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(54) **A METHOD, APPARATUS, DEVICE, AND STORAGE MEDIUM FOR CONTROLLING A HEATING TUBE OF A CLOTHES DRYER**

(57) The present invention provides an improved method, apparatus, and device for controlling a heating tube in a clothes dryer and a storage medium. The method for controlling a heating tube in a clothes dryer includes: obtaining a set temperature Ts and a detected temperature Tc of the heating tube; obtaining a temperature deviation parameter based on the set temperature Ts and the detected temperature Tc; inputting the temperature deviation parameter into each of a first BP network and a second BP network that are pre-trained, to obtain a first control parameter and a second control parameter of the heating tube, where the second control parameter includes a control threshold; obtaining a control quantity of the heating tube based on the first control parameter; and comparing the control quantity with the control threshold, and controlling turning on and off of the heating tube based on a comparison result. In the present invention, the combination of the BP networks and the PID control theory to control the heating tube in the clothes dryer can balance the stability and accuracy of a control action, can realize accurate and thermostatic control over the temperature of the heating tube by the clothes dryer during drying, and has a strong adaptability.

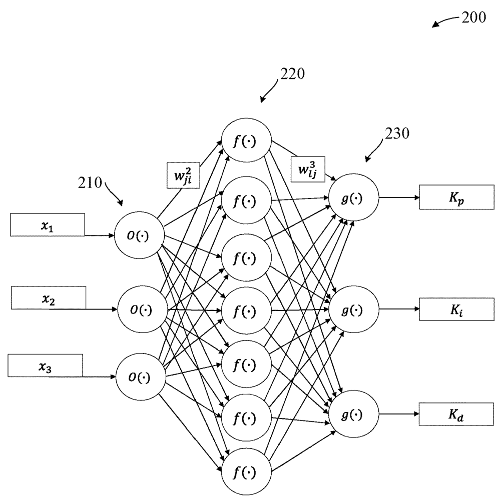

FIG. 3

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Description

[0001] The present invention relates to the field of household appliance technologies, and in particular, to a method, an apparatus, and a device for controlling a heating tube in a clothes dryer, and a storage medium.

[0002] At present, each existing strategy for controlling a heating tube in a clothes dryer on the market is basically to use conventional proportional-integral-derivative (PID) control.

[0003] However, the PID control is actually a compromise among proportional, integral, and derivative control actions, which cannot resolve the contradiction between the stability and accuracy, and cannot achieve the optimal control effect either.

[0004] An objective of the present invention is to provide an improved method, apparatus, and device for controlling a heating tube in a clothes dryer and a storage medium.

[0005] The method for controlling a heating tube in a clothes dryer provided in embodiments of the present invention includes: obtaining a set temperature Ts and a detected temperature *Tc* of the heating tube; obtaining a temperature deviation parameter based on the set temperature Ts and the detected temperature *Tc*; inputting the temperature deviation parameter into each of a first backpropagation (BP) network and a second BP network that are pre-trained, to obtain a first control parameter and a second control parameter of the heating tube, where the second control parameter includes a control threshold; obtaining a control quantity of the heating tube based on the first control parameter; and comparing the control quantity with the control threshold, and controlling turning on and off of the heating tube based on a comparison result.

[0006] Optionally, the second control parameter includes a first duration n, a second duration ε, a third duration $\in$, and a fourth duration q, the control threshold includes a maximum threshold *Judgemax* and a minimum threshold *Judgemin,* and the controlling turning on and off of the heating tube based on a comparison result includes: controlling the heating tube to be turned off and making an off duration thereof the first duration n when the control quantity is greater than or equal to the maximum threshold *Judgemax;* controlling the heating tube to be periodically turned on and off when the control quantity is less than the maximum threshold *Judgemax* and greater than the minimum threshold *Judgemin,* where in one period, an on duration is the second duration ε and an off duration is the third duration $\in$; and controlling the heating tube to be turned on and making an on duration thereof the fourth duration q when the control quantity is less than or equal to the minimum threshold *Judgemin.*

[0007] Optionally, during training of the first BP network and the second BP network, a deviation e(k) between the set temperature *Ts* and the detected temperature *Tc* in training sample data is used as an error, $\frac{1}{2}e(k)^2$ is used as a loss function, and the training is not stopped until the loss function is minimized, to obtain the first BP network and the second BP network that are trained.

[0008] Optionally, the temperature deviation parameter includes: a first temperature deviation parameter $x_1 = e(k)$, a second temperature deviation parameter $x_2 = e(k-1)$, and a third temperature deviation parameter $x_3 = e(k) - e(k-1)$, where e(k) represents a deviation between the set temperature Ts and the detected temperature *Tc* of the heating tube at a moment t, and e(k-1) represents a deviation between the set temperature Ts and the detected temperature *Tc* of the heating tube at a moment *(t-1).*

[0009] Optionally, the first control parameter is a PID control parameter, and the control quantity is represented by a transfer function G(s) of PID control.

[0010] Optionally, the PID control parameter includes a proportional coefficient Kp, an integral coefficient *Ki,* and a derivative coefficient *Kd* of the deviation e(k) of the heating tube at the moment t; and the control quantity is:

$$G(s) = K_p[1 + \frac{1}{K_i \cdot s} + K_d \cdot s].$$

[0011] Optionally, the PID control parameter includes a proportional coefficient Kp, an integral coefficient *Ki,* and a derivative coefficient *Kd* of the deviation e(k) of the heating tube at the moment *t,* any real number α, and any real number β; and the control quantity is:

$$G(s) = K_p[1 + \frac{K_i}{s^\alpha} + K_d \cdot s^\beta].$$

[0012] The apparatus for controlling a heating tube in a clothes dryer provided in the embodiments of the present invention includes: an obtaining module, configured to obtain a set temperature Ts and a detected temperature *Tc* of the heating tube; a first calculation module, configured to obtain a temperature deviation parameter based on the set temperature *Ts* and the detected temperature *Tc;* a BP network module, configured to input the temperature deviation parameter into each of a first BP network and a second BP network that are pre-trained, to obtain a first control parameter and a second control parameter of the heating tube, where the second control parameter includes a control threshold; a second calculation module, configured to obtain a control quantity of the heating tube based on the first control parameter; and a control module, configured to compare the control quantity with the control threshold, and control turning on and off of the heating tube based on a comparison result.

[0013] Optionally, the control threshold includes a maximum threshold *Judgemax* and a minimum threshold *Judgemin,* the second control parameter includes a first duration *n,* a second duration ε, a third duration $\in$, and a fourth duration q, and the control module is configured to: control the heating tube to be turned off and make an off duration thereof the first duration n when the control quantity is greater than or equal to the maximum threshold *Judgemax;* control the heating tube to be periodically turned on and off when the control quantity is less than the maximum threshold *Judgemax* and greater than the minimum threshold *Judgemin,* where in one period, an on duration is the second duration ε and an off duration is the third duration $\in$; and control the heating tube to be turned on and make an on duration thereof the fourth duration q when the control quantity is less than or equal to the minimum threshold *Judgemin.*

[0014] Optionally, the BP network module is configured to train each of the first BP network and the second BP network; and during training of the first BP network and the second BP network, a deviation e(k) between the set temperature Ts and the detected temperature *Tc* in training sample data is used as an error, $\frac{1}{2}e(k)^2$ is used as a loss function, and the training is not stopped until the loss function is minimized, to obtain the first BP network and the second BP network that are trained.

[0015] The device for controlling a heating tube in a clothes dryer provided in the embodiments of the present invention includes: a processor; and a memory, storing a computer program executable on the processor, where when the computer program is executed by the processor, the method for controlling a heating tube in a clothes dryer provided in the embodiments of the present invention is implemented.

[0016] The embodiments of the present invention further provide a computer-readable storage medium. The computer-readable storage medium stores a computer program, where when the computer program is executed, the method for controlling a heating tube in a clothes dryer provided in the embodiments of the present invention is implemented.

[0017] Compared with the related art, the technical solutions of the embodiments of the present invention have the following beneficial effects.

[0018] For example, the combination of the BP networks and the PID control theory to control the heating tube in the clothes dryer can balance the stability and accuracy of a control action. When the control action is strengthened in order to improve the accuracy of the control action and reduce an error, the stability of the control action is not to be reduced. When the control action is restricted in order to ensure the stability of the control action, the accuracy of the control action is not to be reduced either.

