Claims

1. A method for train interior air quality monitoring and ventilation control, comprising the following steps:

step 1, acquiring multiple groups of interior air quality detection data and exterior air quality detection data;

step 2, acquiring an interior air comprehensive evaluation index Q_0 by using the interior air quality detection data in step 1, and acquiring an exterior air comprehensive evaluation index Q_1 by using the exterior air quality detection data in step 1;

step 3, determining the magnitude relationship between Q_0 and Q_1 obtained in step 2, and if $Q_0 \geq Q_1$, skipping to step 41; otherwise, skipping to step 51;

step 41, training an exterior fresh air volume control model according to the following method:

selecting n1 groups of the corresponding interior air quality detection data and the corresponding exterior air quality detection data as experimental data;

setting the ventilation volume level of a ventilation system (501) of the high-speed train to a G1 level;

performing ventilation experiments on the train under the conditions of n1 groups of experimental data, to obtain a minimum ventilation volume level that can reduce the air quality to a human health value within 5 minutes, as a ventilation volume level label corresponding to each group of experimental data; and

training an exterior fresh air volume control model by taking the n1 groups of experimental data as input and taking the ventilation volume level labels corresponding to the n1 groups of experimental data as output to obtain the exterior fresh air volume control model;

step 51, training an interior air purification control model according to the following method:

selecting n2 groups of the corresponding interior air quality detection data and the corresponding exterior air quality detection data as experimental data;

setting the ventilation volume level of the ventilation system (501) of the high-speed train to a G1 level, and setting the power level of an air purification device (502) to a G2 level;

performing ventilation experiments on the train under the conditions of n2 groups of experimental data, to obtain a minimum ventilation volume level and a minimum power level of the air purification device that can reduce the interior air quality to the human health value within 5 minutes, wherein the obtained minimum ventilation volume level is used as a ventilation volume level label corresponding to each group of experimental data, and the

obtained minimum power level of the air purification device is used as a power level label of the air purification device corresponding to each group of experimental data; and

training an interior air purification control model by taking the n2 groups of experimental data as input and taking the ventilation volume level labels and the power level labels of the air purification device corresponding to the n2 groups of experimental data as output to obtain the interior air purification control model;

step 6, detecting an interior air quality detection data and an exterior air quality detection data;

step 7, acquiring an interior air comprehensive evaluation index Q_0 by using the interior air quality detection data in step 6, and acquiring an exterior air comprehensive evaluation indexQ_1 by using the exterior air quality detection data in step 6; and

step 8, determining the magnitude relationship between Q_0 and Q_1 obtained in step 7:

if $Q_0 \geq Q_1$, calling the exterior fresh air volume control model to obtain the required ventilation volume level and controlling the ventilation system (501) of the high-speed train with the ventilation volume level;

otherwise, calling the interior air purification control model to obtain the required ventilation volume level and power level of the air purification device, controlling the ventilation system (501) of the high-speed train with the ventilation volume level, and controlling the air purification device (502) with the power level of the air purification device.

2. The method for train interior air quality monitoring and ventilation control according to claim 1, wherein the interior air quality detection data and the exterior air quality detection data both comprise one or more of CO2 concentration, NO2 concentration, SO2 concentration, PM2.5 concentration, VOC concentration, and dust concentration.

3. The method for train interior air quality monitoring and ventilation control according to claim 1, wherein the interior air quality detection data and/or the exterior air quality detection data are obtained by a multi-point monitoring mode.

4. The method for train interior air quality monitoring and ventilation control according to claim 1, wherein

a calculation method of the interior air comprehensive evaluation indicator Q_0 is:

Q_0=interior *CO2* concentration×p1+interior *NO2* concentration×p_2+interior *SO2* concentration×p_3+interior *PM*2.5 concentration×p_4+interior *VOC* concentration×p_5+interior dust concentration×p_6;

a calculation method of the exterior air comprehensive evaluation indicator Q_1 is:

Q_1=exterior *CO2* concentration×p_1+exterior *NO2* concentration×p_2+exterior *SO2* concentration×p_3+exterior *PM*2.5 concentration×p_4+exterior *VOC* concentration×p_5+exterior dust concentration×p_6;

wherein, P_1, P_2, P_3, P_4, P_5, and P_6 are corresponding weights of pollutants.

