Claims

1. A training method for a distribution prediction model of passengers in a subway car, comprising:

establishing a spatial coordinate system of each car, installing a collection device constituted by temperature and humidity sensors and a CO_2 concentration sensor in each car, each collection device serving as a sample collection point, and obtaining installation coordinates of each sample collection point in the corresponding spatial coordinate system;

obtaining a temperature time series, a humidity time series, and a CO_2 concentration time series at each sample collection point of each carduring a sampling period, and obtaining an average temperature value and an average humidity value locally of the day, wherein the installation coordinates of each sample collection point, the temperature time series, the humidity time series, and the CO_2 concentration time series corresponding to the sample collection point, and the average temperature value and the average humidity value constitute an environmental data sample at each sample collection point of each carduring the sampling period;

recording passenger positions in each car at an end timeof the sampling period, and obtaining coordinates of passengers in the corresponding spatial coordinate system, i.e. obtaining a passenger distribution for each carduring the sampling period;

converting the passenger distribution for each carduring the sampling period into a binary image, and calculating a mean value, a variance, a maximum value and a minimum value of pixels in the binary image;

calculating an amplitude and a gradient direction of each pixel in the binary image, and establishing a frequency distribution histogram with the gradient direction of all pixels as the abscissa axis and the pixel value corresponding to each pixel as the ordinate axis; extracting a frequency distribution feature of the frequency distribution histogram, the frequency distribution feature referring to a feature vector constituted by pixel values corresponding to each interval among R intervals equally divided from the abscissa axis of the frequency distribution histogram;

combining the mean value, the maximum value, the minimum value, the variance and the frequency

distribution feature of the pixels to form an original feature vector, and clustering the binary images with the original feature vectoras input of a clustering algorithm to obtain image clustering results;

coding the passenger distribution mode according to the image clustering results to obtain a passenger distribution code, each category of image clustering result corresponding to a passenger distribution mode, and each passenger distribution mode corresponding to a passenger distribution code; and

establishing a distribution prediction model for each car, and training the distribution prediction model with training samples to obtain a trained distribution prediction model, the training sample taking the environmental data sampleat each sample collection point of each carduring the sampling period as input and the corresponding passenger distribution code as output.

2. The training method for the distribution prediction model of passengers in the subway car according to claim 1, wherein the spatial coordinate system is a two-dimensional rectangular coordinate system with a horizontal centerline of the roof of the car as the *x*-axis and a longitudinal centerline of the roof as the *y*-axis, or the spatial coordinate system is a two-dimensional rectangular coordinate system with a horizontal centerline of the ground of the car as the *x*-axis and a longitudinal centerline of the ground as the *y*-axis.

3. The training method for the distribution prediction model of passengers in the subway car according to claim 1, wherein 15 collection devices are installed on the roof of each car, and the 15 collection devices are arranged in a array.

4. The training method for the distribution prediction model of passengers in the subway car according to claim 1, wherein the specific process of converting the passenger distribution for each carduring the sampling period into a binary image is as follows:

dividing each car into W equal parts along the *x*-axis of the spatial coordinate system of the car, and dividing each car into L equal parts along the *y*-axis of the spatial coordinate system of the car, to convert the space of each car into $W \times L$ independent units;

setting each independent unit as a pixel, the number of passengers in each independent unit being a

pixel value of the pixel; and

obtaining pixel values of all pixels, and converting the passenger distribution into the binary image composed of $W \times L$ pixels.

5. The training method for the distribution prediction model of passengers in the subway car according to claim 1, wherein formulas for calculating the amplitude and the gradient direction of the pixel are respectively:

$$G(l,w)=\sqrt{G_x(l,w)^2+G_y(l,w)^2}\ ,\quad \theta(l,w)=\arctan\frac{G_y(l,w)}{G_x(l,w)}$$

$$G_x(l,w)=I(l+1,w)-I(l-1,w),\quad G_y(l,w)=I(l,w+1)-I(l,w-1)$$

where, $G(l, w)$ is the amplitude of the pixel, $\theta(l, w)$ is the gradient direction of the pixel, $G_x(l, w)$ is the gradient amplitude of the pixel along the x-axis of the spatial coordinate system, $G_y(l, w)$ is the gradient amplitude of the pixel along the y-axis of the spatial coordinate system, $I(l+1, w)$ is the pixel value of the pixel in row $l+1$ and column$w$, $I(l-1, w)$ is the pixel value of the pixel in row $l-1$ and column$w$, $l=1, 2, 3... L$, $w=1, 2, 3...W$, W is a number of equal parts divided from the car along the x-axis of the spatial coordinate system of each car, and L is a number of equal parts divided from the car along the y-axis of the spatial coordinate system of each car.