[0019] In another example, the combination of the BP networks and the PID control theory to control the heating tube in the clothes dryer can realize accurate and thermostatic control over the temperature of the heating tube by the clothes dryer during drying. In this way, the operation efficiency of the clothes dryer can be improved, and dried items can be effectively protected.

[0020] In another example, the combination of the BP networks and the PID control theory to control the heating tube in the clothes dryer has a strong adaptability, which can not only be applied to clothes dryers of different models, but also automatically regulate control parameters based on the clothes dryers of different models.

[0021] Other features of the present invention are to be presented in claims, accompanying drawings, and the description of the accompanying drawings. The features and combination of features described in the foregoing description and the features and combination of features described in the following description of the accompanying drawings and/or briefly shown in the accompanying drawings may be respectively presented in the described combination manner, or may be presented in other combinations or separately without departing from the scope of the present invention. Therefore, embodiments that are not described in the present invention and not shown in detail in the accompanying drawings but may be conceived from the embodiments described in detail and may be obtained from the combination of the features should be considered as being included and disclosed.

FIG. 1 is a schematic structural diagram of a clothes dryer according to an embodiment of the present invention;

FIG. 2 is a schematic flowchart of a method for controlling a heating tube in a clothes dryer according to an embodiment of the present invention;

FIG. 3 is a schematic diagram of a structure of a first BP network according to an embodiment of the present invention;

FIG. 4 is a schematic diagram of another structure of a first BP network according to an embodiment of the present invention;

FIG. 5 is a schematic diagram of a structure of a second BP network according to an embodiment of the present invention;

FIG. 6 is a schematic principle diagram of a method for controlling a heating tube in a clothes dryer according to an embodiment of the present invention; and

FIG. 7 is a principle block diagram of an apparatus for controlling a heating tube in a clothes dryer according to an embodiment of the present invention.

[0022] In the related art, the PID control used for a heating tube of a clothes dryer cannot resolve the contradiction between the stability and accuracy, and cannot achieve the optimal control effect either.

[0023] Different from the related art, the present invention provides an improved method, apparatus, and device for controlling a heating tube in a clothes dryer and a storage medium. The method for controlling a heating tube in a clothes dryer provided in embodiments of the present invention includes: obtaining a set temperature Ts and a detected temperature *Tc* of the heating tube; obtaining a temperature deviation parameter based on the set temperature Ts and the detected temperature *Tc*; inputting the temperature deviation parameter into each of a first BP network and a second BP network that are pre-trained, to obtain a first control parameter and a second control parameter of the heating tube, where the second control parameter includes a control threshold; obtaining a control quantity of the heating tube based on the first control parameter; and comparing the control quantity with the control threshold, and controlling turning on and off of the heating tube based on a comparison result.

[0024] Compared with the related art, the technical solutions of the embodiments of the present invention have the following beneficial effects. For example, the combination of the BP networks and the PID control theory to control the heating tube in the clothes dryer can balance the stability and accuracy of a control action. When the control action is strengthened in order to improve the accuracy of the control action and reduce an error, the stability of the control action is not to be reduced. When the control action is restricted in order to ensure the stability of the control action, the accuracy of the control action is not to be reduced either. In another example, the combination of the BP networks and the PID control theory to control the heating tube in the clothes dryer can realize accurate and thermostatic control over the temperature of the heating tube by the clothes dryer during drying. In this way, the operation efficiency of the clothes dryer can be improved, and dried items can be effectively protected. In another example, the combination of the BP networks and the PID control theory to control the heating tube in the clothes dryer has a strong adaptability, which can not only be applied to clothes dryers of different models, but also automatically regulate control parameters based on the clothes dryers of different models.

[0025] To make the objectives, features, and beneficial effects of the embodiments of the present invention more comprehensible, the specific embodiments of the present invention are described in detail with reference to the accompanying drawings.

[0026] FIG. 1 is a schematic structural diagram of a clothes dryer according to an embodiment of the present invention.

[0027] Referring to FIG. 1, the clothes dryer 100 may include a tub 110, a drum 120 rotatably mounted in the tub 110, and an airflow duct 130 located between the tub 110 and the drum 120. The drum 120 is suitable for receiving items (not shown in the figure) to dry the items. Both ends of the airflow duct 130 are separately in communication with an internal space 121 of the drum 120, to form a drying loop 140 between the airflow duct 130 and the internal space 121 of the drum 120.

[0028] Specifically, the airflow duct 130 may include a heat exchange section 131 and a heating section 132 in communication with each other. The heat exchange section 131 is provided with a condenser 151 and a fan 152, and the heating section 132 is provided with a heating tube 153. The condenser 151 is configured to cool air entering the heat exchange section 131, the fan 152 is configured to generate airflow in the drying loop 140, and the heating tube 153 is configured to heat air entering the heating section 132.

[0029] When the clothes dryer 100 executes a drying process, the condenser 151, the fan 152, and the heating tube 153 are turned on. Hot and wet air in the internal space 121 of the drum 120 enters the heat exchange section 131 of the airflow duct 130 under the action of the fan 152, and is cooled by the condenser 151 to form cold air in the heat exchange section 131. The cold air further enters the heating section 132 under the action of the fan 152, and is heated into hot air under the action of the heating tube 153. The hot air enters the internal space 121 of the drum 120 under the action of the fan 152, and exchanges heat with items in the internal space 121 to form hot and wet air. Such a cycle is repeated to dry the items.

[0030] In a specific implementation, the clothes dryer 100 further includes a temperature sensor suitable for collecting a drying temperature during execution of the drying process.

[0031] Specifically, the temperature sensor is suitable for collecting a heating temperature of the heating tube 153, or collecting a drying temperature of the hot air entering the internal space 121 of the drum 120 during execution of the drying process.

[0032] In a specific implementation, the clothes dryer 100 may include an integrated washer dryer and an independent clothes drying device. In a specific implementation, the clothes dryer 100 may be provided with one heating tube 153, or may be provided with at least two heating tubes 153.

[0033] FIG. 2 is a schematic flowchart of a method for controlling a heating tube in a clothes dryer according to an embodiment of the present invention.

[0034] Referring to FIG. 2, the method for controlling a heating tube in a clothes dryer provided in the embodiments of the present invention may include the following steps:

S1: Obtain a set temperature and a detected temperature of the heating tube.

S2: Obtain a temperature deviation parameter based on the set temperature and the detected temperature.

S3: Input the temperature deviation parameter into each of a first BP network and a second BP network that are pre-trained, to obtain a first control parameter and a second control parameter of the heating tube, where the second control parameter includes a control threshold.

S4: Obtain a control quantity of the heating tube based on the first control parameter.

S5: Compare the control quantity with the control threshold, and control turning on and off of the heating tube based on a comparison result.

[0035] As for step S1, a set temperature and a detected temperature of a heating tube 153 may be obtained during execution of a drying process. The detected temperature is a heating temperature of the heating tube 153 collected by a temperature sensor in a clothes dryer 100, or a drying temperature of hot air entering an internal space 121 of a drum 120. The set temperature is a preset temperature in the drying process.

[0036] In a specific implementation, the clothes dryer 100 may be a water-cooled clothes dryer, or may be an air-cooled clothes dryer. For a water-cooled clothes dryer 100, a set temperature of a heating tube 153 thereof may be set within a range greater than or equal to 90°C and less than or equal to 110°C. For an air-cooled clothes dryer 100, a set temperature of a heating tube 153 thereof may be adjusted according to seasons. In summer, the set temperature of the heating tube 153 may be set to about 70°C. In winter, the set temperature of the heating tube 153 may be set to about 60°C.

[0037] In a specific implementation, set temperatures of clothes dryers 100 of different models are different.

[0038] In a specific implementation, the set temperature of the heating tube 153 may be represented as Ts, and the detected temperature of the heating tube 153 may be represented as *Tc.*

[0039] As for step S2, a temperature deviation parameter may be obtained based on the set temperature Ts and the detected temperature *Tc* of the heating tube 153.

[0040] In a specific implementation, the temperature deviation parameter may include a first temperature deviation parameter, a second temperature deviation parameter, and a third temperature deviation parameter.

[0041] Specifically, the first temperature deviation parameter may be $x_1 = e(k)$, the second temperature deviation parameter may be $x_2 = e(k-1)$, and the third temperature deviation parameter may be $x_3 = e(k) - e(k-1)$, where e(k) represents a deviation between the set temperature Ts and the detected temperature *Tc* of the heating tube 153 at a moment t, and e(k-1) represents a deviation between the set temperature Ts and the detected temperature *Tc* of the heating tube 153 at a moment *(t-1).*

[0042] As for step S3, the temperature deviation parameter may be inputted into each of a first BP network (that is, a backpropagation neural network) and a second BP network that are pre-trained, to obtain a first control parameter and a second control parameter of the heating tube 153. The first control parameter is obtained through the first BP network, and the second control parameter is obtained through the second BP network.

