(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 170 249 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
26.04.2023 Bulletin 2023/17

(21) Application number: **21833477.9**

(22) Date of filing: **28.06.2021**

(51) International Patent Classification (IPC):
F24F 11/00 *(2018.01)*

(52) Cooperative Patent Classification (CPC):
F24F 11/00; F24F 11/61; F24F 11/64; F24F 11/70;
F24F 2110/12; F24F 2130/10

(86) International application number:
PCT/CN2021/102691

(87) International publication number:
WO 2022/001935 (06.01.2022 Gazette 2022/01)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **28.06.2020 CN 202010599919**

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(54) AIR CONDITIONER CONTROL METHOD AND APPARATUS, ELECTRONIC DEVICE, AND MEDIUM

(57) An air conditioner control method, comprising: determining a predicted outdoor temperature at a future target time; according to the target time and the predicted outdoor temperature, determining a predicted operation time period of an air conditioner at the target time, the predicted operation time period being an operation time period that the total power consumption of the air conditioner meets a second predetermined standard when the indoor temperature does not exceed a first predetermined standard; and controlling the air conditioner at the target time according to the predicted operation time period. The present solution further provides an air conditioner control apparatus, an electronic device, and a computer-readable medium.

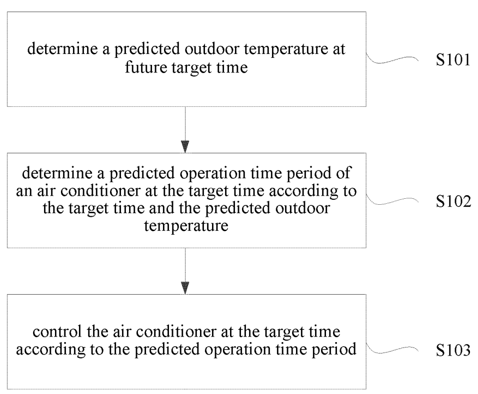

FIG. 1

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Description

TECHNICAL FIELD

[0001] Embodiments of the present disclosure relate to the technical field of communications, and in particular, to an air conditioner control method and device, an electronic device and a computer-readable medium.

BACKGROUND

[0002] In a communication network, about 80% of energy consumption is caused by widely distributed base stations, and air-conditioning energy consumption of the base stations accounts for 46% of the total energy consumption of the base stations.

[0003] Controlling air conditioners in the base stations by setting startup temperatures and shutdown temperatures can realize free setting and adjustment of the startup temperatures and the shutdown temperatures, but it is usually hard to determine real reasonable startup/shutdown temperatures, and improper startup/shutdown temperatures may cause the air conditioners to be frequently turned on and turned off, resulting in more power consumption of the air conditioners in the base stations.

SUMMARY

[0004] An embodiment of the present disclosure provides an air conditioner control method, including: determining a predicted outdoor temperature at future target time; determining a predicted operation time period of an air conditioner at the target time according to the target time and the predicted outdoor temperature, with the predicted operation time period being an operation time period during which total power consumption of the air conditioner meets a second predetermined standard with an indoor temperature not exceeding a first predetermined standard; and controlling the air conditioner at the target time according to the predicted operation time period.

[0005] An embodiment of the present disclosure further provides an air conditioner control device, including: a determination module configured to determine a predicted outdoor temperature at future target time; a prediction module configured to determine a predicted operation time period of an air conditioner at the target time according to the target time and the predicted outdoor temperature, with the predicted operation time period being an operation time period during which total power consumption of the air conditioner meets a second predetermined standard with an indoor temperature not exceeding a first predetermined standard; and a control module configured to control the air conditioner at the target time according to the predicted operation time period.

[0006] An embodiment of the present disclosure further provides an electronic device, including: one or more processors; and a memory having stored thereon one or more programs, which, when executed by the one or more processors, cause the one or more processors to perform the air conditioner control method according to the present disclosure.

[0007] An embodiment of the present disclosure further provides a computer-readable medium having stored thereon a computer program, which, when executed by a processor, causes the processor to perform the air conditioner control method according to the present disclosure.

BRIEF DESCRIPTION OF DRAWINGS

[0008] In the drawings,

FIG. 1 is a flowchart illustrating an air conditioner control method according to the present disclosure;
FIG. 2 is another flowchart illustrating the air conditioner control method according to the present disclosure;
FIG. 3 is a schematic diagram of a logic structure of a deep neural network model used in the air conditioner control method according to the present disclosure;
FIG. 4 is a block diagram of an air conditioner control device according to the present disclosure;
FIG. 5 is a block diagram of an electronic device according to the present disclosure; and
FIG. 6 is a block diagram of a computer-readable medium according to the present disclosure.

DETAIL DESCRIPTION OF EMBODIMENTS

[0009] In order to enable those of ordinary skill in the art to better understand the technical solutions of the present disclosure, an air conditioner control method and device, an electronic device and a computer-readable medium provided by the present disclosure are described in detail below with reference to the drawings.

[0010] The embodiments of the present disclosure will be described more fully below with reference to the drawings, but the embodiments illustrated may be embodied in different forms, and should not be interpreted as being limited to the embodiments described herein. Rather, the embodiments are provided to make the present disclosure thorough and complete, and are intended to enable those of ordinary skill in the art to fully understand the scope of the present disclosure.

[0011] The drawings for the embodiments of the present disclosure are intended to provide a further understanding of the embodiments of the present disclosure and constitute a part of the specification. Together with the embodiments of the present disclosure, the drawings are used to explain the present disclosure, but do not constitute any limitation to the present disclosure The above and other features and advantages will become more apparent to those of ordinary skill in the art from the description of specific embodiments with reference to the drawings.

[0012] The embodiments of the present disclosure can be described with reference to plans and/or cross-sectional views with the aid of idealized schematic diagrams of the present disclosure. Accordingly, the exemplary drawings may be modified according to manufacturing techniques and/or tolerances.

[0013] All the embodiments of the present disclosure and the features therein may be combined with each other if no conflict is incurred.

[0014] The terms used herein are merely used to describe specific embodiments, and are not intended to limit the present disclosure. The term "and/or" used herein includes one associated listed item or any and all combinations of more than one associated listed items. The terms "one" and "the" used herein which indicate a singular form are intended to include a plural form, unless expressly stated in the context. The terms "comprise" and "be made of' used herein indicate the presence of the described features, integers, operations, elements and/or components, but do not exclude the presence or addition of one or more other features, integers, operations, elements, components and/or combinations thereof.

[0015] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by those of ordinary skill in the art. It should be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with a meaning in the context of the related technology and the background of the present disclosure, and should not be interpreted in an idealized or overly formal sense unless expressly so defined herein

[0016] The embodiments of the present disclosure are not limited to those illustrated by the drawings, but include modifications to configuration formed based on a manufacturing process. Thus, regions shown in the drawings are illustrative, and shapes of the regions shown in the drawings illustrate specific shapes of regions of elements, but are not intended to make limitations.

[0017] In the related technology, a temperature-controlled startup-shutdown method may be used to control an air conditioner in a base station. Specifically, according to the temperature-controlled startup-shutdown method, startup/shutdown temperature parameters of the air conditioner such as 35°C/25°C are set according to experience, that is, the air conditioner is controlled to be turned on when an indoor temperature (a room temperature) of the base station exceeds 35 °C and is controlled to be turned off when the indoor temperature is lower than 25 °C .

