\text{PPD} = F(\text{PMV}) = 100 - 95 \times \exp(-0.03353 \times \text{PMV}^4 - 0.2179 \times \text{PMV}^2) \quad [\%] \quad \dots (14)$$

[0067] Fig. 9 shows a relationship between PMV and PPD.

30 The individual thermal sensation model may be defined as a distribution function having a V form of Fig. 9 in

which PMV and PPD are in association with each other. Alternatively, the hot-side dissatisfied rate may be divided from the cold-side dissatisfied rate, and dissatisfied functions (individual thermal sensation models) may be defined.

[0068] Fig. 10 shows an example of the dissatisfied rate functions disclosed in Japanese Patent Application Laid-open No. 2015-4480. In order to obtain the "hot" dissatisfied rate, the dissatisfied rate function 110 of Fig. 10 may be used. In order to obtain the "cold" dissatisfied rate, the dissatisfied rate function 111 of Fig. 10 may be used. The sigmoid function is an example of the function of Fig. 10. Such a typical model is applicable as the function of the individual thermal sensation model.

[0069] In the present embodiment, the occupants' thermal sensation is reflected on the basic function of Formula (14), and the function is thereby modified. The following Formula (15) is thereby obtained. In the example described below, the model of Formula (15) is the individual thermal sensation model (dissatisfied rate model). The form of the individual thermal sensation model of Formula (15) is similar to the form of the function 110 of Fig. 10. The Predicted Percentage of Dissatisfied PPD of Formula (14) corresponds to the dissatisfied rate. In Formula (15), the occupants' thermal sensation is reflected on the dissatisfied rate to thereby obtain the Predicted Percentage of Votes for "hot" PPVh.

[0070] [Math 2]

where $PMV < e$, $PPVh = a - b$

where $PMV \geq e$, $PPVh = a - b \times \exp(c \times (PMV - e)^4 + d \times (PMV - e)^2)$

... (15)

[0071] In Formula (15), a , b , c , d , and e are parameters of a retrieval target model. Formula (16) is obtained where $a = b$ (0 is the smallest value of the Predicted Percentage of Votes for "hot" $PPVh$) is satisfied in Formula (15). Where Formula (16) is used as the model function of the individual thermal sensation model, the parameters of the retrieval target model include a , c , d , and e .

[0072] [Math 3]

where $PMV < e$, $PPVh = 0$

where $PMV \geq e$, $PPVh = a \times \{1 - \exp(c \times (PMV - e)^4 + d \times (PMV - e)^2)\}$

... (16)

[0073] The model function of the individual thermal sensation model such as Formula (15) or Formula (16), the retrieval model parameters, and the optimization method to be used are preset by an indoor environment assessment/control, etc. solution provider or a facilities manager.

[0074] The past model generating module 15 uses the modeling information generated in Step S203, and retrieves the model parameter of the retrieval target for the model function of the individual thermal sensation model. The individual thermal sensation model is thereby identified. The model function of the individual thermal sensation model and the model parameter of the retrieval target are preset by a solution provider or a facilities manager. A typical method such as the least squares method or the simplex method may be used as the

optimization method used to retrieve the parameter.

As a result, the update of the past model is finished.

[0075] The past model storing manager module 16 stores the modeling result of the past model (retrieved model parameter value) and the learning data period information received from the past model generating module 15. In response to a model information send request from the season-dependence manager module 21, the past model storing manager module 16 sends the stored information to the season-dependence manager module 21.

[0076] The outdoor thermal environment information manager module 20 stores past outdoor thermal environment information and future outdoor thermal environment information of the building that has the assessment-target space 101. The past outdoor thermal environment information includes outdoor thermal environment status information, and date-and-time information at which the outdoor thermal environment status information is acquired. The future outdoor thermal environment information is information necessary to estimate the future outdoor thermal environment. The future outdoor thermal environment information includes outdoor thermal environment status information, and estimated date-and-time information at which the outdoor thermal environment status information may occur.

[0077] The seasonal variation is reflected on the outdoor thermal environment status information. Examples of the outdoor thermal environment status information include the outdoor temperature and humidity, an index such as a discomfort index that is a combination of

temperature and humidity, WBGT (Wet Bulb Globe Temperature), and the like. Further, the past outdoor thermal environment information may be a statistical quantity such as climatological normal data (monthly mean temperature, daily mean temperature, etc.).