[0043] In a specific implementation, the first control parameter may include a PID control parameter.

[0044] In some embodiments, the PID control parameter may include a proportional coefficient *Kp,* an integral coefficient *Ki,* and a derivative coefficient *Kd* of the deviation e(k) between the set temperature Ts and the detected temperature *Tc* of the heating tube at the moment t.

[0045] In a specific implementation, the first BP network may be constructed based on input (that is, the temperature deviation parameter) and output (that is, the first control parameter) thereof.

[0046] FIG. 3 is a schematic diagram of a structure of a first BP network according to an embodiment of the present invention.

[0047] Referring to FIG. 3, the first BP network 200 may include an input layer 210, a hidden layer 220, and an output layer 230 connected in sequence. The input layer 210 includes three neurons respectively corresponding to the first temperature deviation parameter $x_1 = e(k)$, the second temperature deviation parameter $x_2 = e(k-1)$, and the third temperature deviation parameter $x_3 = e(k) - e(k-1)$. The output layer 230 includes three neurons respectively corresponding to the proportional coefficient *Kp,* the integral coefficient *Ki,* and the derivative coefficient *Kd* of the deviation *e(k).*

[0048] In a specific implementation, a quantity of neurons in the hidden layer 220 may be obtained based on the Kolmogorov theorem or any known common knowledge or existing technical means in the art.

[0049] In an example shown in FIG. 3, the quantity of the neurons in the hidden layer 220 of the first BP network 200 is obtained by using the Kolmogorov theorem, and is specifically seven.

[0050] In a specific implementation, the hidden layer 220 may use a Sigmoid function as an activation function, and the output layer 230 may use a non-negative Sigmoid function as an activation function.

[0051] In some other embodiments, the PID control parameter may alternatively be a fractional-order $PI^{\alpha}D^{\beta}$ control parameter (the fractional-order $PI^{\alpha}D^{\beta}$ theory was proposed by Professor Podlubny based on a combination of the fractional-order calculus theory and the PID tuning theory), and the use of the $PI^{\alpha}D^{\beta}$ control parameter can obtain better control performance compared with the use of the conventional PID control parameter (that is, the proportional coefficient Kp, the integral coefficient *Ki,* and the derivative coefficient *Kd* of the deviation e(k)).

[0052] Specifically, the PID control parameter may include the proportional coefficient *Kp,* the integral coefficient *Ki,* and the derivative coefficient *Kd* of the deviation e(k) of the heating tube at the moment *t,* any real number α, and any real number β. In this way, a first BP network different from that in the example shown in FIG. 3 may be constructed.

[0053] FIG. 4 is a schematic diagram of another structure of a first BP network according to an embodiment of the present invention.

[0054] Referring to FIG. 4, the first BP network 300 may include an input layer 310, a hidden layer 320, and an output layer 330 connected in sequence. The input layer 310 includes three neurons respectively corresponding to the first temperature deviation parameter x_1

= *e(k),* the second temperature deviation parameter x_2 = e(k-1), and the third temperature deviation parameter $x_3 = e(k) - e(k-1)$. The output layer 330 includes five neurons respectively corresponding to the proportional coefficient *Kp,* the integral coefficient *Ki,* and the derivative coefficient *Kd* of the deviation *e(k)*, any real number α, and any real number β.

[0055] In a specific implementation, a quantity of neurons in the hidden layer 320 of the first BP network 300 may also be obtained based on the Kolmogorov theorem or any known common knowledge or existing technical means in the art.

[0056] In an example shown in FIG. 4, the quantity of the neurons in the hidden layer 320 of the first BP network 300 is obtained by using the Kolmogorov theorem, and is specifically seven.

[0057] In a specific implementation, the hidden layer 320 of the first BP network 300 may also use a Sigmoid function as an activation function, and the output layer 330 thereof may also use a non-negative Sigmoid function as an activation function.

[0058] After the first BP network is constructed, training sample data may be used to train the first BP network to obtain a trained first BP network. Training of the first BP network is described in the subsequent part of this specification.

[0059] In the embodiments of the present invention, the first temperature deviation parameter $x_1 = e(k)$, the second temperature deviation parameter $x_2 = e(k-1)$, and the third temperature deviation parameter $x_3 = e(k) - e(k-1)$ may be inputted into the pre-trained first BP network, to obtain the first control parameter of the heating tube 153.

[0060] In some embodiments, the first control parameter includes the proportional coefficient *Kp,* the integral coefficient *Ki,* and the derivative coefficient *Kd* of the deviation e(k) of the heating tube at the moment t.

[0061] In some other embodiments, the first control parameter includes the proportional coefficient *Kp,* the integral coefficient *Ki,* and the derivative coefficient *Kd* of the deviation e(k) of the heating tube at the moment *t,* any real number α, and any real number β.

[0062] As for step S4, a control quantity of the heating tube 153 may be obtained based on the first control parameter.

[0063] In a specific implementation, the control quantity of the heating tube 153 may be represented by a transfer function G(s) of PID control.

[0064] When the first control parameter includes the proportional coefficient Kp, the integral coefficient *Ki,* and the derivative coefficient *Kd* of the deviation e(k) of the heating tube at the moment t, the control quantity of the heating tube 153 may be represented as:

$$G(s) = K_p[1 + \frac{1}{K_i \cdot s} + K_d \cdot s].$$

[0065] When the first control parameter includes the proportional coefficient Kp, the integral coefficient *Ki,* and the derivative coefficient *Kd* of the deviation e(k) of the heating tube at the moment *t,* any real number α, and any real number β, the control quantity of the heating tube 153 may be represented as:

$$G(s) = K_p[1 + \frac{K_i}{s^\alpha} + K_d \cdot s^\beta].$$

[0066] In some embodiments, the second control parameter may include a control threshold.

[0067] In a specific implementation, the second BP network may be constructed based on input (that is, the temperature deviation parameter) and output (that is, the second control parameter) thereof.

[0068] In a specific implementation, the second BP network may also include an input layer, a hidden layer, and an output layer connected in sequence. The input layer includes three neurons respectively corresponding to the first temperature deviation parameter $x_1 = e(k)$, the second temperature deviation parameter $x_2 = e(k-1)$, and the third temperature deviation parameter $x_3 = e(k) - e(k-1)$. A quantity of neurons in the output layer may be a quantity of parameters of the control threshold.

[0069] In a specific implementation, a quantity of neurons in the hidden layer of the second BP network may also be obtained based on the Kolmogorov theorem or any known common knowledge or existing technical means in the art.

[0070] In a specific implementation, the hidden layer of the second BP network may also use a Sigmoid function as an activation function, and the output layer may also use a non-negative Sigmoid function as an activation function.

[0071] After the second BP network is constructed, training sample data may be used to train the second BP network to obtain a trained second BP network.

[0072] In the embodiments of the present invention, the first temperature deviation parameter $x_1 = e(k)$, the second temperature deviation parameter $x_2 = e(k-1)$, and the third temperature deviation parameter $x_3 = e(k) - e(k-1)$ may be inputted into the pre-trained second BP network, to obtain the second control parameter of the heating tube 153, including the control threshold.

[0073] As for step S5, the control quantity G(s) of the heating tube 153 may be compared with the control threshold, and turning on and off of the heating tube 153 may be controlled based on a comparison result.

[0074] In some embodiments, the control threshold may be a single parameter. When the control quantity G(s) of the heating tube 153 is greater than or equal to the control threshold, an on control signal may be generated to control the heating tube 153 to be turned on. When the control quantity G(s) of the heating tube 153 is less than the control threshold, an off control signal may be generated to control the heating tube 153 to be turned off.

[0075] In some other embodiments, the control threshold may include two parameters that are respectively a maximum threshold and a minimum threshold. When the control quantity G(s) of the heating tube 153 is greater than or equal to the maximum threshold, a first control signal may be generated to control the heating tube 153 to be turned on. When the control quantity G(s) of the heating tube 153 is less than the maximum threshold and greater than the minimum threshold, a second control signal may be generated to control the heating tube 153 to be periodically turned on and off. When the control quantity G(s) of the heating tube 153 is less than or equal to the minimum threshold, a third control signal may be generated to control the heating tube 153 to be turned off.