6. The training method for the distribution prediction model of passengers in the subway car according to claim 1, wherein the clustering algorithm is an OPTICS algorithm, the initial neighborhood distance parameter ε of the OPTICS algorithm is 0.2, and the initial neighborhood sample parameter *MinPts* is 3.

7. The training method for the distribution prediction model of passengers in the subway car according to any one of claims 1-6, wherein the temperature time series, the humidity time series, and the CO_2 concentration time series in the training samples are replaced with a temperature time series feature vector, a humidity time series feature vector, and a CO_2 concentration time series feature vector, respectively, wherein the temperature time series feature vector, the humidity time series feature vector, and the CO_2 concentration time series feature vector are obtained as follows:

establishing a temperature time series LSTM neural network model, and randomly dividing the temperature time series in the training samples into two temperature training sets, wherein one of the temperature training sets and the passenger distribution code corresponding to the temperature training set constitute a first training set, and the other temperature training set is a second training set; training the temperature time series LSTM neural network model with the first training set to obtain a trained temperature time series LSTM neural network model; removing a classification layer of the trained temperature time series LSTM neural network model, and obtaining the temperature time series feature vector with the second training set as input and a vector outputted by a fully connected layer as output;

establishing a humidity time series LSTM neural network model, and randomly dividing the humidity time series in the training samples into two humidity training sets, wherein one of the humidity training sets and the passenger distribution code corresponding to the humidity training set constitute a third training set, and the other humidity training set is a fourth training set; training the humidity time series LSTM neural network model with the third training set to obtain a trained humidity time series LSTM neural network model; removing a classification layer of the trained humidity time series LSTM neural network model, and obtaining the humidity time series feature vector with the fourth training set as input and a vector outputted by a fully connected layer as output; and

establishing a CO_2 concentration time series LSTM neural network model, and randomly dividing the CO_2 concentration time series in the training samples into two CO_2 concentration training sets, wherein one of the CO_2 concentration training sets and the passenger distribution code corresponding to the CO_2 concentration training set constitute a fifth training set, and the other CO_2 concentration training set is a sixth training set; training the CO_2 concentration time series LSTM neural network model with the fifth training set to obtain a trained CO_2 concentration time series LSTM neural network model; removing a classification layer of the trained CO_2 concentration time series LSTM neural network model, and obtaining the CO_2 concentration time series feature vector

with the sixth training set as input and a vector outputted by a fully connected layer as output.

8. A training system for a distribution prediction model of passengers in a subway car, comprising a plurality of training subsystems, each car corresponding to a training subsystem, wherein each training subsystem comprises a plurality of collection devices arranged on the roof of the car and a control device; the collection device comprises temperature and humidity sensors and a CO_2 concentration sensor;

the control device comprises:

a coordinate system establishment unit, configured to establish a spatial coordinate system of each car, and obtain installation coordinates of each sample collection point in the corresponding spatial coordinate system, each collection device serving as a sample collection point;

an environmental data obtaining unit, configured to obtain a temperature time series, a humidity time series, and a CO_2 concentration time series at each sample collection point of each carduring a sampling period, and obtain an average temperature value and an average humidity value locally of the day, wherein the installation coordinates of each sample collection point, the temperature time series, the humidity time series, and the CO_2 concentration time series corresponding to the sample collection point, and the average temperature value and the average humidity value constitute an environmental data sample at each sample collection point of each carduring the sampling period;

a passenger distribution obtaining unit, configured to obtain coordinates of passengers in the corresponding spatial coordinate system according to a recorded passenger positions in each car at the end timeof the sampling period, i.e. obtain a passenger distribution for each carduring the sampling period;

an image conversion and feature extraction unit, configured to convert the passenger distribution for each carduring the sampling period into a binary image, and calculate a mean value, a variance, a maximum value and a minimum value of pixels in the binary image; calculate an amplitude and a gradient direction of each pixel in the binary image, and establish a frequency distribution histogram with the gradient direction of all pixels as the abscissa axis and the pixel value