Alternatively, the past outdoor thermal environment information may be a measured value measured by an outdoor temperature sensor or the like. The future outdoor thermal environment information is essentially the past outdoor thermal environment information corresponding to the future learning data period. The future outdoor thermal environment information may be similar to the past outdoor thermal environment information assuming that the past outdoor thermal environment information is repeated in the future.

Alternatively, the future outdoor thermal environment information may be an outdoor thermal environment information estimation value estimated on a basis of weather forecast and the like.

[0078] The method of acquiring the outdoor thermal environment information is preset by an indoor environment assessment/control, etc. solution provider or a facilities manager. Where available data such as monthly mean temperature is used as the outdoor thermal environment status information, such data may be preset in the outdoor thermal environment information manager module 20.

In the present embodiment, the climatological normal monthly mean outdoor temperature of each month is used as the past and future outdoor thermal environment status information.

[0079] Next, in response to a request from the future model generating module 22, the season-dependence manager module 21 determines the characteristic quantity modified function Gpm. The season-dependence manager module 21
5 sends the characteristic quantity modified function Gpm and the modeling result (retrieved model parameter value) of the past model stored in the past model storing manager module 16 to the future model generating module 22.

10 [0080] Fig. 11 is a flowchart illustrating an operation of the season-dependence manager module 21. The season-dependence manager module 21 acquires N_ref-times (N_ref is the preset number of reference models) of modeling results (i.e., from the latest modeling result
15 to the modeling result (N_ref-1)-times backward) and the learning data period information, which is used for the N_ref-times of modeling, from the past model storing manager module 16 (Fig. 11, Step S400).

[0081] Next, the season-dependence manager module 21
20 acquires the past outdoor thermal environment information corresponding to each of the learning data periods, which are used for the N_ref-times of modeling, from the outdoor thermal environment information manager module 20 (Fig. 11, Step S401).

25 [0082] Further, the season-dependence manager module 21 calculates, for each learning data period, the past outdoor thermal environment representative value Eot corresponding to each of the learning data periods, which are used for the N_ref-times of modeling, on a basis of
30 the acquired past outdoor thermal environment information (Fig. 11, Step S402). For example, the past outdoor

thermal environment status information, which is acquired from the outdoor thermal environment information manager module 20, is the outdoor temperature measured every hour, and the learning data period is 1/August/2018 0:00 to 10/August/2018 23:59. In such a case, the mean value (mean outdoor temperature) of the outdoor temperature in this learning data period may be calculated to thereby obtain the past outdoor thermal environment representative value Eot.

[0083] However, in the aforementioned case, the climatological normal monthly mean outdoor temperature of each month is used as the past outdoor thermal environment status information. In such a case, the season-dependence manager module 21 may use the monthly mean outdoor temperature of the month as it is (the month including the learning data period) as the past outdoor thermal environment representative value Eot. Alternatively, where the learning data period includes multiple months, the past outdoor thermal environment representative value Eot may be the mean value of the monthly mean outdoor temperatures of the multiple months, or the weighed mean value depending on the number of days.

[0084] Next, the season-dependence manager module 21 obtains the characteristic quantity modified function Gpm, which indicates the relationship between the past outdoor thermal environment representative value Eot and the model characteristic quantity SZ of the past model (Fig. 11, Step S403). The model characteristic quantity SZ is one quantity for determining the form of the function of the past model. Where the characteristic quantity

modified function Gpm is determined, then it is possible to estimate the model characteristic quantity SZ corresponding to an arbitrary outdoor thermal environment representative value Eot.

5 [0085] Fig. 12 is a flowchart illustrating an operation of determining the characteristic quantity modified function by the season-dependence manager module 21. In the following description, i is a variable for counting the number of past models, and is an integer
10 from 1 to N_ref. The smaller value of the variable i means the newer past model.

[0086] Further, as shown in Fig. 13, the model characteristic quantity SZ is the saturation value of the Predicted Percentage of Votes for "hot" PPVh. The
15 characteristic quantity modified function Gpm is the linear approximation function of the past outdoor thermal environment representative value Eot and the model characteristic quantity SZ. In other words, where an arbitrary outdoor thermal environment representative
20 value Eot is determined, then it is possible to calculate the estimation value of the model characteristic quantity SZ corresponding to the arbitrary outdoor thermal environment representative value Eot by using the characteristic quantity modified function Gpm. Where the
25 individual thermal sensation model is represented by Formula (15) or Formula (16), the saturation value of the Predicted Percentage of Votes PPVh corresponds to the retrieved parameter a out of the retrieved parameters a, b, c, d, and e of the model.