[0076] In a specific implementation, the second control parameter may further include a first duration, a second duration, a third duration, and a fourth duration, and the controlling turning on and off of the heating tube 153 based on a comparison result described in step S5 may include:

controlling the heating tube 153 to be turned off and making an off duration thereof the first duration when the control quantity G(s) of the heating tube 153 is greater than or equal to the maximum threshold;
controlling the heating tube 153 to be periodically turned on and off when the control quantity G(s) of the heating tube 153 is less than the maximum threshold and greater than the minimum threshold, where in one period, an on duration is the second duration and an off duration is the third duration; and
controlling the heating tube 153 to be turned on and making an on duration thereof the fourth duration when the control quantity G(s) of the heating tube 153 is less than or equal to the minimum threshold.

[0077] In a specific implementation, the maximum threshold may be represented as *Judgemax,* the minimum threshold may be represented as *Judgemin,* the first duration may be represented as n, the second duration may be represented as ε, the third duration may be represented as ϵ, and the fourth duration may be represented as q. In addition, the six parameters (that is, the second control parameter) are all used as the output of the second BP network.

[0078] In a specific implementation, the second BP network may be constructed based on the input (that is, the temperature deviation parameter) and the output (that is, the second control parameter) thereof.

[0079] FIG. 5 is a schematic diagram of a structure of a second BP network according to an embodiment of the present invention.

[0080] Referring to FIG. 5, the second BP network 400 may include an input layer 410, a hidden layer 420, and an output layer 430 connected in sequence. The input layer 410 includes three neurons respectively corresponding to the first temperature deviation parameter $x_1 = e(k)$, the second temperature deviation parameter x_2 = e(k-1), and the third temperature deviation parameter $x_3 = e(k) - e(k-1)$. The output layer 430 includes six neurons respectively corresponding to the maximum threshold *Judgemax,* the minimum threshold *Judgemin,* the first duration n, the second duration ε, the third duration ϵ, and the fourth duration q.

[0081] In a specific implementation, a quantity of neurons in the hidden layer 420 of the second BP network 400 may also be obtained based on the Kolmogorov theorem or any known common knowledge or existing technical means in the art.

[0082] In an example shown in FIG. 5, the quantity of the neurons in the hidden layer 420 of the second BP network 400 is obtained by using the Kolmogorov theorem, and is specifically seven.

[0083] In a specific implementation, the hidden layer 420 of the second BP network 400 may also use a Sigmoid function as an activation function, and the output layer 430 thereof may also use a non-negative Sigmoid function as an activation function.

[0084] After the second BP network 400 is constructed, training sample data may be used to train the second BP network to optimize a weight and a bias of the second BP network 400 and obtain a trained second BP network 400.

[0085] In the embodiments of the present invention, the first temperature deviation parameter $x_1 = e(k)$, the second temperature deviation parameter $x_2 = e(k-1)$, and the third temperature deviation parameter $x_3 = e(k) - e(k-1)$ may be inputted into the pre-trained second BP network 400, to obtain the second control parameter of the heating tube 153, including the maximum threshold *Judgemax,* the minimum threshold *Judgemin,* the first duration n, the second duration ε, the third duration ϵ, and the fourth duration q.

[0086] In a specific implementation of step S5, the control quantity G(s) of the heating tube 153 may be compared with the maximum threshold *Judgemax* and the minimum threshold *Judgemin,* and the heating tube 153 may be controlled to be turned on or off based on a comparison result and the first duration n, the second duration ε, the third duration ϵ, and the fourth duration q.

[0087] FIG. 6 is a schematic principle diagram of a method for controlling a heating tube in a clothes dryer according to an embodiment of the present invention. Training of a first BP network and a second BP network is described below with reference to FIG. 6. The first BP network 300 shown in FIG. 4 is used as an example of the first BP network, and the second BP network 400 shown in FIG. 5 is used as an example of the second BP network.

[0088] In a specific implementation, training sample data suitable for training the first BP network 300 and the second BP network 400 may include the set temperature *Ts*, the detected temperature *Tc*, and the on and off control signals of the heating tube 153.

[0089] In a specific implementation, the training sample data may be obtained based on the clothes dryers 100 of different models, so as to train the first BP network 300 and the second BP network 400 for each of the clothes dryers 100 of different models. In this way, the heating tube 153 in the clothes dryer 100 of each model can be accurately controlled.

[0090] In a specific implementation, noise reduction and filtering may be performed on the training sample data first, and the training sample data after processing is then labeled based on the model of the clothes dryer 100 and the set temperature Ts, to obtain labeled final training sample data.

[0091] The noise reduction, the filtering, and the labeling of the training sample data may be implemented by using common knowledge or existing technical means in the art, which are not described in detail herein.

[0092] In a specific implementation, the first BP network 300 and the second BP network 400 may be trained based on the final training sample data.

[0093] During the training, common knowledge or existing algorithms in the art may be used to optimize parameters of the first BP network 300 and the second BP network 400 such as weights ω, learning rates ρ, and inertial rates α. The embodiments of the present invention make no limitation on the selection of a specific algorithm, as long as the algorithm can optimize the parameters of the first BP network 300 and the second BP network 400 such as the weights ω, the learning rates ρ, and the inertial rates α.

[0094] For example, a genetic algorithm may be used to optimize the parameters of the first BP network 300 and the second BP network 400 such as the weights ω, the learning rates ρ, and the inertial rates α.

[0095] In some embodiments, when the genetic algorithm is used to optimize the first BP network 300, the learning rate $\rho = 0.26$ and the inertial rate $\alpha = 0.05$ of the first BP network 300 can be obtained.

[0096] During the training of the first BP network 300, the deviation e(k) between the set temperature Ts and the detected temperature *Tc* in the final training sample data is used as an error, $\frac{1}{2}e(k)^2$ is used as a loss function, and the training is not stopped until the loss function is minimized, to obtain the trained first BP network 300.

[0097] During the training of the second BP network 400, similarly, the deviation e(k) between the set temperature Ts and the detected temperature *Tc* in the final training sample data is used as an error, $\frac{1}{2}e(k)^2$ is used as a loss function, and the training is not stopped until the loss function is minimized, to obtain the trained second BP network 400.

[0098] The method for controlling the heating tube 153 in the clothes dryer 100 provided in the embodiments of the present invention needs to be implemented based on the first control parameter and the second control parameter; and the first control parameter is obtained based on the first BP network 300, and the second control parameter is obtained based on the second BP network 400. In addition, the training of both the first BP network 300 and the second BP network 400 uses the deviation e(k) between the set temperature *Ts* and the detected temperature *Tc* in the training sample data as the error, and uses $\frac{1}{2}e(k)^2$ as the loss function. Therefore, the training of the first BP network 300 and the second BP network 400 needs to be carried out simultaneously. That is, the training of the first BP network 300 and the second BP network 400 may be implemented in a same training process, the training of the first BP network 300 and the second BP network 400 cannot be split, and the training of the first BP network 300 and the second BP network 400 cannot be carried out separately or independently.

[0099] FIG. 7 is a principle block diagram of an apparatus for controlling a heating tube in a clothes dryer according to an embodiment of the present invention.

[0100] Referring to FIG. 7, the apparatus 500 for controlling a heating tube 153 in a clothes dryer 100 includes an obtaining module 510, a first calculation module 520, a BP network module 530, a second calculation module 540, and a control module 550.

[0101] Specifically, the obtaining module 510 is configured to obtain a set temperature Ts and a detected temperature *Tc* of the heating tube 153 when the clothes dryer 100 executes a drying process; the first calculation module 520 is configured to obtain a temperature deviation parameter based on the set temperature Ts and the detected temperature *Tc*; the BP network module 530 is configured to input the temperature deviation parameter into each of a first BP network and a second BP network that are pre-trained, to obtain a first control parameter and a second control parameter of the heating tube 153, where the second control parameter includes a control threshold; the second calculation module 540 is configured to obtain a control quantity G(s) of the heating tube 153 based on the first control parameter; and the control module 550 is configured to compare the control quantity G(s) with the control threshold, and control turning on and off of the heating tube 153 based on a comparison result.