[0018] However, the above temperature parameters are all "bi-directional", that is, the temperature parameters are not beneficial when the temperature parameters are too high or too low. For example, if the startup temperature is set to be too high, the air conditioner may not be turned on in time, so that devices in the base station may easily overheat and cause an accident; while if the startup temperature is set to be too low, the air conditioner may be frequently turned on, resulting in an increase of unnecessary power consumption.

[0019] Although the temperature-controlled startup-shutdown method is simple, it is hard to be implemented in practical applications because merely the indoor temperature of the base station is taken as a reference for controlling the air conditioner and no other factors are considered, that is, the startup/shutdown temperature parameters cannot be determined, for example, it is hard to determine whether the startup/shutdown temperature parameters of the air conditioner are better when set to 35°C/25 °C, or 33 °C /23 °C, or 37°C /23 °C .

[0020] For example, if the indoor temperature of a certain base station is lower than 35 °C for a long period of time but may temporarily exceed 35°C at a certain moment due to superposition of a traffic peak and a temperature peak, the air conditioner will be turned on when the indoor temperature temporarily exceeds 35°C, but in fact, the indoor temperature may decrease after a short period of time even if the air conditioner is not turned on, which makes it unnecessary to turn on the air conditioner, because an upper limit of an operating temperature range of the devices in the base station can reach 40°C for a long period of time and can reach 50°C for a short period of time. By taking the indoor temperature alone as a standard, whether the indoor temperature exceeds 35°C for a long period of time or just for a short period of time cannot be determined, so that it cannot be determined whether taking 35 °C as a parameter value is reasonable.

[0021] FIG. 1 is a flowchart illustrating an air conditioner control method according to the present disclosure.

[0022] With reference to FIG. 1, the air conditioner control method according to the present disclosure includes operations S101 to S103.

[0023] In operation S101, a predicted outdoor temperature at future target time is determined.

[0024] For example, as a cloud management system, the Unified Management Expert (UME) can determine a future moment or period (e.g., one day) when an air conditioner needs to be controlled as the target time, and acquire a predicted outdoor temperature of a place where the base station is located at the target time.

[0025] Since the target time is the future moment (or period), the predicted outdoor temperature needs to be acquired with a prediction method such as the weather forecast. Thus, the outdoor temperature (i.e., an ambient temperature) when the air conditioner is to be controlled in the future is acquired in this operation.

[0026] In operation S102, a predicted operation time period of the air conditioner at the target time is determined according to the target time and the predicted outdoor temperature.

[0027] The predicted operation time period is an operation time period during which total power consumption of the air conditioner meets a second predetermined standard with the indoor temperature not exceeding a first predetermined standard.

[0028] For example, the UME may determine the predicted operation time period of the air conditioner in the base station at the target time according to the target time and the acquired predicted outdoor temperature. That is, according to the target time and the predicted outdoor temperature, the UME determines during which time period the air conditioner operates, it may be ensured that the indoor temperature of the base station does not exceed the first predetermined standard and the total power consumption of the air conditioner meets the second predetermined standard within the target time.

[0029] When the indoor temperature of the base station meets the first predetermined standard, it may be ensured that the devices in the base station do not overheat, that is, the first predetermined standard may ensure that the devices in the base station do not overheat; apparently, it is also feasible if the first predetermined standard may also prevent the devices in the base station from overheating in a better way (for example, the devices are kept far away from overheating to some extent).

[0030] The second predetermined standard refers to a standard by which the total power consumption of the air conditioner can be made relatively low. For example, the second predetermined standard may ensure that the total power consumption of the air conditioner is the minimum with the indoor temperature not exceeding the first predetermined standard; or the second predetermined standard may ensure that the total power consumption of the air conditioner does not to exceed a predetermined "preset value" with the indoor temperature not exceeding the first predetermined standard.

[0031] That is, the predicted operation time period actually represents a time period when the air conditioner theoretically "should" operate (be turned on) or a "preferred operation time period" of the air conditioner, and may be embodied in various specific forms.

[0032] For example, the predicted operation time period may include a plurality of (e.g., 12) sets of "startup moments" and "operation time periods", and the air conditioner needs to be turned on (started up) at each of the startup moments, and turned off (shut down) after operating for a corresponding operation time period.

[0033] For example, the predicted operation time period may include a plurality of discontinuous operation time periods during which the air conditioner needs to operate; and time intervals between the operation time periods are shutdown time periods during which the air conditioner needs to be turned off.

[0034] In operation S103, the air conditioner is controlled at the target time according to the predicted operation time period.

[0035] When the target time is reached, the UME sends the predicted operation time period to an air conditioning controller Field Supervision Unit (FSU), so as to control the air conditioner in the base station according to the predicted operation time period through the FSU, that is, the UME may keep the air conditioner in the base station in an on state during the predicted operation time period.

[0036] In the embodiment of the present disclosure, the predicted operation time period at the target time is obtained according to the specific future time (the target time) and the outdoor temperature (the predicted outdoor temperature) at the target time, that is, a preferred operation mode of the air conditioner at the target time is predicted, and the air conditioner is controlled to be turned on or turned off at the target time according to the preferred operation mode, so as to ensure that the devices in the base station do not overheat while reducing energy consumption as much as possible.

[0037] FIG. 2 is another flowchart illustrating the air conditioner control method according to the present disclosure.

[0038] With reference to FIG. 2, the operation of determining the predicted outdoor temperature at the future target time (i.e., the operation S101) may include operation S1011.

[0039] In operation S1011, an actual outdoor temperature and a temperature at the target time forecast by the weather forecast are acquired, and the predicted outdoor temperature at the target time is calculated according to the actual outdoor temperature and the forecast temperature.

[0040] The predicted outdoor temperature of the base station at the future target time may be calculated based on the actual outdoor temperature of the base station together with the temperature at the target time forecast by the weather forecast. For example, a weighted average of the temperature forecast by the weather forecast and actual outdoor temperatures in the last hour may be taken as the predicted outdoor temperature.

[0041] With reference to FIG. 2, the operation of controlling the air conditioner at the target time according to the predicted operation time period (i.e., the operation S103) may include operation S1031.

[0042] In operation S 1031, the air conditioner is controlled at the target time according to a real-time indoor temperature, a preset additional rule and the predicted operation time period.

[0043] As a prediction result, the predicted operation time period may hardly be absolutely consistent with an actual situation. For example, when an actual temperature of the place where the base station is located at the target time is higher than the predicted outdoor temperature, the devices in the base station may overheat and be damaged if the air conditioner in the base station is still controlled merely according to the predicted operation time period.

[0044] In order to reduce the overheating and damage such caused, the additional rule may be configured for the UME, so that an actual operating state of the air conditioner at the target time may be "adjusted" to some extent according to the real-time indoor temperature of the base station and the preset additional rule.