30 [0087] In Step S400, the season-dependence manager module 21 acquires the N_ref-times of modeling results

Sp(i) and the information of the learning data periods LP(i), which are used for the N_ref-times of modeling, from the past model storing manager module 16. In other words, the modeling result Sp(i) is the set of retrieved parameter values (in the present embodiment, set of retrieved parameters a(i), b(i), c(i), d(i), and e(i)) retrieved for the i-th past model. After that, the season-dependence manager module 21 sets the default value "1" for the variable i (Fig. 12, Step S500).

[0088] The season-dependence manager module 21 acquires the past outdoor thermal environment representative value Eot(i) corresponding to the learning data period LP(i), which is used for the i-th modeling backward from the newest modeling, out of the values calculated in Step S402 (Fig. 12, Step S501).

[0089] The season-dependence manager module 21 determines whether or not the processing of Step S501 is done for all the N_ref learning data periods LP(i), i.e., i = N_ref is satisfied (Fig. 12, Step S502). Where the variable i is smaller than N_ref (i < N_ref), the season-dependence manager module 21 increments the variable i (i = i+1) since the processing is not finished (Fig. 12, Step S503). In such a manner, the season-dependence manager module 21 executes the processing of Step S501 for each learning data period LP(i).

[0090] The season-dependence manager module 21 finishes the processing of Step S501 for all the N_ref learning data periods LP(i), i.e., i = N_ref is satisfied (Step S502, YES). Then the season-dependence manager module 21 obtains a linear approximation function of the relationship of the model characteristic quantity SZ(i)

and the outdoor thermal environment representative value $Eot(i)$. The model characteristic quantity $SZ(i)$ is determined on a basis of the function of the individual thermal sensation model and the modeling result $Sp(i)$, which is the set of retrieved parameter values. The season-dependence manager module 21 treats the obtained function as the characteristic quantity modified function Gpm (Fig. 12, Step S504). Here, in the present embodiment, the model characteristic quantity SZ is the saturation value of the Predicted Percentage of Votes for "hot" PPVh. In such a case, $SZ(i) = a(i)$ is satisfied.

[0091] Fig. 14A and Fig. 14B illustrate a method of determining the characteristic quantity modified function Gpm . In the example of Fig. 14A and Fig. 14B, $N_{ref} = 3$ is satisfied. The function $Mp(1)$ shows the latest past model, the function $Mp(2)$ shows the second-latest past model, and the function $Mp(3)$ shows the third-latest past model.

[0092] For example, the learning data period $LP(1)$ used for modeling of the latest past model is September, the learning data period $LP(2)$ used for modeling of the second-latest past model is August, and the learning data period $LP(3)$ used for modeling of the third-latest past model is July. In such a case, the past outdoor thermal environment representative values $Eot(1)$, $Eot(2)$, and $Eot(3)$ are the climatological normal outdoor temperatures of September, August, and July, respectively. Further, the model characteristic quantities $SZ(1)$, $SZ(2)$, and $SZ(3)$ are the saturation values (parameters $a(1)$, $a(2)$, and $a(3)$) of the functions $Mp(1)$, $Mp(2)$, and $Mp(3)$, respectively.

[0093] Further, as shown in Fig. 14B, each linear approximation function shows the relationship of the past outdoor thermal environment representative value {Eot(1), Eot(2), Eot(3)} and the model characteristic quantity {SZ(1), SZ(2), SZ(3)}. The linear approximation function is the characteristic quantity modified function Gpm. The characteristic quantity modified function Gpm is a function for estimating, from an arbitrary month's climatological normal outdoor temperature, the model characteristic quantity SZ(saturation value of the Predicted Percentage of Votes for "hot" PPVh) corresponding to the arbitrary month's climatological normal outdoor temperature.

[0094] Note that, in the present embodiment, the characteristic quantity modified function Gpm is obtained by using the linear approximation method. Alternatively, the characteristic quantity modified function Gpm may be determined arbitrarily by using a polynomial approximation or exponential approximation method, in consideration of effects of seasonal variation on the thermal sensation.