[0102] In some embodiments, the control threshold may include a maximum threshold *Judgemax* and a minimum threshold *Judgemin,* the second control parameter may further include a first duration n, a second duration ε, a third duration $\in$, and a fourth duration q, and the control module 550 may be configured to:

control the heating tube 153 to be turned off and make an off duration thereof n when G(s) $\geq$ *Judgemax;*

control the heating tube 153 to be periodically turned on and off when *Judgemax* > *G(s)* > *Judgemin*, where in one period, an on duration is ε and an off duration is $\in$; and

control the heating tube 153 to be turned on and make an on duration thereof q when $G(s) \leq Judgemin$.

[0103] In some embodiments, the BP network module 530 is further configured to separately train the first BP network and the second BP network; and during training of the first BP network and the second BP network, a deviation e(k) between the set temperature Ts and the detected temperature *Tc* in training sample data is used as an error, $\frac{1}{2}e(k)^2$ is used as a loss function, and the training is not stopped until the loss function is minimized, to obtain the first BP network and the second BP network that are trained.

[0104] In a specific implementation, the obtaining module 510, the first calculation module 520, the BP network module 530, the second calculation module 540, and the control module 550 may all be implemented based on the technical solutions of the method for controlling a heating tube in a clothes dryer disclosed in the embodiments of the present invention.

[0105] The embodiments of the present invention further provide a device for controlling a heating tube in a clothes dryer. The device includes a processor and a memory, the memory storing a computer program executable on the processor, where when the computer program is executed by the processor, the method for controlling a heating tube in a clothes dryer disclosed in the embodiments of the present invention is implemented.

[0106] Further referring to FIG. 1, the clothes dryer 100 provided in the embodiments of the present invention may further include a control apparatus 160.

[0107] Specifically, the control apparatus 160 may include the foregoing processor and memory. The processor may be connected to electrical components such as the heating tube 153, and is suitable for controlling the electrical components such as the heating tube 153 to work when executing the foregoing computer program.

[0108] The embodiments of the present invention further provide a computer-readable storage medium. The computer-readable storage medium stores a computer program, where when the computer program is executed, the method for controlling a heating tube in a clothes dryer disclosed in the embodiments of the present invention is implemented.

[0109] Although specific implementations are described above, the implementations are not intended to limit the scope disclosed in the present invention, even if only a single implementation is described relative to a specific feature. The feature examples provided in the present invention are intended to be illustrative rather than limiting, unless different expressions are made. During specific implementation, according to an actual requirement, in a technically feasible case, the technical features of one or more dependent claims may be combined with the technical features of the independent claims, and the technical features from the corresponding independent claims may be combined in any appropriate way instead of using just specific combinations listed in the claims.

[0110] Although the present invention is disclosed above, the present invention is not limited thereto. A person skilled in the art can make various changes and modifications without departing from the spirit and the scope of the present invention. Therefore, the protection scope of the present invention should be subject to the scope defined by the claims.

Claims

1. A method for controlling a heating tube (153) in a clothes dryer (100), **characterized by** comprising:

   obtaining a set temperature Ts and a detected temperature *Tc* of the heating tube (153);
   obtaining a temperature deviation parameter based on the set temperature Ts and the detected temperature *Tc*;
   inputting the temperature deviation parameter into each of a first backpropagation (BP) network (200, 300) and a second BP network (400) that are pre-trained, to obtain a first control parameter and a second control parameter of the heating tube (153), wherein the second control parameter comprises a control threshold;
   obtaining a control quantity of the heating tube (153) based on the first control parameter; and
   comparing the control quantity with the control threshold, and controlling turning on and off of the heating tube (153) based on a comparison result.

2. The method according to claim 1, **characterized in that** the second control parameter comprises a first duration n, a second duration ε, a third duration $\in$, and a fourth duration q, the control threshold comprises a maximum threshold *Judgemax* and a minimum threshold *Judgemin,* and the controlling turning on and off of the heating tube (153) based on a comparison result comprises:

   controlling the heating tube (153) to be turned off and making an off duration thereof the first duration n when the control quantity is greater than or equal to the maximum threshold *Judgemax;*
   controlling the heating tube (153) to be periodically turned on and off when the control quantity is less than the maximum threshold *Judgemax* and greater than the minimum threshold *Judgemin,* wherein in one period, an on duration

is the second duration ε and an off duration is the third duration $\in$; and

controlling the heating tube (153) to be turned on and making an on duration thereof the fourth duration q when the control quantity is less than or equal to the minimum threshold *Judgemin*.

3. The method according to claim 1 or 2, **characterized in that** during training of the first BP network (200, 300) and the second BP network (400), a deviation e(k) between the set temperature *Ts* and the detected temperature *Tc* in training sample data is used as an error, $\frac{1}{2}e(k)^2$ is used as a loss function, and the training is not stopped until the loss function is minimized, to obtain the first BP network (200, 300) and the second BP network (400) that are trained.

4. The method according to claim 1 or 2, **characterized in that** the temperature deviation parameter comprises: a first temperature deviation parameter $x_1 = e(k)$, a second temperature deviation parameter $x_2 = e(k-1)$, and a third temperature deviation parameter $x_3 = e(k) - e(k-1)$, wherein e(k) represents a deviation between the set temperature Ts and the detected temperature *Tc* of the heating tube (153) at a moment t, and e(k-1) represents a deviation between the set temperature Ts and the detected temperature *Tc* of the heating tube (153) at a moment *(t-1)*.

5. The method according to claim 4, **characterized in that** the first control parameter is a proportional-integral-derivative (PID) control parameter, and the control quantity is represented by a transfer function G(s) of PID control.

6. The method according to claim 5, **characterized in that** the PID control parameter comprises a proportional coefficient Kp, an integral coefficient *Ki,* and a derivative coefficient *Kd* of the deviation e(k) of the heating tube (153) at the moment t; and

the control quantity is:

$$G(s) = K_p[1 + \frac{1}{K_i \cdot s} + K_d \cdot s].$$

7. The method according to claim 5, **characterized in that** the PID control parameter comprises a proportional coefficient Kp, an integral coefficient *Ki,* and a derivative coefficient *Kd* of the deviation e(k) of the heating tube (153) at the moment *t,* any real number α, and any real number β; and

the control quantity is:

$$G(s) = K_p[1 + \frac{K_i}{s^\alpha} + K_d \cdot s^\beta].$$

8. An apparatus (500) for controlling a heating tube (153) in a clothes dryer (100), **characterized by** comprising:

an obtaining module (510), configured to obtain a set temperature Ts and a detected temperature *Tc* of the heating tube (153);

a first calculation module (520), configured to obtain a temperature deviation parameter based on the set temperature *Ts* and the detected temperature *Tc;*

a backpropagation (BP) network module (530), configured to input the temperature deviation parameter into each of a first BP network (200, 300) and a second BP network (400) that are pre-trained, to obtain a first control parameter and a second control parameter of the heating tube (153), wherein the second control parameter comprises a control threshold;

a second calculation module (540), configured to obtain a control quantity of the heating tube (153) based on the first control parameter; and

a control module (550), configured to compare the control quantity with the control threshold, and control turning on and off of the heating tube (153) based on a comparison result.

9. The apparatus (500) according to claim 8, **characterized in that** the control threshold comprises a maximum threshold *Judgemax* and a minimum threshold *Judgemin,* the second control parameter comprises a first duration n, a second duration ε, a third duration $\in$, and a fourth duration q, and the control module (550) is configured to:

control the heating tube (153) to be turned off and make an off duration thereof the first duration n when the control quantity is greater than or equal to the maximum threshold *Judgemax;*

control the heating tube (153) to be periodically turned on and off when the control quantity is less than the maximum threshold *Judgemax* and greater than the minimum threshold *Judgemin,* wherein in one period, an on duration is the second duration ε and an off duration is the third duration $\in$; and

control the heating tube (153) to be turned on and make an on duration thereof the fourth duration q when the control quantity is less than or equal to the minimum threshold *Judgemin.*

10. The apparatus according to claim 8, **characterized in that** the BP network module (530) is configured to train each of the first BP network (200, 300) and the second BP network (400); and during training of the first BP network (200, 300) and the second BP network (400), a deviation e(k) between the set temperature Ts and the detected temperature *Tc* in training sample data is used as an error, $\frac{1}{2}e(k)^2$ is used as a loss function, and the training is not stopped until the loss function is minimized, to obtain the first BP network (200, 300) and the second BP network (400) that are trained.

11. A device for controlling a heating tube (153) in a clothes dryer (100), **characterized by** comprising:

a processor; and
a memory, storing a computer program executable on the processor,
wherein when the computer program is executed by the processor, the method according to any one of claims 1 to 7 is implemented.