[0045] The additional rule may include: controlling the air conditioner to be turned on if the real-time indoor temperature exceeds a preset very high temperature threshold and the air conditioner does not operate; controlling the air conditioner to be turned off if the real-time indoor temperature is lower than a preset very low temperature threshold and the air conditioner is operating; and controlling the air conditioner to be in an operating state if the real-time indoor temperature exceeds a preset operation high temperature threshold and it is within the predicted operation time period.

[0046] When it is detected that the real-time indoor temperature of the base station exceeds the very high temperature threshold (a relatively high preset temperature value), it is indicated that the devices in the base station are likely to fail due to overheating if the temperature is not decreased in time. Therefore, if the air conditioner in the base station is not turned on at this time (for example, it is not within the predicted operation time period), the air conditioner in the base station needs to be controlled to be turned on forcibly to cool the devices in the base station, so as to prevent the devices from failing due to the overheating.

[0047] When it is detected that the real-time indoor temperature of the base station is lower than the very low temperature threshold (a relatively low preset temperature value), it is indicated that the temperatures of the devices in the base station are in a very safe range, and the devices may be probably kept from overheating for a long period of time. Therefore, if the air conditioner in the base station is turned on at this time (for example, it is within the predicted operation time period), the air conditioner in the base station may be controlled to be turned off forcibly to save energy.

[0048] When it is within the predicted operation time period, the air conditioner should be turned on theoretically. However, if the real-time indoor temperature of the base station is not high at this time (not exceeding the operation high temperature threshold), it is indicated that the air conditioner does not need to be turned on in fact, so that the air conditioner may be controlled to be in the on state merely when the real-time indoor temperature of the base station exceeds the operation high temperature threshold and it is within the predicted operation time period.

[0049] The additional rule may further include other parameters, such as minimum shutdown duration and maximum operation duration.

[0050] For example, when the air conditioner is to be turned on (for example, it is within the predicted operation time period), it needs to be ensured that the air conditioner has been off for a period of time longer than the minimum shutdown duration (e.g., 0.5 hours) since the air conditioner was turned off previously, otherwise the air conditioner is not turned on, so as to prevent the air conditioner from being turned on frequently.

[0051] For example, when the air conditioner continuously operates for a period of time longer than the maximum operation duration (e.g., 12 hours), the air conditioner may be forcibly turned off to rest.

[0052] Specific values of the above parameters, such as the very high temperature threshold, the very low temperature threshold, the high temperature threshold, the minimum shutdown duration and the maximum operation duration, may be set as required (but it needs to be ensured that the very high temperature threshold is higher than the high temperature threshold, and the high temperature threshold is higher than the very low temperature threshold). For example, if the devices in a certain base station are sensitive to temperature, both the very high temperature threshold and the high temperature threshold need to be set to be relatively low.

[0053] The number of the used parameters such as the very high temperature threshold, the very low temperature threshold, the high temperature threshold, the minimum shutdown duration and the maximum operation duration, priority relationships between the parameters, and priority relationships between the rules may also be set as required. For example, the air conditioner may not be turned on even if the temperature exceeds the very high temperature threshold when the rule of the minimum shutdown duration is not met; or the air conditioner may be turned on when the temperature exceeds the very high temperature threshold no matter whether the rule of the minimum shutdown duration is met or not.

[0054] With reference to FIG. 2, the operation of determining the predicted operation time period of the air conditioner at the target time according to the target time and the predicted outdoor temperature (i.e., the operation S102) may include operation S1021.

[0055] In operation S1021, the target time and the predicted outdoor temperature are input into a preset deep neural network model, and the predicted operation time period output by the deep neural network model is acquired.

[0056] In an implementation of the present disclosure, the predicted operation time period may be obtained by using a predetermined Deep Neural Network (NN) model.

[0057] Specifically, the deep neural network model may be deployed on the UME, so that the UME may acquire the predicted operation time period from the deep neural network model, and control the air conditioner through the FSU based on the internally configured additional rule.

[0058] FIG. 3 is a schematic diagram of a logic structure of a deep neural network model used in the air conditioner control method according to the present disclosure.

[0059] With reference to FIG. 3, the deep neural network model may include a first submodel, a second submodel, and a third submodel.

[0060] The first submodel is configured to determine a predicted load of the base station at the target time and input the predicted load to the second submodel.

[0061] The second submodel is configured to determine, according to the predicted load and the predicted outdoor temperature, a predicted indoor temperature of the base station with the air conditioner not operating, and input the predicted indoor temperature into the third submodel.

[0062] The third submodel is configured to determine the predicted operation time period according to the predicted indoor temperature and a cooling parameter of the air conditioner.

[0063] The operation of inputting the target time and the predicted outdoor temperature into the preset deep neural network model (i.e., the operation S1021) may include: inputting the target time into the first submodel, and inputting the predicted outdoor temperature into the second submodel.

[0064] The deep neural network model may include three submodels, and all of the three submodels may also be deep neural network models.

[0065] Apparently, there may be some correlation between the load of the base station and the characteristics of time (i.e., a time parameter). For example, a particular day (e.g., a weekend), whether it is a holiday, a service tide, or whether there is a regional event (e.g., a large gathering) may affect the load of the base station. Therefore, the first submodel after trained may predict the load of the base station at the target time (e.g., one day) according to historical actual loads of the base stations and corresponding time parameters (e.g., the holiday, the service tide, or the regional event), and the target time and a corresponding time parameter.

[0066] The indoor temperature of the base station is mainly determined by the load of the base station (which is related to the amount of the heat generated by the devices in the base station) in a case where the air conditioner is not turned on and an outdoor temperature. Therefore, the second submodel after trained may predict, according to the predicted load obtained by the first submodel and the predicted outdoor temperature, the predicted indoor temperature of the base station at the target time in the case where the air condition is not turned on.

[0067] With other conditions unchanged, a cooling effect which may be produced by turning on the air conditioner at a certain indoor temperature may be calculated. Therefore, the third submodel may calculate an indoor temperature of the base station (i.e., an indoor temperature after the air conditioner is turned on) in each operation mode of the air conditioner (i.e., each operation time period of the air conditioner) according to the predicted indoor temperature obtained by the second submodel, determine in which operation mode the power consumption of the air conditioner meets the second predetermined standard (e.g., the minimum power consumption), with the operation mode being one of the operation modes in which the indoor temperature meets the first predetermined standard (e.g., the devices in the base station are kept from overheating), and output the operation mode as the predicted operation time period.

[0068] The cooling parameter of the air conditioner refers to an actual cooling capacity of the air conditioner (or the capacity to reduce the indoor temperature) under current actual conditions of the base station and the air conditioner, and may be expressed in a form of a cooling efficiency factor.

[0069] Specifically, the cooling parameter (the cooling efficiency factor) of the air conditioner may be determined according to a layout of the base station (such as a floor area and a house type), a layout of devices in the base station (such as, types and the number of the devices, and locations of the devices in the base station), the performance of the air conditioner (such as the power, model and parameter setting of the air conditioner), and the arrangement of the air conditioner (such as a location of the air conditioner in the base station, and a location of an air duct of the air conditioner in the base station), which may be derived theoretically or obtained through actual tests on the base station.