[0095] Note that, in the present embodiment, the saturation value of the Predicted Percentage of Votes for "hot" PPVh is used as the model characteristic quantity SZ to determine the characteristic quantity modified function Gpm. Alternatively, the model characteristic quantity SZ may be another quantity that determines the form of the function of the past model. Further, the model characteristic quantity SZ may have multiple types.

[0096] For example, the saturation value of the Predicted Percentage of Votes for "hot" PPVh is the model

characteristic quantity SZ1 (Fig. 13, SZ). As shown in Fig. 15A, the PMV value of the rising point of the Predicted Percentage of Votes PPVh is the model characteristic quantity SZ2. As shown in Fig. 15B, the PMV value where the Predicted Percentage of Votes PPVh reaches 50% of the saturation value is the model characteristic quantity SZ.

[0097] In the example of Fig. 15A, where the individual thermal sensation model is Formula (15) and Formula (16), the model characteristic quantity SZ2 corresponds to the model retrieved parameter e of the model retrieved parameters a, b, c, d, and e.

Therefore the season-dependence manager module 21 acquires the model characteristic quantity $SZ2(i) = e(i)$ from each of the N_{ref} -times of modeling results $Sp(i)$. Similar to the case of the model characteristic quantity SZ1, the season-dependence manager module 21 obtains a linear approximation function of the relationship between the model characteristic quantity $SZ2(i) = e(i)$ and the past outdoor thermal environment representative value $Eot(i)$. The season-dependence manager module 21 may treat the obtained function as the characteristic quantity modified function Gpm_2 (Step S504).

[0098] Further, in the example of Fig. 15B, the model characteristic quantity SZ3 is the PMV value when the Predicted Percentage of Votes PPVh reaches 50% of the saturation value. Therefore the season-dependence manager module 21 calculates the value $a_{50}(i)$, i.e., 50% of $a(i)$, from the model function of the individual thermal sensation model and each of the N_{ref} -times of modeling results $Sp(i)$. The season-dependence manager

module 21 calculates the PMV value, with which the Predicted Percentage of Votes for "hot" PPVh is $a_{50}(i)$, on a basis of Formula (16) (or Formula (15)) and the modeling result $Sp(i)$. The season-dependence manager module 21 may treat the calculated result as $SZ3(i)$.

[0099] Further, similar to the case of the model characteristic quantity $SZ1$, the season-dependence manager module 21 obtains a linear approximation function of the relationship between the model characteristic quantity $SZ3(i)$ and the past outdoor thermal environment representative value $Eot(i)$. The season-dependence manager module 21 may treat the obtained function as the characteristic quantity modified function Gpm_3 (Step S504). The characteristic quantity modified function obtained from the aforementioned model characteristic quantity $SZ1$ (Fig. 13, SZ) is the characteristic quantity modified function Gpm_1 .

In such a manner, it is possible to obtain the characteristic quantity modified function for each type of the model characteristic quantity SZ .

[0100] Finally, in response to an information send request from the future model generating module 22, the season-dependence manager module 21 sends the characteristic quantity modified function Gpm (Gpm_1 , Gpm_2 , Gpm_3) and the modeling result of the latest past model (Fig. 11, Step S404).

[0101] Note that the number of reference models N_{ref} , the method of determining the past outdoor thermal environment representative value Eot , the method of determining the model characteristic quantity SZ , and the method of determining the characteristic quantity

modified function Gpm corresponding to each characteristic quantity are preset by an indoor environment assessment/control, etc. solution provider or a facilities manager.

5 [0102] Fig. 16 is a flowchart illustrating an operation of the future model generating module 22. The future model generating module 22 acquires the future date-and-time (estimation future date-and-time Tm), which is instructed by an operator, for example. The future
10 date-and-time (estimation future date-and-time Tm) is the future date-and-time at which the occupants' thermal sensation (i.e., percentage of occupants who vote for dissatisfaction with thermal environment of the assessment-target space 101, i.e., the Predicted
15 Percentage of Votes for "hot" PPVh) for the assessment-target space 101 is to be estimated (Fig. 16, Step S600).