12. A computer-readable storage medium, storing a computer program, **characterized in that** when the computer program is executed, the method according to any one of claims 1 to 7 is implemented.

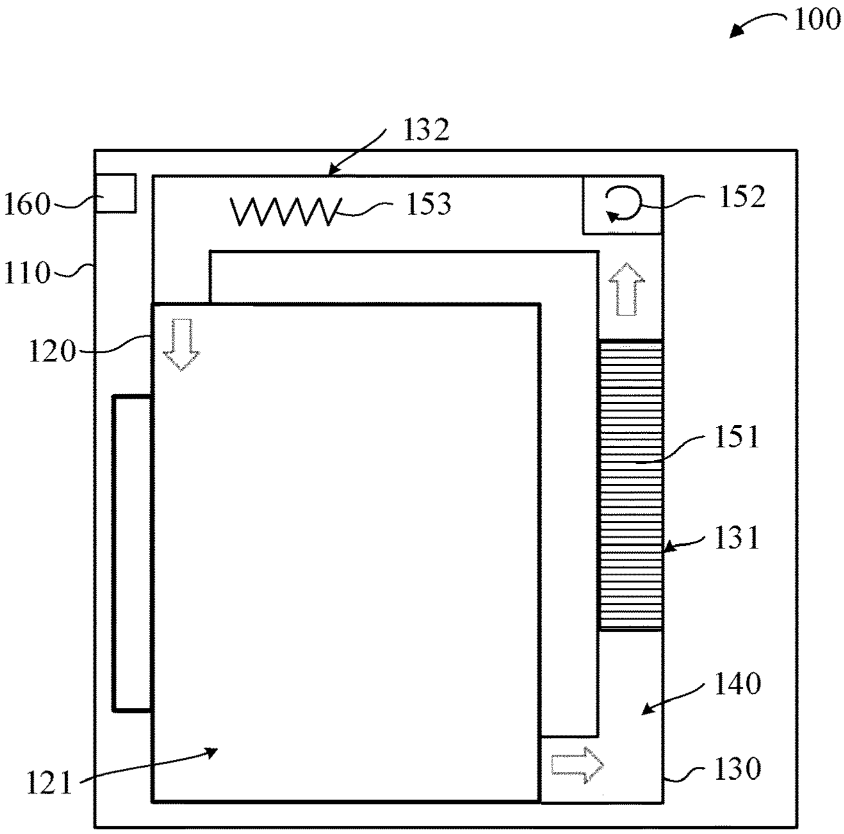

FIG. 1

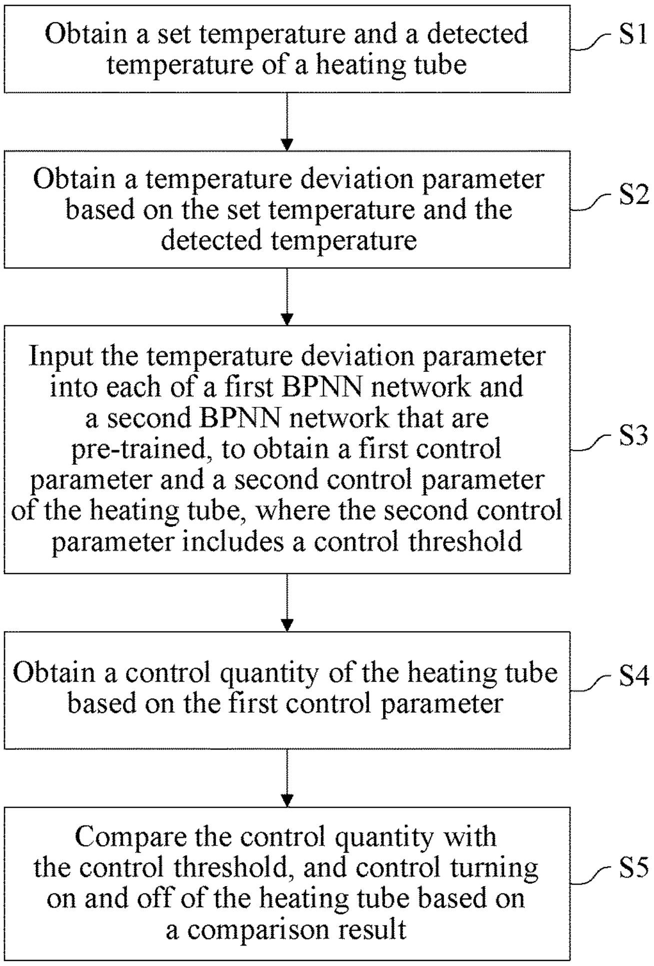
Obtain a set temperature and a detected temperature of a heating tube
S1
Obtain a temperature deviation parameter based on the set temperature and the detected temperature
S2
Input the temperature deviation parameter into each of a first BPNN network and a second BPNN network that are pre-trained, to obtain a first control parameter and a second control parameter of the heating tube, where the second control parameter includes a control threshold
S3
Obtain a control quantity of the heating tube based on the first control parameter
S4
Compare the control quantity with the control threshold, and control turning on and off of the heating tube based on a comparison result
S5

FIG. 2

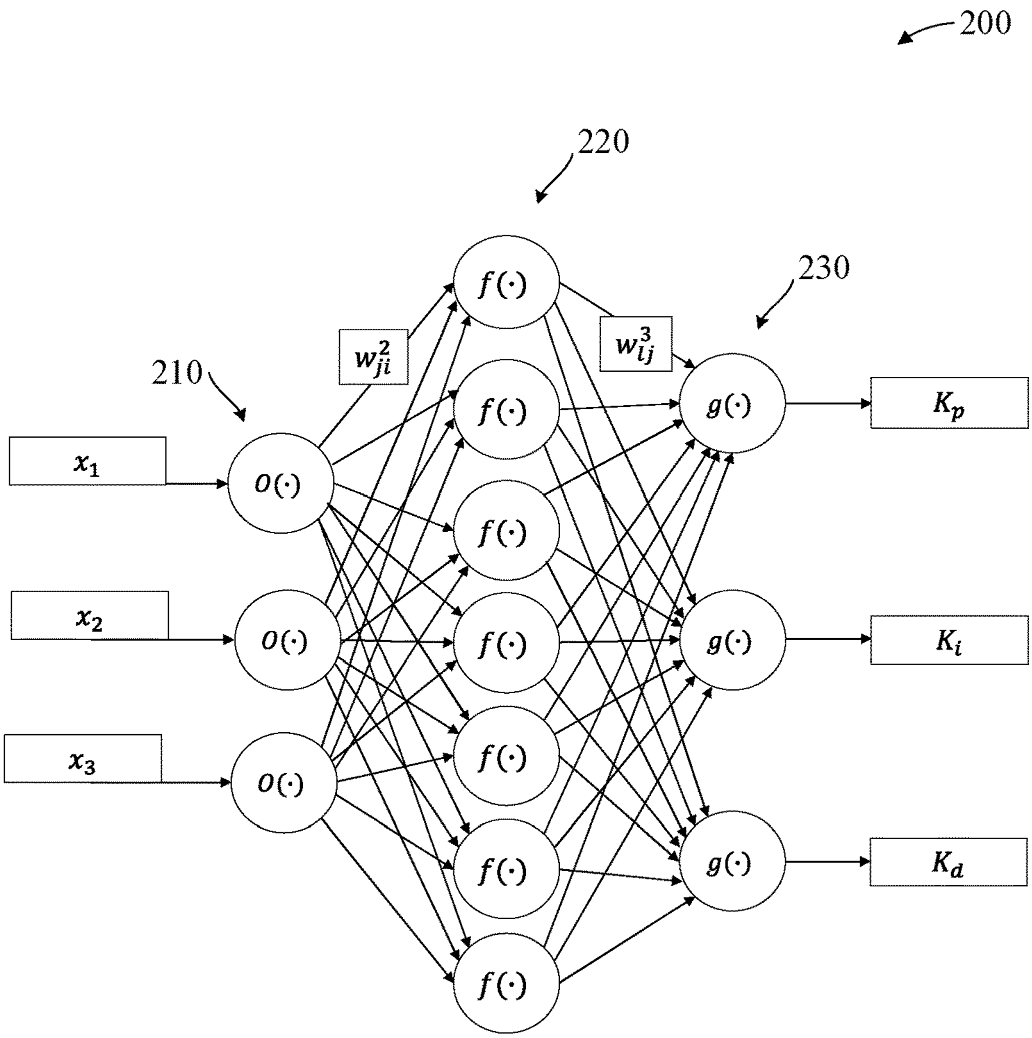
200
220
230
210
w_{ji}^2
w_{lj}^3
x_1
x_2
x_3
$o(\cdot)$
$o(\cdot)$
$o(\cdot)$
$f(\cdot)$
$g(\cdot)$
K_p
K_i
K_d