[0070] Apparently, under the condition that the arrangement of the base station and the air conditioner is not changed, the cooling parameter (the cooling efficiency factor) of the air conditioner is a constant value which is not changed. Therefore, the cooling parameter (the cooling efficiency factor) of the air conditioner in the third submodel may be predetermined, and be reset merely when the arrangement of the base station is changed or when the arrangement of the devices and the air conditioner in the base station is changed.

[0071] The above division of the three submodels is merely for obtaining the predicted operation time period more accurately, and is not a limitation on the scope of the embodiments of the present disclosure, and the deep neural network model of the present disclosure may also have other different structures.

[0072] With reference to FIG. 2, before the operation of inputting the target time and the predicted outdoor temperature into the preset deep neural network model (i.e., the operation S1021), the air conditioner control method may further include operation S100.

[0073] In operation S100, the deep neural network model is trained.

[0074] Deep neural network models are generally trained before use.

[0075] A basic training process of the deep neural network models is to input training data whose actual result is known into the models, obtain prediction results output by the models, and adjust each parameter of the deep neural network models according to a difference between the prediction result and the actual result, so as to gradually optimize the performance of the deep neural network models.

[0076] The training of the deep neural network models may be just "one time" training, that is, the training is not continued after the deep neural network models have required performance through an intensive training process by using a large amount of training data.

[0077] The training of the deep neural network models may also be continuous, that is, the deep neural network models are continuously trained or continuously optimized during practical applications thereof according to new data accumulated during the practical applications.

[0078] Since the three submodels in the deep neural network model of the present disclosure are relatively independent of each other, the three submodels may be trained independently. That is, although the output of the previous submodel is used as the input into the next submodel in the practical applications, but measured data may be directly input into the next submodel during the training, so as to make the training more accurate and more efficiently.

[0079] Specifically, a training process of the deep neural network model according to the present disclosure may include the following operations A1 to A8.

[0080] In operation A1, a heat distribution map of a room environment, heat generating devices and the air conditioner is created through computer simulation, and a cooling parameter (the cooling efficiency factor) of the air conditioner is obtained according to the heat distribution map.

[0081] In operation A2, a large amount of sample data such as outdoor temperatures, indoor temperatures (when the air conditioner is not turned on) and loads of the base station at different historical time is collected.

[0082] In operation A3, an air conditioner control optimal solution vector (i.e., a preferred operation time period of the air conditioner) is manually calculated according to the indoor temperatures and the cooling parameter of the air conditioner.

[0083] For example, each air conditioner control optimal solution vector may include a plurality of sets of startup moment and corresponding operation duration of the air conditioner.

[0084] In operation A4, all the sample data is normalized according to the following formula to allow each sample data to be between 0 and 1:

$$X^* = \frac{Xreal - Xmin}{Xmax - Xmin}$$

where X* is the normalized sample data, Xreal is a true value of the sample data, Xmax is a maximum value or an upper limit of the sample data, and Xmin is a minimum value or a lower limit of the sample data.

[0085] The normalization is just for simplifying the data and facilitating the processing, and is not an operation that must be performed.

[0086] In operation A5, the sample data at the different time is sorted into a training set, a verification set, and a test set.

[0087] The training set is used to train the model (or for an earlier period in the training process), the verification set is used to verify whether the training of the model is completed (or for a latter period of the training process), and the test set is used to test the trained model (or to test a training result).

[0088] In operation A6, the first submodel is built and trained.

[0089] With the load at certain historical time and corresponding time parameter (such as the holiday, the service tide or the regional event), and time to be measured (which is also the historical time) and corresponding time parameter taken as input parameters, the first submodel is used to output a predicted load at the time to be measured and compare the predicted load with the actual load at the corresponding time, thus being trained.

[0090] In operation A7, the second submodel is built and trained.

[0091] With the actual outdoor temperature and the load periodically collected at certain historical time taken as input parameters, the second submodel is used to output a predicted indoor temperature at the historical time and compare the predicted indoor temperature with the actual indoor temperature at the historical time, thus being trained.

[0092] In operation A8, the third submodel is built and trained.

[0093] With the actual indoor temperature and the cooling efficiency factor periodically collected at certain historical time taken as input parameters, the third submodel is used to output an air conditioner control optimal solution vector at the historical time and compare the air conditioner control optimal solution vector with the air conditioner control optimal solution vector obtained in the operation A3, thus being trained.

[0094] The air conditioner control method according to the present disclosure may specifically include the following operations B01 to B14.

[0095] In operation B01, an additional rule is set in advance.

[0096] The additional rule is set in advance according to conventional operation and maintenance experience of the base station.

[0097] For example, if the air conditioner in the base station is generally turned on when the indoor temperature exceeds 35°C and turned off when the temperature drops to about 25°C, the following parameters may be configured for the FSU or the UME:

1) the high temperature threshold HT: the air conditioner is turned on when the indoor temperature exceeds the threshold, and a default value is 35°C;
2) the very high temperature threshold VHT: the air conditioner needs to be turned on unconditionally when the indoor temperature exceeds the threshold, and a default value is 40°C;
3) a low temperature threshold LT: the air conditioner which is operating is turned off when the indoor temperature is lower than the threshold, and a default value is 25°C;
4) the very low temperature threshold VLT: the air conditioner needs to be turned off unconditionally when the indoor temperature is lower than the

threshold, and a default value of 15°C;

5) Maximum Continuous operation time (MAXCOT): the maximum continuous operation duration during which the air conditioner is allowed to operate, and a default value is 12 hours; and

6) Minimum Continuous shutdown time (MINCST): the minimum continuous shutdown duration during which the air conditioner is allowed to be off, and a default value is 0.5 hour.

[0098] In operation B02, data is collected to obtain the sample data.

[0099] A large number of external characteristic parameters such as the outdoor temperatures TRout, the indoor temperatures TRin and the loads LR of a machine room are collected.

[0100] Collection periods of the above parameters may be determined according to general change speeds of the parameters, for example, the collection period of TRout is 10 minutes, and the collection periods of TRin and LR are both 5 minutes.

[0101] The above data may be the measured data. For example, in a case where TRin is high and the air conditioner needs to operate, a dummy load is used to simulate the device, and real-time data of TRout, TRin and LR are collected and recorded.

[0102] The above data may also be the historical data. For example, in a case where TRin is low and the air conditioner is off for a long period of time (such as in a season or at nights when TRout is low), a large amount of the existing historical data may be used.

[0103] In operation B03, the data is labeled to obtain sample labels.

[0104] A simulation model of a room environment, heat generating devices and the air conditioner is built through Computational Fluid Dynamics (CFD) software (e.g., FloTHERM), so as to obtain the cooling parameter (the cooling efficiency factor) of the air conditioner.

[0105] The sample data (TRin, LR) is subjected to simulation calculation to obtain an air conditioner control optimal solution vector (i.e., an optimal operation time period of the air conditioner). For example, the air conditioner control optimal solution vector may include a plurality of startup moments Tmoment (hh:mm:ss) and corresponding operation durations Thours of the air conditioner. The air conditioner control optimal solution vector is stored in the Big Data as corresponding sample labels.