5. The method for train interior air quality monitoring and ventilation control according to claim 1, wherein in step 41, the exterior fresh air volume control model is trained by using a BP neural network algorithm, wherein the weight and threshold of the BP neural network are obtained by quantum particle swarm optimization with self-adaptive weights, comprising:

step A1: using a position vector of each quantum particle individual in quantum particle swarms as the weight and threshold of the BP neural network, and initializing the position vector parameter of the quantum particle swarm individual to a random number of [-1, 1];

wherein the number of the quantum particle swarms ranges [25, 70], the number of particles in a quantum particle swarm ranges [5, 50], the maximum number of iterations ranges [400, 1000], the number of iterations for forming an elite swarm ranges [60, 180], the premature convergence determination threshold ranges [0.01, 0.45], and the worst particle variation ratio among the swarms δ% ranges [2%, 7%];

step A2: setting a fitness function, and determining the position vector and the number of iterations t of an initial optimal quantum particle individual, wherein t=1;

substituting the weight and threshold corresponding to the position vector of the quantum particle individual into the exterior fresh air volume control model based on the BP neural network, determining the type of an identified vector label by using the exterior fresh air volume control model based on the BP neural network determined from the position vector of the quantum particle individual, and using the reciprocal of the mean square error of the outputted vector label and the actual vector label as a second fitness function;

step A3: calculating a swarm fitness variance of each quantum particle swarm, and performing premature convergence determination;

if the swarm fitness variance of the quantum particle swarm is smaller than a premature convergence determination threshold γ, mutating δ% of worst fitness particles and swarm extreme particles in the quantum particle swarm, and using the current best fitness particles as global optimal quantum particle individuals;

step A4: determining whether to form an elite swarm;

when the number of iterations is greater than the number of the elite swarm iterations,

extracting extreme values of each swarm by means of information sharing between the swarms to form the elite swarm, and turning to step A8, otherwise, turning to step A5;

step A5: updating particle parameters of each swarm;

step A6: recalculating and comparing the fitness value of each particle; if the fitness value is superior to the current individual extreme value, updating the individual extreme value; comparing the global extreme particles; if the fitness value of a particle is superior to the current swarm extreme value, updating the global extreme particles, assuming t=t+1, and turning to step A3;

step A7: continuing to evolve the elite swarm;

step A8: determining whether the maximum number of iterations is satisfied, and exiting if it is satisfied, otherwise, assuming t=t+1, and turning to step A3 till the global optimal value is found; and outputting the weight and threshold of the BP neural network.

6. The method for train interior air quality monitoring and ventilation control according to claim 1, wherein in step 51, the interior air purification control model is trained by using a gray neural network, wherein the weight and threshold of the gray neural network are obtained by optimization using a chaotic bat algorithm, comprising:

step B1: using the position of a bat individual as the weight and threshold of the interior air purification control model based on the gray neural network, initializing bat swarms, and setting parameters of the bat swarms;

wherein the size of a bat swarm ranges [200, 500], the maximum pulse frequency r_0 of the bat individual ranges [0.25, 0.5], the maximum pulse sound intensity A_0 ranges [0.25, 0.5], the maximum number of iterations ranges [150, 300], the search accuracy ranges [0.001, 0.1], the pulse frequency ranges [0, 1.5], the bat search frequency increase coefficient ranges [0.02, 0.08], the sound intensity attenuation coefficient ranges [0.8, 0.96], the maximum number of iterations ranges [100, 500], and the maximum search accuracy ranges [0.01, 0.1];

step B2: setting a fitness function, and determining an initial optimal position of the bat individual and the number of iterations t, t=1; substituting the weight and threshold corresponding to the position of the bat individual into the interior air purification control model based on the gray neural network, obtaining a detection result by using the interior air purification control model based on the gray neural network model determined from the position of the bat individual, and building a first fitness function f1(x) (f1(x)=1/(E+1)) with the difference E between the detection result and the actual situation;

calculating the fitness of the position of each bat individual by using the first fitness function, and using the position of the bat individual corresponding to the maximum fitness as the initial optimal position of the bat individual;

step B3: updating the speed and position of the bat individual by using a set pulse frequency;

step B4: if Rand1>r_i, randomly disturbing the bat at the optimal individual position to generate a disturbance position of the bat individual;

wherein, Rand1 is a random number uniformly distributed on [0, 1], and r_i is a pulse frequency of the i-th bat;

step B5: if Rand2>A_i, and the fitness of the disturbed position of the bat individual is superior to the fitness of the position of the bat individual before disturbance, moving the bat individual to the disturbance position, or else keeping the bat individual at the original position;

wherein, Rand2 is a random number uniformly distributed on [0, 1], and A_i is the sound intensity of the i-th bat;

step B6: if the condition of step B5 is satisfied, updating the pulse frequency and pulse sound intensity of the bat individual by using the bat search frequency increase coefficient and the sound intensity attenuation coefficient, and skipping to step B4, or else skipping to step B7;

step B7: calculating the fitness of the position of each bat individual in the current bat swarm, and performing chaotic optimization of position and speed on top m% bat individuals in descending order to obtain updated top m% bat individuals, wherein m ranges [5, 20]; and

step B8: determining whether the maximum number of iterations or the maximum search accuracy is reached; if it is reached, selecting a global optimal bat individual from the updated top m% bat individuals according to the fitness value, and outputting the optimal weight and threshold of the interior air purification control model based on the gray neural network corresponding to the global optimal bat individual; otherwise, assuming t=t+1, and turning to step B3 to continue next iteration.