FIG. 3

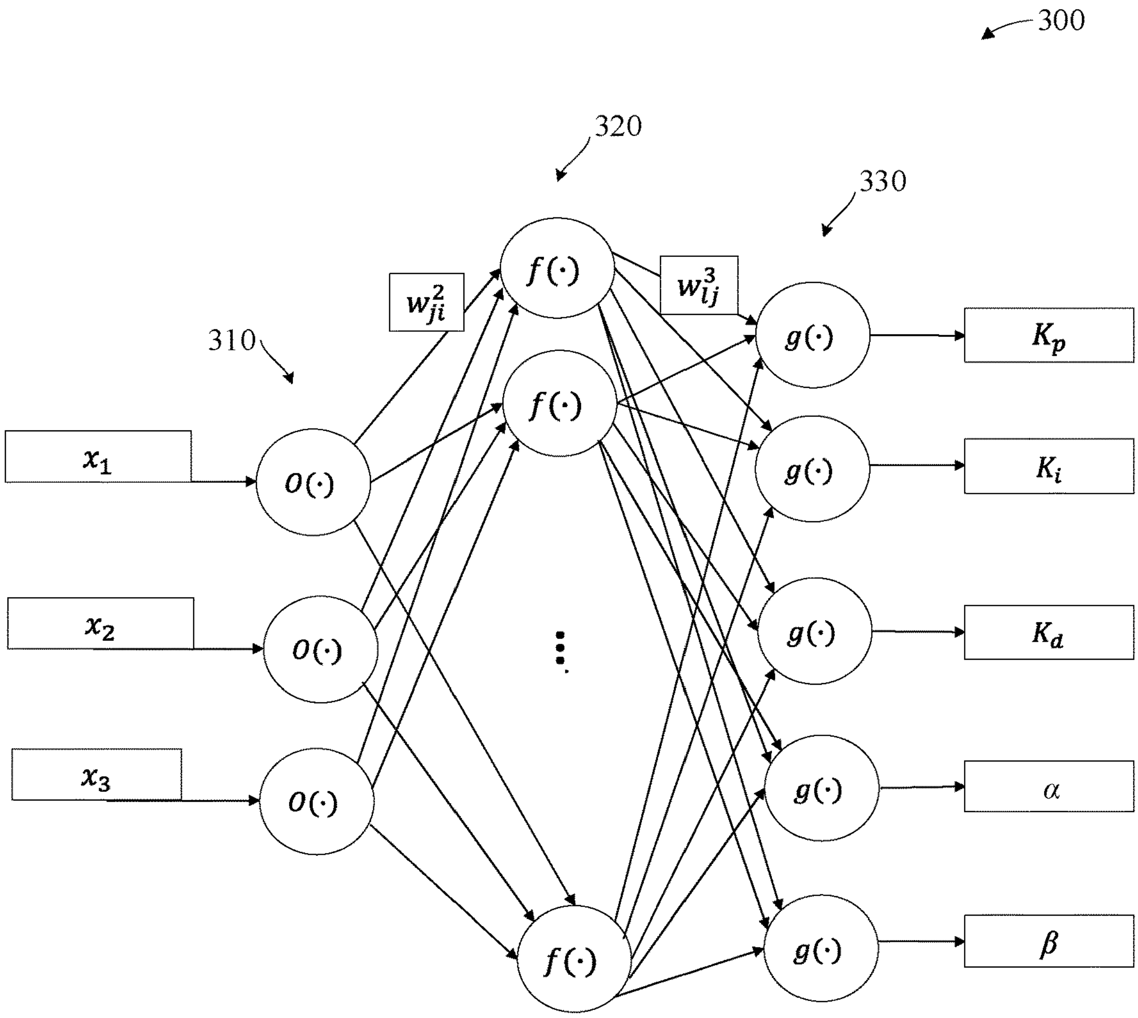
300
320
330
310
x_1
x_2
x_3
$o(\cdot)$
$o(\cdot)$
$o(\cdot)$
w_{ji}^2
$f(\cdot)$
$f(\cdot)$
$f(\cdot)$
w_{lj}^3
$g(\cdot)$
$g(\cdot)$
$g(\cdot)$
$g(\cdot)$
$g(\cdot)$
K_p
K_i
K_d
α
β

FIG. 4

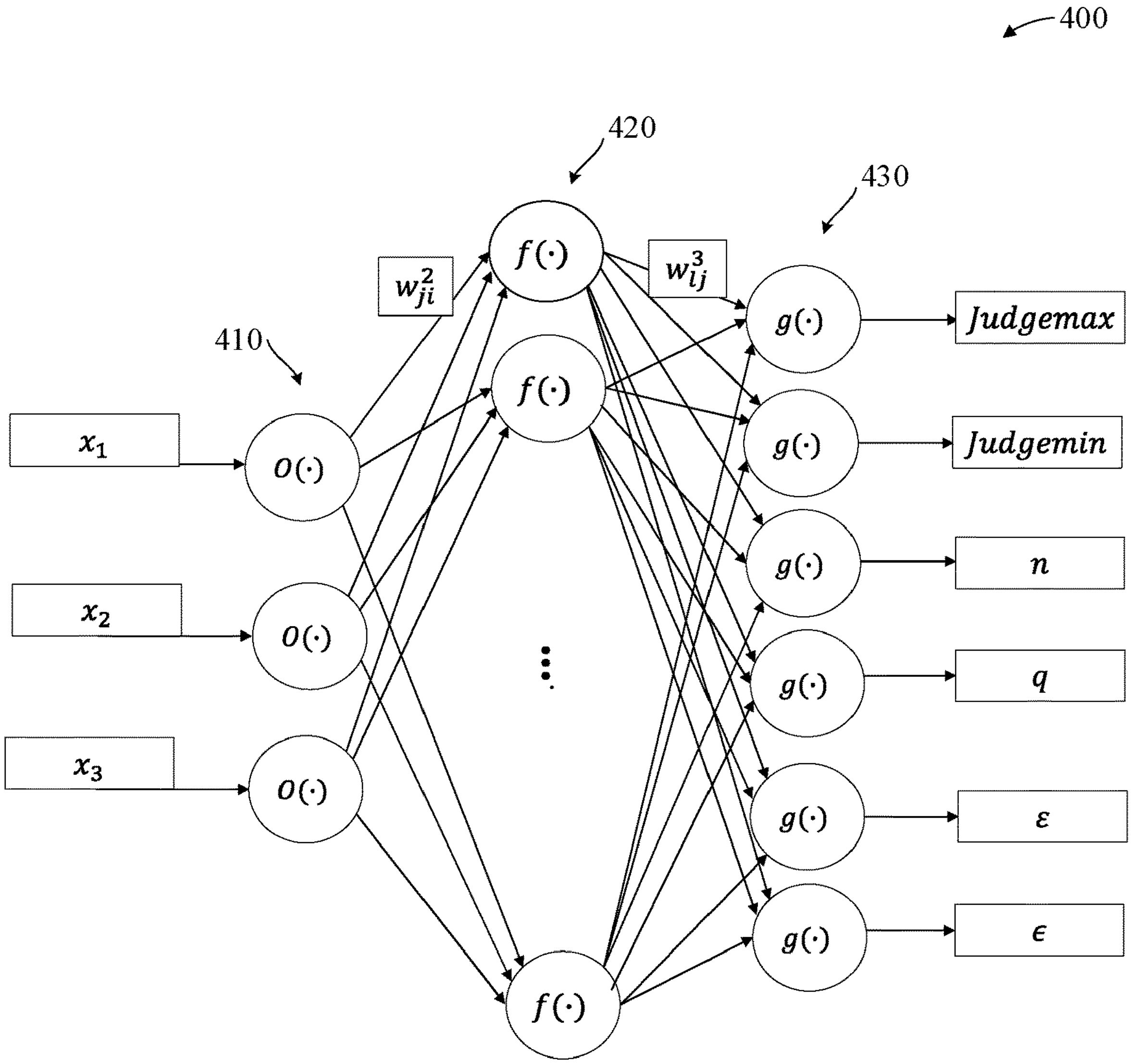
400
420
430
410
x_1
x_2
x_3
$o(\cdot)$
$o(\cdot)$
$o(\cdot)$
w_{ji}^2
$f(\cdot)$
$f(\cdot)$
$f(\cdot)$
w_{lj}^3
$g(\cdot)$
$g(\cdot)$
$g(\cdot)$
$g(\cdot)$
$g(\cdot)$
$g(\cdot)$
$Judgemax$
$Judgemin$
n
q
ε
ϵ