[0106] It can be known from the simulation result and daily experience that the air conditioner should not be turned on frequently each day. For example, a maximum startup number per day may be set to be 12, and thus if the Tmoment/Thours label set has 2 valid values, it is indicated that the air conditioner needs to be turned on twice, that is, the air conditioner needs to be turned on at each Tmoment and operate during the corresponding Thours.

[0107] In operation B04, all the sample data is normalized according to the following formula to allow each sample data to be between 0 and 1:

$$X^* = \frac{Xreal - Xmin}{Xmax - Xmin}$$

where X* is the normalized sample data, Xreal is a true value of the sample data, Xmax is a maximum value or an upper limit of the sample data, and Xmin is a minimum value or a lower limit of the sample data.

[0108] Xmax in the normalization may be set as required.

[0109] For example, for TRout and TRin, it may be determined that Xmax is an upper limit of 100°C and Xmin is a lower limit of -40°C.

[0110] For example, For LR, Xmax may be set to be a value of a full load of the base station, and Xmin may be set to be 0.

[0111] For example, for Tmoment (hh:mm:ss), Xmax may be set to be an upper limit of 1440 (24×60=1440 minutes per day), and Xmin may be set to be 0.

[0112] For example, for Thours, Xmax may be set to be an upper limit of 24 (24 hours per day), and Xmin may be set to be 0.

[0113] In operation B05, the sample data at different time is sorted into a training set, a verification set, and a test set.

[0114] The samples may be allocated to the training set, the verification set and the test set at a quantitative ratio of 6:2: 2.

[0115] In operation B06, a first submodel (a load prediction model) is built and trained.

[0116] With the load at certain historical time and corresponding time parameter (such as the holiday, the service tide or the regional event), and time to be measured (which is also the historical time) and corresponding time parameter taken as input parameters, the first submodel is used to output a predicted load at the time to be measured and compare the predicted load with the actual load at the corresponding time, thus being trained.

[0117] The data may be embodied in various forms.

[0118] For example, the load at certain historical time may be an average of loads within the corresponding time.

[0119] For example, a holiday parameter Fholiday may be a characteristic parameter in a range of (0, 1), and it is agreed according to experience that, for example, for a community, Fholiday is 0 on weekdays, is 0.1 on the weekend, and is 0.25 in the Spring Festival holidays.

[0120] For example, a service tide parameter Ftide may be a characteristic parameter in a range of (0, 1), and it is agreed according to experience that, for example, for an industrial park, Ftide is 0.5 during working time periods, is 0.4 during overtime periods, and is 0.3 at late nights or on the weekend.

[0121] For example, a regional event parameter Fevent may be a characteristic parameter in a range of (0, 1), and it is agreed according to experience that, for example, for a region, Fevent is 0 under normal conditions, is 0.1 in the presence of a commercial marketing activity, is 0.2 in the presence of a gathering, and is 0.3 in the presence of a concert.

[0122] In operation B07, a second submodel (an indoor temperature prediction model) is built and trained.

[0123] With the actual outdoor temperature and the load periodically collected at certain historical time taken as input parameters, the second submodel is used to output a predicted indoor temperature at the historical time and compare the predicted indoor temperature with the actual indoor temperature at the historical time, thus being trained.

[0124] In operation B08, a third submodel (an air conditioner control prediction model) is built and trained.

[0125] With the actual indoor temperature and the cooling efficiency factor periodically collected at certain historical time taken as input parameters, the third submodel is used to output an air conditioner control optimal solution vector at the historical time and compare the air conditioner control optimal solution vector with the air conditioner control optimal solution vector at the corresponding time obtained in the operation B03, thus being trained.

[0126] The cooling efficiency factor may be a fixed value, such as 0.5.

[0127] The value of the cooling efficiency factor is generally not changed unless the arrangement of the base station or the air conditioner is changed (for example, the air conditioner is replaced with a new one, the location of the air duct of the air conditioner is changed, or some devices in the base station are replaced).

[0128] Illustratively, assuming that Tmoment/Thours in a certain air conditioner control optimal solution vector has 2 valid values, for example, Tmoment1 is 0.45, Thours1 is 0.05, Tmoment2 is 0.60 and Thours2 is 0.10, the air conditioner control optimal solution vector indicates:

1) the air conditioner is to be turned on and operate twice that day;
2) the first startup moment is 10:48 (0.45*24=10.8=10:48), and the first operation duration is 1.2 hours (0.05*24=1.2), that is, the operation time period lasts from 10:48 to 12:00 (0.45*24+0.05*24=12); and
3) the second startup moment is 14:24 (0.60*24=14.4=14:24), and the second operation duration is 2.4 hours (0.10*24=2.4), that is, the operation time period lasts from 14:24 to 16:48 (0.60*24+0.10*24=16.8=16:48).

[0129] In operation B09, the deep neural network model is deployed.

[0130] After the deep neural network model is trained and optimized, the deep neural network model is deployed according to an actual running environment, for example, the three submodels are all deployed on the UME, so as to achieve real-time or online training by taking full use of powerful computing resources in the cloud.

[0131] If necessary, the deep neural network model may also be deployed at an edge side by adding a compute stick or by other means, for example, the deep neural network model may be deployed on the FSU,.

[0132] In operation B10, the FSU collects real-time information such as the indoor temperatures, the outdoor temperatures and the loads, and uploads the information to the UME.

[0133] During actual operation of the base station, the FSU collects various parameters in real time and uploads the parameters to the UME.

[0134] In operation B11, the model is run on the UME to output the air conditioner control optimal solution vector (the predicted operation time period).

[0135] Each submodel operates according to its own function, so as to output the predicted operation time period of the air conditioner at the future target time (e.g., one day).

[0136] The predicted outdoor temperature input into the second submodel may be obtained based on the temperature forecast by the weather forecast and the actual outdoor temperature. For example, predicted outdoor temperature=local temperature from weather forecast*0.8+actual outdoor temperature in last hour*0.2.

[0137] In operation B12, control commands for the air conditioner are calculated.

[0138] A control scheme for the air conditioner is determined according to the air conditioner control optimal solution vector (the predicted operation time period), the preset additional rule and the real-time indoor temperatures of the base station.

[0139] For example, a specific process may be as follows:

1) initializing the air conditioner: setting an initial state of the air conditioner to be "of", clearing operation duration Ton of the air conditioner and clearing shutdown duration Toff of the air conditioner;
2) starting to count time for the shutdown duration Toff of the air conditioner;
3) acquiring current time;
4) acquiring a current real-time indoor temperature Temp;
5) determining whether a high-temperature abnormal startup process is started: if Temp is greater than VHT and Toff is greater than MINCST, setting the maximum operation duration Ton-max of the air conditioner to be MAXCOT, and then performing the following operation 8), otherwise, performing operation 6);
6) determining whether a low-temperature abnormal shutdown process is started: if Tmep is less than VLT, performing the following operation 10), otherwise, performing operation 7);
7) determining whether a high-temperature pre-start process is started: if the current time reaches Tmoment, Tmep is greater than HT and Toff is greater

than MINCST, setting Ton-max to be the smaller one of Thours and MAXCOT, and performing operation 8), otherwise, returning to the operation 2);

8) performing a startup process of the air conditioner: executing an air conditioner startup action, clearing Toff, and starting to count time for Ton;

9) determining whether the air conditioner operates overtime: if Ton is greater than Ton-max, performing operation 10), otherwise, acquiring the current time and continuing to determine whether the air conditioner operates overtime; and

10) performing a shutdown process of the air conditioner: executing an air conditioner shutdown action, clearing Ton, starting to count time for Toff, and returning to the operation 3).