[0103] The future model generating module 22 acquires the update timing of the individual thermal sensation model information from the data period manager module 14,
20 and determines the future learning data period LPF including the estimation future date-and-time Tm (Fig. 16, Step S601). For example, the estimation future date-and-time Tm is 15/October/2019. The update timing of the individual thermal sensation model is the 1st day of
25 every month, 0:00. The learning data period length is one month. In such a case, the future model generating module 22 determines that the future learning data period LPF is October 2019.

[0104] Further, the future model generating module 22
30 acquires the future outdoor thermal environment information corresponding to the future learning data

period LPF from the outdoor thermal environment information manager module 20 (Fig. 16, Step S602). The future model generating module 22 determines the future outdoor thermal environment representative value Eotf corresponding to the future learning data period LPF on a basis of the acquired future outdoor thermal environment information (Fig. 16, Step S603). For example, where the future learning data period LPF is October 2019, the future model generating module 22 may acquire the climatological normal monthly mean outdoor temperature of October, and treat the acquired temperature as the future outdoor thermal environment representative value Eotf.

[0105] Next, the future model generating module 22 calculates, by using the characteristic quantity modified function Gpm (in this case, Gpm₁) sent from the season-dependence manager module 21, the model characteristic quantity $SZ1 = Gpm_1(Eotf)$ corresponding to the future outdoor thermal environment representative value Eotf. The future model generating module 22 treats the calculated value as the estimated characteristic quantity SZest (Fig. 16, Step S604).

[0106] Finally, the future model generating module 22 generates an individual thermal sensation model (future model). The individual thermal sensation model (future model) is generated by modifying the latest past model on a basis of the calculated estimated characteristic quantity SZest (Fig. 16, Step S605). The method of modifying the past model is preset by an indoor environment assessment/control, etc. solution provider or a facilities manager.

[0107] In the present embodiment, the ratio of the

estimated characteristic quantity SZest and the model characteristic quantity SZ1(1) = a(1) of the latest past model is treated as a model correction parameter η .

$$\eta = \text{SZest}/\text{SZ1}(1) \dots (17)$$

[0108] Further, the future model generating module 22 modifies the function Mp(1) of the latest past model on a basis of the model correction parameter η to thereby obtain the next formula.

[0109] [Math 4]

where $\text{PMV} < e(1)$, $\text{PPVh} = 0$

where $\text{PMV} \geq e(1)$, $\text{PPVh} = \eta \times \text{Mp}(1)$

$$= \eta \times a(1) \times \{1 - \exp(c(1) \times (\text{PMV} - e(1))^4 + d(1) \times (\text{PMV} - e(1))^2)\} \dots (18)$$

[0110] Formula (18) means that the parameter a(1) is modified on a basis of the model correction parameter η out of the parameters a(1), c(1), d(1), and e(1) of the latest past model (Formula (16)).

[0111] Note that, in the method of modifying the past model of the present embodiment, the scaling of the PPVh axis is only modified on a basis of the correction parameter η . Alternatively, the rising point of the Predicted Percentage of Votes PPVh may be modified by using the aforementioned model characteristic quantity SZ2. The scaling of the PMV axis may be modified by using the aforementioned model characteristic quantity SZ3, for example.

[0112] Specifically, the future model generating module 22 calculates the model characteristic quantity $\text{SZ2} = \text{Gpm_2}(\text{Eoft})$ corresponding to the future outdoor thermal environment representative value Eotf by using the characteristic quantity modified function Gpm_2 sent

from the season-dependence manager module 21. The future model generating module 22 treats the calculated value as the estimated characteristic quantity SZest_2. Further, the future model generating module 22 calculates the

5 model characteristic quantity $SZ3 = Gpm_3(Eoft)$ corresponding to the future outdoor thermal environment representative value Eotf by using the characteristic quantity modified function Gpm_3. The future model generating module 22 treats the calculated value as the

10 estimated characteristic quantity SZest_3 (Fig. 16, Step S604).

[0113] Further, for example, the difference between the estimated characteristic quantity SZest_2 and the model characteristic quantity $SZ2(1) = e(1)$ of the latest

15 past model is treated as a model correction parameter δ .

$$\delta = SZest_2 - SZ2(1) \dots (19)$$

[0114] Further, for example, the ratio of the difference $(SZest_3 - SZest_2)$ and the difference $(SZ3(1) - SZ2(1))$ is treated as a model correction parameter ξ .