corresponding to each pixel as the ordinate axis; and extract a frequency distribution feature of the frequency distribution histogram, the frequency distribution feature referring to a feature vector constituted by pixel values corresponding to each interval among *R* intervals equally divided from the abscissa axis of the frequency distribution histogram;

a clustering classification unit, configured to combine the mean value, the maximum value, theminimum value, the variance and the frequency distribution feature of the pixels to form an original feature vector, and cluster the binary images with the original feature vectoras input of a clustering algorithm to obtain image clustering results;

a coding unit, configured to code the passenger distribution mode according to the image clustering results to obtain a passenger distribution code, each category of image clustering result corresponding to a passenger distribution mode, and each passenger distribution mode corresponding to a passenger distribution code; and

a model training unit, configured to establish a distribution prediction model for each car, and train the distribution prediction model with training samples to obtain a trained distribution prediction model, the training sample taking the environmental data sampleof each sample collection point of the car during the sampling period as input and the corresponding passenger distribution code as output.

9. A method for guiding passengers in a subway car based on environmental monitoring and lighting guidance, comprising:

obtaining an environmental data sample at each sample collection point of each carduring each sampling period in real time, the environmental data sample being constituted by installation coordinates of each sample collection point, a temperature time series, a humidity time series, and a CO_2 concentration time series corresponding to the sample collection point, and an average temperature value and an average humidity value;

inputting the environmental data samples into the distribution prediction model for the corresponding car which is trained by the training method according to any one of claims 1-7, to

obtain a predicted passenger distribution code for each car during the corresponding sampling period; and

adjusting the brightness of lighting tubes in the corresponding car according to the predicted passenger distribution code forthe car during the corresponding sampling period to guide passenger flow.

10. The training method for distribution prediction model of passengers in a subway car according to claim 9, wherein the temperature time series, the humidity time series, and the CO_2 concentration time series in the environmental data samples are replaced with a temperature time series feature vector, a humidity time series feature vector, and a CO_2 concentration time series feature vector, respectively, wherein the temperature time series feature vector, the humidity time series feature vector, and the CO_2 concentration time series feature vector are obtained as follows:

inputting the temperature time series into the trained temperature time series LSTM neural network model with the classification layer removed according to claim 7, the vector outputted by the fully connected layer being the corresponding temperature time series feature vector;

inputting the humidity time series into the trained humidity time series LSTM neural network model with the classification layer removed according to claim 7, the vector outputted by the fully connected layer being the corresponding humidity time series feature vector; and

inputting the CO_2 concentration time series into the trained CO_2 concentration time series LSTM neural network model with the classification layer removed according to claim 7, the vector outputted by the fully connected layer being the corresponding CO_2 concentration time series feature vector.

11. The method for guiding passengers in the subway car according to claims 9 or 10, wherein the specific process of controlling the brightness of lighting tubes in the corresponding car according to the predicted passenger distribution code forthe car during the corresponding sampling period is as follows:

obtaining a current image clustering result according to the predicted passenger distribution code

forthe car during the corresponding sampling period, and determining a clustering center corresponding to the current image according to the current image clustering result;

defining S binary images closest to the clustering center as typical clustering images of a corresponding category, and calculating an average pixel value ofeach pixel position in the S typical clustering images, to obtain an average pixel image under the category;

assigning each lighting tube to a lighting area according to the layout of lighting tubes in the corresponding car, and calculating an average value of pixel valuesfor pixels in the lighting area corresponding to each lighting tube;

if the maximum pixel value in the average pixel image is greater thana pixel threshold, starting lighting guidance and performing next step, otherwise skipping lighting guidance;

extracting pixels in the average pixel image whose average pixel values are greater than the pixel threshold, the pixels greater than the pixel threshold constituting a set of pixels to be guided;

calculating a lighting guidance coefficient according to the coordinates of the lighting tubes in the spatial coordinate system, the coordinates of pixels in the set of pixels to be guided in the spatial coordinate system, and the average value of pixel values for the pixels in the lighting area, wherein the specific calculation expression is:

$$\beta_n = A_n\left(\sqrt{\left(x_0^n - x_1^l\right)^2 + \left(y_0^n - y_1^w\right)^2} + \sqrt{\left(x_0^n - x_2^l\right)^2 + \left(y_0^n - y_2^w\right)^2} + \cdots + \cdots + \sqrt{\left(x_0^n - x_H^l\right)^2 + \left(y_0^n - y_H^w\right)^2}\right)$$