[0140] In operation B13, the UME issues the control commands for the air conditioner obtained in the operation B12 to the FSU, and the FSU controls the air conditioner to be turned on or turned off in practical applications according to the control commands for the air conditioner.

[0141] The FSU may also be provided with a built-in program corresponding to the conventional temperature-controlled startup-shutdown method. If failing to receive the control commands for the air conditioner from the UME in time (for example, due to a long interruption of a communication network), the FSU automatically executes the built-in program and temporarily controls the air conditioner with the conventional temperature-controlled startup-shutdown method.

[0142] In operation B14, real-time training is performed.

[0143] If environmental conditions are good enough (for example, the FSU and the UME are connected on a fast Ethernet, and the computing power resources in the cloud are sufficient) to support real-time or online training, the training of the deep neural network model may be continued in real time using newly collected data according to the outdoor temperatures, the loads and the indoor temperatures collected in real time when the air conditioner does not operate for a long period of time (such as in a cool season with low temperatures or at nights with low temperatures), so as to improve prediction accuracy of the model.

[0144] The above operations B01 to B09 may be collectively performed once before the subsequent operations are started; and the operations B10 to B14 may be designed as independently running tasks (or processes), and may be executed concurrently. The operation B10 may be performed periodically (for example, the operation B10 may be performed with a period of 5 minutes), the operation B11 may be performed once before zero each day to output the air conditioner control optimal solution vector for that day, the operation B12 may be performed in real time, and the operation B13 may be performed immediately after the issued control commands for the air conditioner are received. If the actual startup moments and the actual operation durations of the air conditioner in the operation B12 are not consistent with Tmoment and Thours output in the operation B11 (for example, with an error exceeding 10 minutes), the operation B11 may be executed again to update the air conditioner control optimal solution vector for that day, so as to improve prediction accuracy.

[0145] FIG. 4 is a block diagram of an air conditioner control device according to the present disclosure.

[0146] With reference to FIG. 4, the air conditioner control device according to the present disclosure includes a determination module, a prediction module, and a control module.

[0147] The determination module is configured to determine a predicted outdoor temperature at future target time.

[0148] The prediction module is configured to determine a predicted operation time period of an air conditioner at the target time according to the target time and the predicted outdoor temperature, and the predicted operation time period is an operation time period during which total power consumption of the air conditioner meets a second predetermined standard with an indoor temperature not exceeding a first predetermined standard.

[0149] The control module is configured to control the air conditioner at the target time according to the predicted operation time period.

[0150] In the embodiment of the present disclosure, the predicted operation time period at the target time is obtained according to the specific future time (the target time) and the outdoor temperature (the predicted outdoor temperature) at the target time, that is, a preferred operation mode of the air conditioner at the target time is predicted, and the air conditioner is controlled to be turned on or turned off at the target time according to the preferred operation mode, so as to ensure that devices in a base station do not overheat while reducing energy consumption as much as possible.

[0151] FIG. 5 is a block diagram of an electronic device according to the present disclosure.

[0152] With reference to FIG. 5, the electronic device according to the present disclosure includes: one or more processors; and a memory having stored thereon one or more programs, which, when executed by the one or more processors, cause the one or more processors to perform the air conditioner control method according to the present disclosure.

[0153] The electronic device may further include one or more I/O interfaces connected between the processor and the memory for enabling information interaction between the processor and the memory.

[0154] The processor is a device having data processing capability, and includes, but is not limited to, a Central Processing Unit (CPU); the memory is a device having data storage capability, and includes, but is not limited to, a Random Access Memory (RAM, more specifically, a Synchronous Dynamic RAM (SDRAM), a Double Data Rate SDRAM (DDR SDRAM), etc.), a Read-Only Memory (ROM), an Electrically Erasable Programmable Read-Only Memory (EEPROM), and a flash memory (FLASH); and the I/O interface (read/write interface) is connected between the processor and the memory, is configured to enable the information interaction between the memory and the processor, and includes, but is not limited to, a data bus (Bus).

[0155] FIG. 6 is a block diagram of a computer-readable medium according to the present disclosure.

[0156] With reference to FIG. 6, the present disclosure provides a computer-readable medium having stored thereon a computer program, which, when executed by a processor, causes the processor to perform the air conditioner control method according to the present disclosure.

[0157] It should be understood by those of ordinary skill in the art that the functional modules/units in all or some of the operations, systems and devices disclosed above may be implemented as software, firmware, hardware, or suitable combinations thereof.

[0158] If implemented as hardware, the division between the functional modules/units stated above is not necessarily corresponding to the division of physical components; and for example, one physical component may have a plurality of functions, or one function or operation may be performed through cooperation of several physical components.

[0159] Some or all of the physical components may be implemented as software executed by a processor, such as a CPU, a digital signal processor or a microprocessor, or may be implemented as hardware, or may be implemented as an integrated circuit, such as an application specific integrated circuit. Such software may be distributed on a computer-readable medium, which may include a computer storage medium (or a non-transitory medium) and a communication medium (or a transitory medium). As well known by those of ordinary skill in the art, the term "computer storage medium" includes volatile/nonvolatile and removable/non-removable media used in any method or technology for storing information (such as computer-readable instructions, data structures, program modules and other data). The computer storage medium includes, but is not limited to, an RAM (more specifically, an SDRAM, a DDR, etc.), an ROM, an EEPROM, a flash memory or other magnetic disks, a Compact Disc Read Only Memory (CD-ROM), a Digital Versatile Disc (DVD) or other optical discs, a magnetic cassette, a magnetic tape, a magnetic disk or other magnetic storage devices, or any other medium which can be configured to store desired information and can be accessed by a computer. In addition, it is well known by those of ordinary skill in the art that the communication media generally include computer-readable instructions, data structures, program modules, or other data in modulated data signals such as carrier wave or other transmission mechanism, and may include any information delivery medium.

[0160] The present disclosure discloses exemplary embodiments using specific terms, but the terms are merely used and should be merely interpreted as having general illustrative meanings, rather than for the purpose of limitation. Unless expressly stated, it is apparent to those of ordinary skill in the art that features, characteristics and/or elements described in connection with a particular embodiment can be used alone or in combination with features, characteristics and/or elements described in connection with other embodiments. Therefore, it should be understood by those of ordinary skill in the art that various changes in the forms and the details can be made without departing from the scope of the present disclosure of the appended claims.

Claims

1. An air conditioner control method, comprising:

determining a predicted outdoor temperature at future target time;
determining a predicted operation time period of an air conditioner at the target time according to the target time and the predicted outdoor temperature, wherein the predicted operation time period is an operation time period during which total power consumption of the air conditioner meets a second predetermined standard with an indoor temperature not exceeding a first predetermined standard; and
controlling the air conditioner at the target time according to the predicted operation time period.