20 The difference $(SZest_3 - SZest_2)$ is the difference between the estimated characteristic quantities SZest_3 and SZest_2. The difference $(SZ3(1) - SZ2(1))$ is the difference between the model characteristic quantities of the latest past model SZ3(1) and SZ2(1).

25 $\xi = (SZest_3 - SZest_2) / (SZ3(1) - SZ2(1)) \dots (20)$

[0115] Further, the future model generating module 22 modifies the function Mp(1) of the latest past model on a basis of the model correction parameters η , δ , and ξ to thereby obtain the next formula.

30 [0116] [Math 5]

where $PMV < (e(1) + \delta)$, $PPVh = 0$

where $PMV \geq (e(1) + \delta)$,

$$PPVh = \eta \times a(1) \times \{1 - \exp(c(1) \times (\xi \times PMV - (e(1) + \delta))^4 + d(1) \times (\xi \times PMV - (e(1) + \delta))^2)\} \cdot \cdot \cdot (21)$$

[0117] By modifying the past model as shown in Formula (21), it is possible to modify the rising point of the Predicted Percentage of Votes $PPVh$ by using the model correction parameter δ , and modify the scaling of the PMV axis by using the model correction parameter ξ .

[0118] After all, the processing of the future model generating module 22 is finished. According to the present embodiment, the past model is modified on a basis of the outdoor thermal environment status, on which the seasonal variation is reflected. As a result, the future model is generated. As a result, an estimation error resulting from a seasonal variation element may be reduced. The estimated PMV value at the estimation future date-and-time is input into the future model. Then it is possible to estimate the occupants' thermal sensation (i.e., percentage of occupants who vote for dissatisfaction with thermal environment of the assessment-target space 101, i.e., the Predicted Percentage of Votes for "hot" $PPVh$) for the assessment-target space 101 at the estimation future date-and-time. As a result, in the present embodiment, the estimated result of the occupants' thermal sensation may be closer to the real thermal sensation.

[0119] [Second embodiment]

Next, a second embodiment of the present disclosure will be described. The configuration of the thermal sensation model generating apparatus of the second

embodiment is similar to the configuration of the first embodiment. So the description will be made with reference to the reference symbols of Fig. 2.

Learning data corresponding to a period of about several days includes a short-term variance. The reliability of the model becomes lower if such a learning data is used. So it is necessary to ensure data of a certain period as learning data (combination information).

As described in the first embodiment, about one month is appropriate for the learning data period length. Further, in order to maintain the contiguousness of seasonal variations, overlapping periods are provided. In the overlapping period, individual learning data periods overlap one another. In an example of the present embodiment described below, the overlapping period, i.e., a reliable certain period, is two weeks.

[0120] In the present embodiment, similar to the first embodiment, the data period manager module 14 of the thermal sensation model generating apparatus has data period management information. The data period management information is used to determine the update timing and the learning data period of the individual thermal sensation model (past model). The data period management information is preset by an indoor environment assessment/control, etc. solution provider or a facilities manager.

[0121] The difference from the first embodiment is as follows. The data period management information includes, in addition to the update timing and the learning data period length information of the individual thermal sensation model information, information of the

overlapping period length L_o .

[0122] Fig. 17A and Fig. 17B illustrate the learning data periods of the first and second embodiments. Note that, for easier understandings, Fig. 17A and Fig. 17B show the dates of update timing assuming that all the months have 30 days uniformly. Fig. 17A and Fig. 17B show learning data periods of respective update timings from 1/October/2018 (i.e., latest update timing) to the update timing 1/August/2018. Further, in Fig. 17A and Fig. 17B, the update start date-and-time is 1/August/2018 0:00, and each learning data period length has 30 days. In the example of Fig. 17B of the present embodiment, the overlapping period length L_o is 15 days. Fig. 17A shows the contiguous update timings and the contiguous learning data periods. To the contrary, according to the present embodiment of Fig. 17B, the overlapping period length L_o is set. So the model updating span is shorter than the first embodiment corresponding to the overlapping period length L_o .