7. An interior air quality monitoring and ventilation control system for a train, comprising:

an interior air quality detection module (1), configured to acquire interior air quality detection data;

an exterior air quality detection module (2), configured to acquire exterior air quality detection data;

a data transmission module (3), configured to transmit the acquired interior air quality detection data and the acquired exterior air quality detection data to a data processing module

(4);

the data processing module (4), configured for modeling and control; wherein:

the modeling process comprises:

acquiring an interior air comprehensive evaluation index Q_0 by using the interior air quality detection data, and acquiring an exterior air comprehensive evaluation index Q_1 by using the exterior air quality detection data;

when $Q_0 \geq Q_1$, training an exterior fresh air volume control model according to the following process:

selecting n1 groups of corresponding interior air quality detection data and the corresponding exterior air quality detection data as experimental data;

setting the ventilation volume level of a ventilation system (501) of the train to a G1 level;

performing ventilation experiments on the train under the conditions of n1 groups of experimental data, to obtain a minimum ventilation volume level that can reduce the air quality to a human health value within 5 minutes, as a ventilation volume level label corresponding to each group of experimental data; and

training an exterior fresh air volume control model by taking the n1 groups of experimental data as input and taking the ventilation volume level labels corresponding to the n1 groups of experimental data as output to obtain the exterior fresh air volume control model;

when $Q_0 < Q_1$, training an interior air purification control model according to the following process:

selecting n2 groups of the corresponding interior air quality detection data and the corresponding exterior air quality detection data as experimental data;

setting the ventilation volume level of the ventilation system (501) of the train to a G1 level, and setting the power level of an air purification device (502) to a G2 level;

performing ventilation experiments on the train under the conditions of n2 groups of experimental data, to obtain a minimum ventilation volume level and a minimum power level of the air purification device that can reduce the air quality to the human health value within 5 minutes, wherein the obtained minimum ventilation volume level is used as a ventilation volume level label corresponding to each group of experimental data, and the obtained minimum power level of the air purification device is used as a power level label of the air purification device corresponding to each group of experimental data; and

training an interior air purification control model by taking the n2 groups of experimental data

as input and taking the ventilation volume level labels and the power level labels of the air purification device corresponding to the n2 groups of experimental data as output to obtain the interior air purification control model;

the control process comprises:

obtaining an interior air quality detection data and an exterior air quality detection data;

acquiring an interior air comprehensive evaluation index Q_0 by using the interior air quality detection data, and acquiring an exterior air comprehensive evaluation index Q_1 by using the exterior air quality detection data;

if $Q_0 \geq Q_1$, calling the exterior fresh air volume control model to obtain the required ventilation volume level and controlling the ventilation system (501) of the high-speed train with the ventilation volume level;

otherwise, calling the interior air purification control model to obtain the required ventilation volume level and power level of the air purification device, controlling the ventilation system (501) of the high-speed train with the ventilation volume level, and controlling the air purification device (502) with the power level of the air purification device; and

a ventilation control module (5), comprising the ventilation system (501) and the air purification device (502); wherein the ventilation system (501) is configured to ventilate the train according to the ventilation volume level outputted by the data processing module (4), and the air purification device (502) is configured to purify the air in the train according to the power level of the air purification device outputted by the data processing module (4).

8. The interior air quality monitoring and ventilation control system for the train according to claim 7, wherein both the interior air quality detection module (1) and the exterior air quality detection module (2) comprise one or more of a CO2 concentration sensor, a NO2 concentration sensor, a SO2 concentration sensor, a PM2.5 concentration sensor, a VOC concentration sensor, and a dust concentration sensor.

9. The modeling system for a train interior air quality monitoring and ventilation control model according to claim 7, wherein

the interior air quality detection module (1) comprises several interior air quality detection devices (101), and an interior air quality detection device (101) is arranged at the head, middle and tail of each compartment, respectively;

the exterior air quality detection module (2) comprises several exterior air quality detection devices (201), and an exterior air quality detection device (201) is arranged at an outside air

inlet of each ventilation duct of each compartment; and

every three compartments share a data processing module (4).

10. The modeling system for a train interior air quality monitoring and ventilation control model according to claim 7, wherein the data transmission module (3) comprises a wireless transmission module (301).