2. The method of claim 1, wherein controlling the air conditioner at the target time according to the predicted operation time period comprises:
controlling the air conditioner at the target time according to a real-time indoor temperature, a preset additional rule and the predicted operation time period.

3. The method of claim 2, wherein the additional rule comprises:

in response to a case where the real-time indoor temperature exceeds a preset very high temperature threshold and the air conditioner does not operate, controlling the air conditioner to be turned on;
in response to a case where the real-time indoor temperature is lower than a preset very low temperature threshold and the air conditioner is operating, controlling the air conditioner to be turned off; and
in response to a case where the real-time indoor temperature exceeds a preset operation high temperature threshold and it is within the predicted operation time period, controlling the air

conditioner to be in an operating state.

4. The method of claim 1, wherein determining the predicted operation time period of the air conditioner at the target time according to the target time and the predicted outdoor temperature comprises:
inputting the target time and the predicted outdoor temperature into a preset deep neural network model, and acquiring the predicted operation time period output by the deep neural network model.

5. The method of claim 4, wherein the air conditioner is used in a base station, and the deep neural network model comprises a first submodel, a second submodel, and a third submodel,

the first submodel is configured to determine a predicted load of the base station at the target time and input the predicted load to the second submodel;
the second submodel is configured to determine, according to the predicted load and the predicted outdoor temperature, a predicted indoor temperature of the base station with the air conditioner not operating, and input the predicted indoor temperature into the third submodel;
the third submodel is configured to determine the predicted operation time period according to the predicted indoor temperature and a cooling parameter of the air conditioner, and
inputting the target time and the predicted outdoor temperature into the preset deep neural network model comprises:
inputting the target time into the first submodel, and inputting the predicted outdoor temperature into the second submodel.

6. The method of claim 4, before inputting the target time and the predicted outdoor temperature into the preset deep neural network model, further comprising:
training the deep neural network model.

7. The method of claim 1, determining the predicted outdoor temperature at the future target time and comprises:
acquiring an actual outdoor temperature and a temperature at the target time forecast by weather forecast, and calculating the predicted outdoor temperature at the target time according to the actual outdoor temperature and the forecast temperature.

8. An air conditioner control device, comprising:

a determination module configured to determine a predicted outdoor temperature at future target time;
a prediction module configured to determine a predicted operation time period of an air conditioner at the target time according to the target time and the predicted outdoor temperature, wherein the predicted operation time period is an operation time period during which total power consumption of the air conditioner meets a second predetermined standard with an indoor temperature not exceeding a first predetermined standard; and
a control module configured to control the air conditioner at the target time according to the predicted operation time period.

9. An electronic device, comprising:

one or more processors; and
a memory having stored thereon one or more programs, which, when executed by the one or more processors, cause the one or more processors to perform the air conditioner control method of any one of claims 1 to 7.

10. A computer-readable medium having stored thereon a computer program, which, when executed by a processor, causes the processor to perform the air conditioner control method of any one of claims 1 to 7.

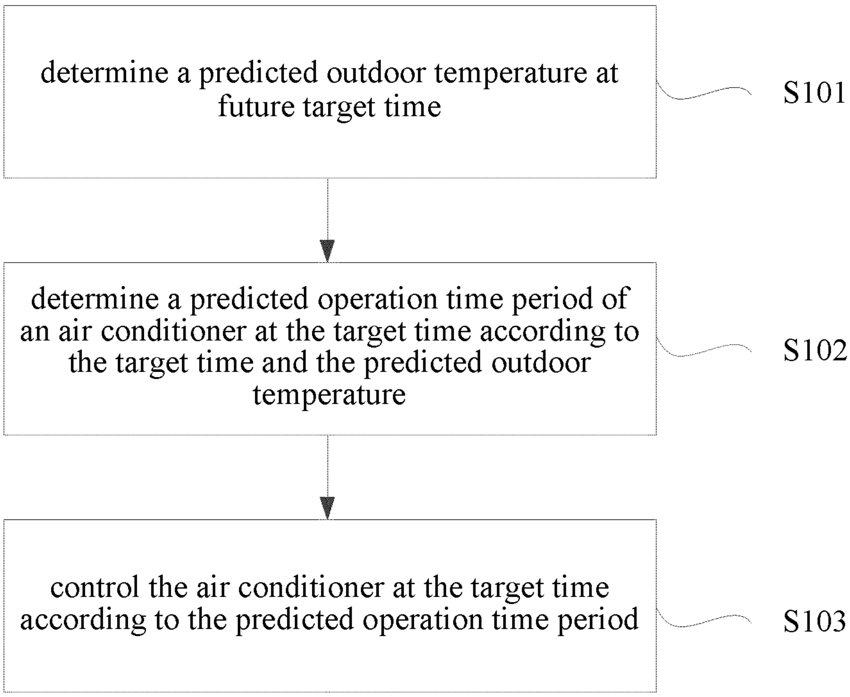
determine a predicted outdoor temperature at future target time
S101
determine a predicted operation time period of an air conditioner at the target time according to the target time and the predicted outdoor temperature
S102
control the air conditioner at the target time according to the predicted operation time period
S103

FIG. 1

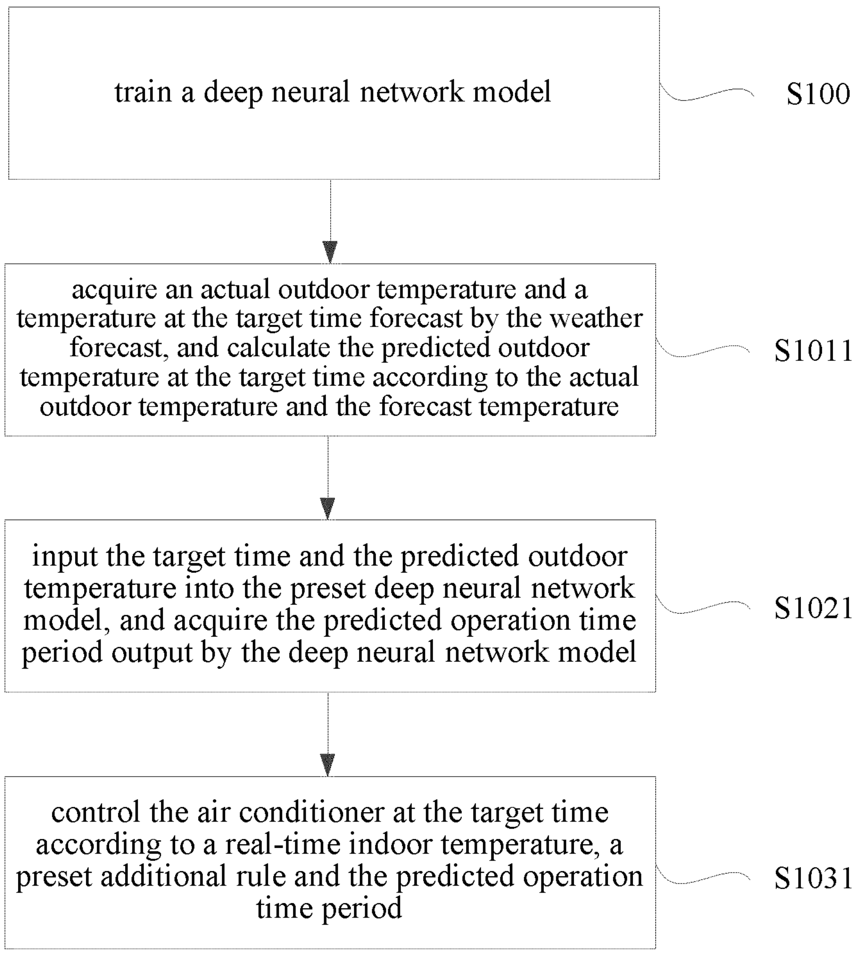
train a deep neural network model
S100
acquire an actual outdoor temperature and a temperature at the target time forecast by the weather forecast, and calculate the predicted outdoor temperature at the target time according to the actual outdoor temperature and the forecast temperature
S1011
input the target time and the predicted outdoor temperature into the preset deep neural network model, and acquire the predicted operation time period output by the deep neural network model
S1021
control the air conditioner at the target time according to a real-time indoor temperature, a preset additional rule and the predicted operation time period
S1031