[0123] In the present example corresponding to the first embodiment, as shown in Fig. 17A, for example, the past model $M_p(2)$ is updated at 1/September/2018 0:00. The learning data period SW of the past model $M_p(2)$ has 30 days from the start timing 1/August/2018 0:00 to the end timing 30/August/2018 23:59 (in this case, 30/August/2018 corresponds to the last day of August, where all the months have 30 days uniformly). Further, the learning data period SW of the past model $M_p(3)$, which is immediately before the past model $M_p(2)$, has 30 days from the start timing 1/July/2018 0:00 to the end timing 30/July/2018 23:59 (in this case, 30/July/2018

corresponds to the last day of July, where all the months have 30 days uniformly). The learning data periods SW of the past models Mp(2) and Mp(3) having the contiguous update timings do not overlap one another.

[0124] Meanwhile, in the present embodiment, as shown in Fig. 17B, for example, the past model Mp(3) is updated at 1/September/2018 0:00. The learning data period SW of the past model Mp(3) has 30 days from the start timing 1/August/2018 0:00 to the end timing 30/August/2018 23:59 (in this case, 30/August/2018 corresponds to the last day of August, where all the months have 30 days uniformly). The learning data period SW of the past model Mp(3) of Fig. 17B is the same as the learning data period SW of the past model Mp(2) of Fig. 17A. However, in Fig. 17B, the learning data period SW of the past model Mp(4), which is immediately before the past model Mp(3), has 30 days from the start timing 16/July/2018 0:00 to the end timing 15/August/2018 23:59. The learning data period SW of the past model Mp(4) includes the overlapping period length L_o (i.e., 15 days from 1/August/2018 to 15/August/2018), which overlaps with the learning data period SW of the past model Mp(3) of Fig. 17B. The learning data periods SW of the past models Mp(3) and Mp(4) having the contiguous update timings overlap one another by the overlapping period length L_o .

[0125] The other configuration is similar to the configuration described in the first embodiment. Note that, in the present embodiment, the learning data period length is appropriately about one month. In such a case, further, it is desirable that two contiguous learning data periods overlap one another by a reliable period

length in order to maintain contiguousness of seasonal variations. The overlapping period length L_o has appropriately a long period such as two weeks or more.

[0126] Fig. 18A shows the two-week mean value variation of the outdoor temperature measured in a certain building from July to September 2017. Fig. 18B shows the four-week mean value variation of the outdoor temperature measured in a certain building from July to September 2017. In each of Fig. 18A and Fig. 18B, the horizontal axis shows the elapsed weeks counted from the first week.

[0127] In the example of Fig. 18A, the overlapping period has one week. In the example of Fig. 18B, the overlapping period has two weeks. As apparent from the comparison between Fig. 18A and Fig. 18B, the mean value of four weeks, in which the overlapping period has two weeks, has less short-term variance in the outdoor temperature mean value.

[0128] The thermal sensation model generating apparatus described in the first and second embodiments is realized by a computer including a CPU (Central Processing Unit), a storage device, and an interface, and programs that control those hardware resources. Fig. 19 shows an example of a configuration of the computer.

[0129] The computer includes the CPU 200, the storage device 201, and the interface device (referred to as I/F) 202. The environment measuring device and the like are connected to the interface 202. In such a computer, the storage device 201 stores a program that realizes the thermal sensation model generating method of the present disclosure. The CPU 200 executes the program stored in

the storage device 201 to thereby execute the processing described in the first and second embodiments.

[0130] The present disclosure is applicable to a technology of estimating the occupants' thermal sensation in the future date-and-time.

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What is claimed is:

1. A thermal sensation model generating apparatus,
comprising:

5 a data period manager module configured to store
update timing information of a first model, the
first model being a model of a relationship between a
living environment index of an assessment-target space
and occupants' thermal sensation for the assessment-
target space, and

10 learning data period information;

a first model generating module configured to
generate the first model at the update timing on a basis
of the living environment index and the occupants'
thermal sensation information in the learning data
15 period;

a season-dependence manager module configured to
obtain a characteristic quantity modified function on a
basis of multiple first models and past outdoor thermal
environment representative values, the multiple first
20 models being generated in multiple learning data periods
respectively, the past outdoor thermal environment
representative values corresponding to the multiple
learning data periods respectively, the characteristic
quantity modified function indicating a relationship
25 between a model characteristic quantity determining a
form of a function of the first model and an outdoor
thermal environment representative value; and

a second model generating module configured to
determine a future learning data period to be
30 set for future date-and-time at which occupants' thermal
sensation is to be estimated,

calculate a model characteristic quantity
corresponding to an outdoor thermal environment
representative value in the future learning data period
on a basis of the characteristic quantity modified
5 function, and

generate a second model by modifying a latest
first model on a basis of the calculated model
characteristic quantity.