FIG. 5

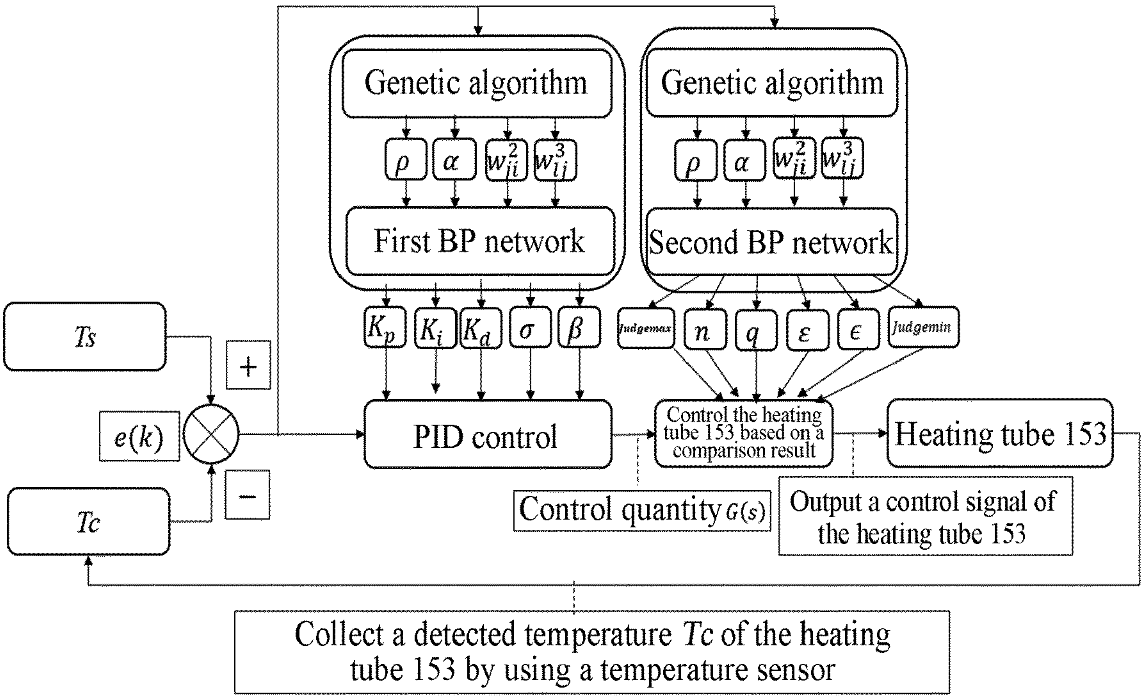
Genetic algorithm
ρ
α
w_{ji}^2
w_{lj}^3
First BP network
Genetic algorithm
ρ
α
w_{ji}^2
w_{lj}^3
Second BP network
Ts
+
e(k)
Tc
−
K_p
K_i
K_d
σ
β
PID control
Judgemax
n
q
ε
ϵ
Judgemin
Control the heating tube 153 based on a comparison result
Heating tube 153
Control quantity G(s)
Output a control signal of the heating tube 153
Collect a detected temperature Tc of the heating tube 153 by using a temperature sensor

FIG. 6

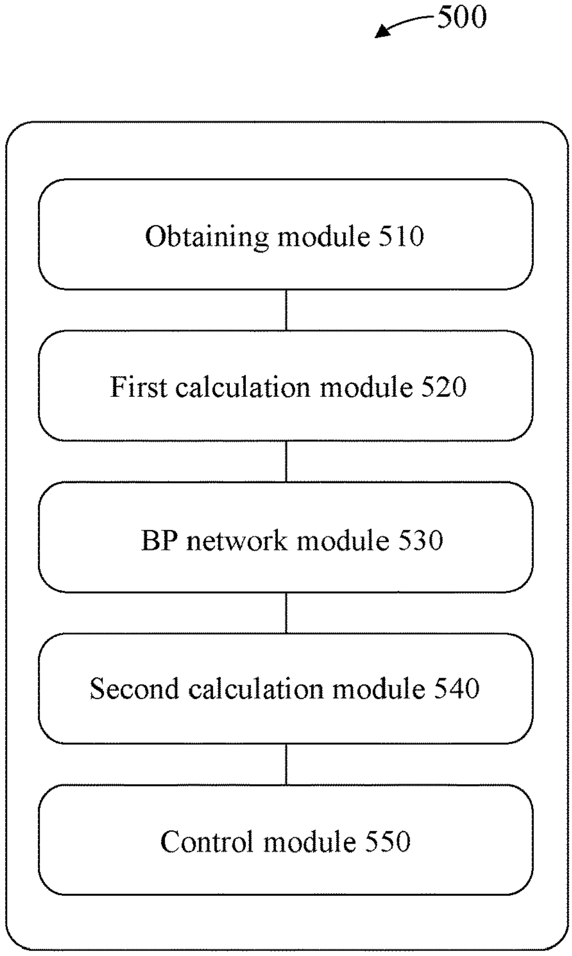
500
Obtaining module 510
First calculation module 520
BP network module 530
Second calculation module 540
Control module 550

FIG. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 22 15 2726

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	EP 0 029 810 A1 (SCHULTHESS & CO AG MASCHF [CH]) 3 June 1981 (1981-06-03) * page 5, line 17 - page 9, line 19 * * figures 1-2 *	1,8,11,12	INV. D06F58/38 ADD. D06F103/32 D06F103/52 D06F105/28
Y	US 2020/087847 A1 (CHOUNG DONGSOO [KR] ET AL) 19 March 2020 (2020-03-19) * paragraphs [0094] - [0120] * * paragraphs [0138] - [0153] * * claims 1-18; figures 1-16 *	1,8,11,12	
A	US 2020/002873 A1 (CHAE JONGHOON [KR] ET AL) 2 January 2020 (2020-01-02) * paragraphs [0191] - [0220] * * pages 1-15 *	1-12	
A	DE 199 18 877 A1 (BSH BOSCH SIEMENS HAUSGERAETE [DE]) 2 November 2000 (2000-11-02) * paragraphs [0005] - [0026] * * figure 1 *	1-12	TECHNICAL FIELDS SEARCHED (IPC)
A	CN 111 012 061 A (CSG HOLDING CO LTD; SHENZHEN CSG APPLIED TECH CO LTD) 17 April 2020 (2020-04-17) * paragraphs [0038], [0039] *	1,8,11,12	D06F F24H
A	EP 3 034 669 A1 (SAMSUNG ELECTRONICS CO LTD [KR]) 22 June 2016 (2016-06-22) * paragraphs [0018], [0019] * * paragraphs [0053] - [0058] * * claims 1,8; figures 1-8 *	1,8,11,12	
A	CN 105 734 941 A (XI'AN ZHONGZHI HUIZE PHOTOELECTRIC TECH CO LTD) 6 July 2016 (2016-07-06) * claims 1-5; figure 1 * * paragraphs [0017] - [0027] *	1,8,11,12	

The present search report has been drawn up for all claims

3

Place of search	Date of completion of the search	Examiner
Munich	24 June 2022	Weinberg, Ekkehard

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 22 15 2726

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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24-06-2022

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0029810 A1	03-06-1981	AT 19110 T	15-04-1986
		CH 646242 A5	15-11-1984
		EP 0029810 A1	03-06-1981
US 2020087847 A1	19-03-2020	KR 20210023034 A	04-03-2021
		US 2020087847 A1	19-03-2020
US 2020002873 A1	02-01-2020	KR 20190100116 A	28-08-2019
		US 2020002873 A1	02-01-2020
DE 19918877 A1	02-11-2000	AT 225956 T	15-10-2002
		DE 19918877 A1	02-11-2000
		EP 1048996 A1	02-11-2000
CN 111012061 A	17-04-2020	NONE	
EP 3034669 A1	22-06-2016	EP 3034669 A1	22-06-2016
		KR 20160072604 A	23-06-2016
CN 105734941 A	06-07-2016	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82