where, β_n is the lighting guidance coefficient, A_n is the average value of pixel valuesfor pixels in the lighting area corresponding to the n^{th} lighting tube, $\left(x_0^n, y_0^n\right)$ is the coordinates of the n^{th} lighting tube in the spatial coordinate system, $\left(x_1^l, y_1^w\right)$ is the coordinates of the first pixel in the set of pixels to be guided in the spatial coordinate system, $\left(x_2^l, y_2^w\right)$ is the coordinates of the second pixel in the set of pixels to be guided in the spatial coordinate system, $\left(x_H^l, y_H^w\right)$ is the coordinates of the H^{th} pixel in the set of pixels to be guided in the spatial coordinate system, and H is the number of

pixels in the set of pixels to be guided;

adjusting the brightness of the lighting tubes in the lighting areas corresponding to the $\beta_n$values according to the order of the β_n values, and guiding passengers to flow toward the lighting area with a smaller β_n value.

12. A system for guiding passengers in a subway car based on environmental monitoring and lighting guidance, comprising:

a real-time data obtaining unit, configured to obtain an environmental data sample at each sample collection point of each carduring each sampling period in real time, the environmental data sample being constituted by installation coordinates of each sample collection point, a temperature time series, a humidity time series, and a CO_2 concentration time series corresponding to the sample collection point, and an average temperature value and an average humidity value;

a prediction unit, configured to input the environmental data samples into the distribution prediction model for the corresponding car which is trained by the training method according to any one of claims 1-7, to obtain a predicted passenger distribution code for each car during the corresponding sampling period; and

an adjustment and guidance unit, configured to adjust the brightness of lighting tubes in the corresponding car according to the predicted passenger distribution code forthe car during the corresponding sampling period to guide passenger flow.

13. The system for guiding passengers in the subway car according to claim 12, wherein the adjustment and guidance unit is specifically configured to:

obtain a current image clustering result according to the predicted passenger distribution code forthe car during the corresponding sampling period, and determine a clustering center corresponding to the current image according to the current image clustering result;

define *S* binary images closest to the clustering center as typical clustering images of a corresponding category, and calculate an average pixel value ofeach pixel position in the *S* typical clustering images, to obtain an average pixel image under the category;

assign each lighting tube to a lighting area according to the layout of lighting tubes in the corresponding car, and calculate an average value of pixel valuesfor pixels in the lighting area corresponding to each lighting tube;

if the maximum pixel value in the average pixel image is greater thana pixel threshold, start lighting guidance and perform next step, otherwise skip lighting guidance;

extract pixels in the average pixel image whose average pixel values are greater than the pixel threshold, the pixels greater than the pixel threshold constituting a set of pixels to be guided;

calculate a lighting guidance coefficient according to the coordinates of the lighting tubes in the spatial coordinate system, the coordinates of pixels in the set of pixels to be guided in the spatial coordinate system, and the average value of pixel values for the pixels in the lighting area, wherein the specific calculation expression is:

$$\beta_n = A_n\left(\sqrt{\left(x_0^n - x_1^l\right)^2 + \left(y_0^n - y_1^w\right)^2} + \sqrt{\left(x_0^n - x_2^l\right)^2 + \left(y_0^n - y_2^w\right)^2} + \cdots \right.$$
$$\left. \cdots + \sqrt{\left(x_0^n - x_H^l\right)^2 + \left(y_0^n - y_H^w\right)^2}\right)$$

where, β_n is the lighting guidance coefficient, A_n is the average value of pixel valuesfor pixels in the lighting area corresponding to the n^{th} lighting tube, $\left(x_0^n, y_0^n\right)$ is the coordinates of the n^{th} lighting tube in the spatial coordinate system, $\left(x_1^l, y_1^w\right)$ is the coordinates of the first pixel in the set of pixels to be guided in the spatial coordinate system, $\left(x_2^l, y_2^w\right)$ is the coordinates of the second pixel in the set of pixels to be guided in the spatial coordinate system, $\left(x_H^l, y_H^w\right)$ is the coordinates of the H^{th} pixel in the set of pixels to be guided in the spatial coordinate system, and H is the number of pixels in the set of pixels to be guided;

adjust the brightness of the lighting tubes in the lighting areas corresponding to the $\beta_n$values according to the order of the β_n values, and guide passengers to flow toward the lighting area with a smaller β_n value.