2. The thermal sensation model generating apparatus
10 according to claim 1, wherein

the data period manager module is configured to
store overlapping period information in addition to the
update timing information and the learning data period
information, and

15 the multiple learning data periods are set such that
two contiguous learning data periods overlap one another
by a length of the overlapping period.

3. The thermal sensation model generating apparatus
according to claim 1 or 2, further comprising:

20 an outdoor thermal environment information manager
module configured to store past outdoor thermal
environment information of a building having the
assessment-target space, wherein

25 the season-dependence manager module is configured
to

acquire past outdoor thermal environment
information corresponding to the multiple learning data
periods respectively, from the outdoor thermal
environment information manager module,

30 determine past outdoor thermal environment
representative values corresponding to the multiple

learning data periods respectively, and

obtain the characteristic quantity modified
function, and

the second model generating module is configured to
5 acquire the past outdoor thermal environment
information corresponding to the future learning data
period from the outdoor thermal environment information
manager module, and

determine an outdoor thermal environment
10 representative value corresponding to the future learning
data period.

4. The thermal sensation model generating apparatus
according to any one of claims 1 to 3, wherein

the second model generating module is configured to
15 modify the latest first model on a basis of

a model characteristic quantity calculated on a
basis of the characteristic quantity modified function,
and

a model characteristic quantity of the latest
20 first model.

5. The thermal sensation model generating apparatus
according to any one of claims 1 to 4, wherein

the living environment index is a PMV (Predicted
Mean Vote), and

25 occupants' thermal sensation is a percentage of
occupants who vote for dissatisfaction with a thermal
environment.

6. A thermal sensation model generating method,
comprising:

30 the first step of, with reference to a data period
manager module configured to store

update timing information of a first model, the first model being a model of a relationship between a living environment index of an assessment-target space and occupants' thermal sensation for the assessment-target space, and

learning data period information,
generating the first model at the update timing on a basis of the living environment index and the occupants' thermal sensation information in the learning data period;

the second step of obtaining a characteristic quantity modified function on a basis of multiple first models and past outdoor thermal environment representative values, the multiple first models being generated in multiple learning data periods respectively, the past outdoor thermal environment representative values corresponding to the multiple learning data periods respectively, the characteristic quantity modified function indicating a relationship between a model characteristic quantity determining a form of a function of the first model and an outdoor thermal environment representative value; and

the third step of
determining a future learning data period to be set for future date-and-time at which occupants' thermal sensation is to be estimated,

calculating a model characteristic quantity corresponding to an outdoor thermal environment representative value in the future learning data period on a basis of the characteristic quantity modified function, and

generating a second model by modifying a latest first model on a basis of the calculated model characteristic quantity.

7. The thermal sensation model generating method according to claim 6, wherein

the data period manager module is configured to store overlapping period information in addition to the update timing information and the learning data period information, and

the multiple learning data periods are set such that two contiguous learning data periods overlap one another by a length of the overlapping period.

8. The thermal sensation model generating method according to claim 6 or 7, wherein

the second step includes

with reference to an outdoor thermal environment information manager module configured to store past outdoor thermal environment information of a building having the assessment-target space,

acquiring past outdoor thermal environment information corresponding to the multiple learning data periods respectively, from the outdoor thermal environment information manager module,

determining past outdoor thermal environment representative values corresponding to the multiple learning data periods respectively, and

obtaining the characteristic quantity modified function, and

the third step includes

acquiring the past outdoor thermal environment information corresponding to the future learning data

period from the outdoor thermal environment information manager module, and

determining an outdoor thermal environment representative value corresponding to the future learning data period.

9. The thermal sensation model generating method according to any one of claims 6 to 8, wherein

the third step includes modifying the latest first model on a basis of

a model characteristic quantity calculated on a basis of the characteristic quantity modified function, and

a model characteristic quantity of the latest first model.

10. The thermal sensation model generating method according to any one of claims 6 to 9, wherein

the living environment index is a PMV (Predicted Mean Vote), and

occupants' thermal sensation is a percentage of occupants who vote for dissatisfaction with a thermal environment.