FIG. 2

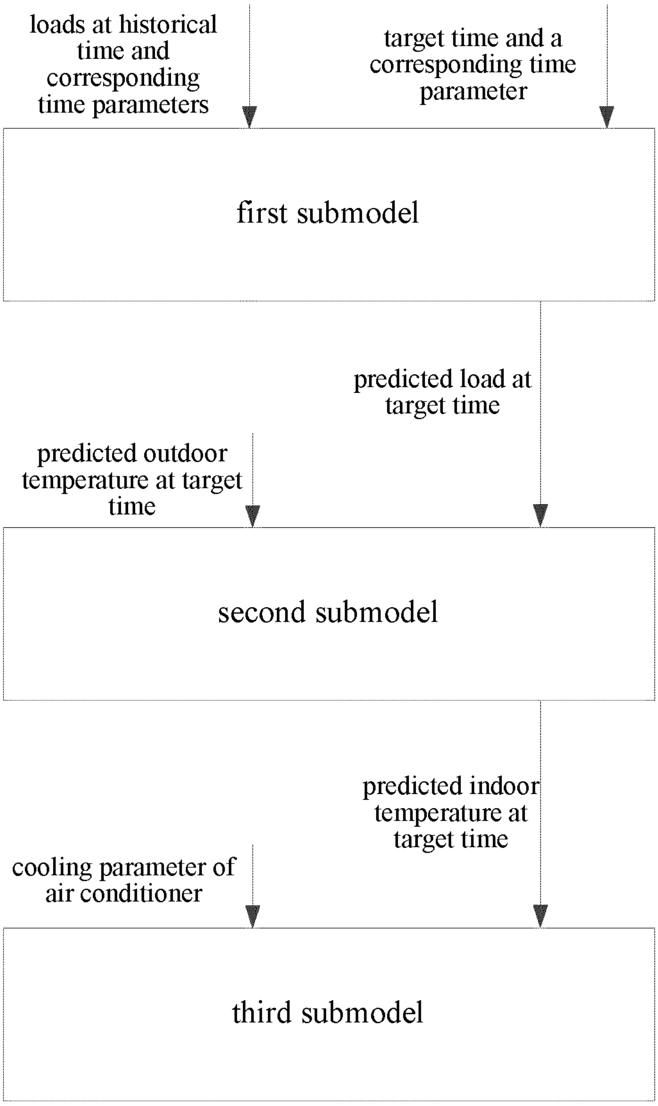
loads at historical time and corresponding time parameters
target time and a corresponding time parameter
first submodel
predicted load at target time
predicted outdoor temperature at target time
second submodel
predicted indoor temperature at target time
cooling parameter of air conditioner
third submodel

FIG. 3

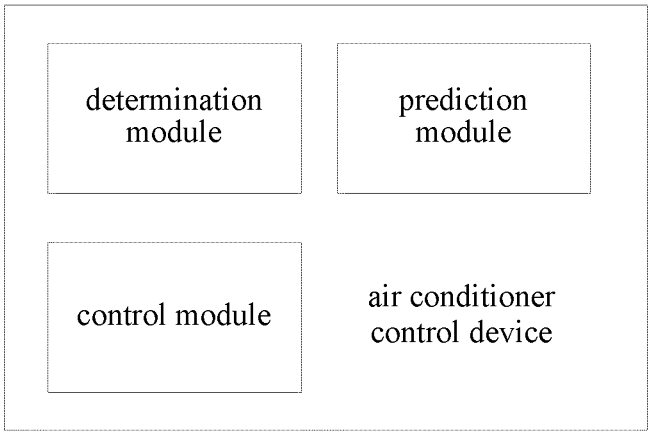

FIG. 4

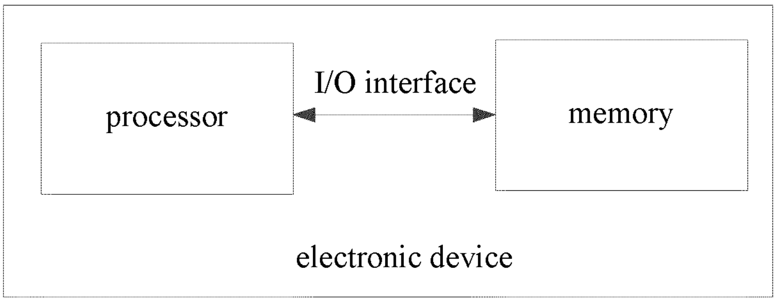

FIG. 5

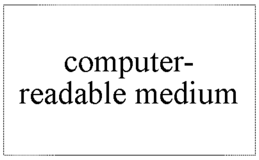

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2021/102691

A. CLASSIFICATION OF SUBJECT MATTER

F24F 11/00(2018.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F24F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

DWPI, CNABS, CNTXT, CNKI: Air Conditioning, Prediction, Outdoor, Temperature, Time, Excess, Standard, Deep Neural Network, Threshold, 空调, 预测, 室外, 温度, 时间, 超过, 标准, 深度神经网络, 阈值

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 102821581 A (SHANGHAI QIDIAN INFORMATION TECHNOLOGY CO., LTD.) 12 December 2012 (2012-12-12) description paragraphs 0010-0014, 0023-0049, figures 1-5	1-10
A	CN 102272533 A (SANYO ELECTRIC CO., LTD.) 07 December 2011 (2011-12-07) entire document	1-10
A	US 2016138819 A1 (VIVINT INC.) 19 May 2016 (2016-05-19) entire document	1-10
A	CN 110701732 A (NANCHANG JUECE DATA SERVICE CO., LTD.) 17 January 2020 (2020-01-17) entire document	1-10
A	CN 111237989 A (QINGDAO HISENSE TRANSTECH CO., LTD.) 05 June 2020 (2020-06-05) entire document	1-10

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

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

Date of the actual completion of the international search	Date of mailing of the international search report
10 September 2021	**16 September 2021**

Name and mailing address of the ISA/CN	Authorized officer
China National Intellectual Property Administration (ISA/CN) **No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088** **China**	
Facsimile No. **(86-10)62019451**	Telephone No.

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2021/102691

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CN 111237989 A	05 June 2020	None	

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