CONTROL METHOD OF MECHANICAL SMOKE EMISSION IN HIGH-RISE BUILDING CORRIDOR

by

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The traditional method has a large control error in the corridor mechanical smoke control method. Therefore, a multi-task convolutional neural network-based high-rise building corridor mechanical smoke control method is proposed. Through the mechanical smoke exhaust principle of high-rise building corridors, the threshold of mechanical smoke exhaust is set to predict the mechanical smoke exhaust volume of high-rise building corridors. The movement of mechanical smoke in high-rise building corridors is simulated according to fire dynamics simulator to determine the turbulence state of mechanical smoke in high-rise building corridors. Input the mechanical smoke exhaust data of high-rise building corridors into the multi-task convolutional neural network to complete the mechanical smoke exhaust control of high-rise building corridors. Experimental results show that the maximum accuracy of this method is about 98%, and the control time is always less than 1 second.

Key words*: high-rise buildings, mechanical flue gas emission,
fire dynamics simulator simulation, turbulent regime
multi-task convolutional neural networks*

Introduction

In recent years, fire accidents in high-rise buildings have been increasing. According to statistics, more than 80% of deaths in fires are caused by smoke, most of which are caused by inhalation of smoke and toxic gases [1]. Corridor is the indoor passage for evacuees from the room to the safety exit (such as evacuation stairs or external exit), and is usually the first safe area for evacuation [2]. Whether the smoke in the corridor can be discharged in time, to a large extent determines whether the people in the building can escape safely. After a fire in a high-rise building, the smoke spreads with the location of the fire and spreads to other spaces in the building. The corridors of high-rise buildings are the only way for people to evacuate from the building and the main way for smoke to spread. The moving speed of the mechanical exhaust port, the height of the exhaust layer, temperature, and gas concentration are important factors affecting evacuation [3]. In order to improve the impact of mechanical smoke in the

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corridors of high-rise buildings on evacuation and disaster relief, researchers in this field have conducted a lot of research and achieved certain results.

Zhu [4] proposed a method to analyze the influence of coupling factors on the smoke exhaust effect of evacuation corridors in high-rise buildings. This method mainly analyzes the influencing factors of smoke exhaust in evacuation corridors of high-rise buildings and can determine the speed of smoke movement. However, this method does not carry out a detailed analysis of the control method of the smoke movement, and further research on the control method is needed. Zhang [5] puts forward a study on corridor smoke characteristics under the combined action of DUI outdoor air and mechanical smoke exhaust. In this method, a 3:1 small experimental platform is designed. Considering the comprehensive effect of outdoor air and mechanical smoke exhaust, 32 sets of working conditions are designed. A theoretical model of Froude number for flue gas stratification was established and the model was revised. The research results can provide references for building fire safety assessment and mechanical smoke exhaust system optimization design under outdoor wind. However, this method can be used to analyze the smoke state of buildings, but it still needs to be improved.

Aiming at the problems existing in the aforementioned methods, this paper proposes a new control method of mechanical smoke emission in high-rise building corridor. The principle of mechanical smoke emission in high-rise building corridor was analyzed, the threshold value of mechanical smoke emission in high-rise building corridor was set, and the prediction of mechanical smoke emission in high-rise building corridor was completed. With the help of fire dynamics simulator (FDS), the movement model of mechanical smoke in high-rise building corridor was simulated to determine the turbulent movement state of mechanical smoke in high-rise building corridor. On this basis, the mechanical smoke emission data of high-rise building corridor was input into the multi-task convolutional neural network to complete the mechanical smoke emission control of high-rise building corridor. The technical route studied in this paper are:

– Analyze the principle of mechanical smoke emission in high-rise building corridor, set the threshold of mechanical smoke emission in high-rise building corridor, and complete the prediction of mechanical smoke emission in high-rise building corridor.
– Using FDS to simulate the movement model of mechanical smoke in the corridor of high-rise building, the turbulent movement state of mechanical smoke in the corridor of high-rise building was determined.
– On this basis, the mechanical smoke emission data of high-rise building corridor is input into the multi-task convolutional neural network to complete the mechanical smoke emission control of high-rise building corridor.
– Experimental analysis.
– Conclusions and future prospects.

Mechanical smoke movement model of high-rise building corridor

In order to control the mechanical smoke exhaust in the corridors of high-rise buildings, first analyze the principle of mechanical smoke exhaust in the corridors of high-rise buildings, and build a mechanical smoke movement model in the corridors of high-rise buildings on this basis, so as to obtain the control parameters of the smoke exhaust movement and realize the mechanical exhaust control.

Principle analysis of mechanical smoke emission in high-rise building corridor

When controlling the mechanical smoke emission in the corridor of high-rise buildings, the current mechanical smoke emission in the corridor of high-rise buildings is predicted through eq. (1), that is:

$$\min_{\Delta i(k)} j = C_V^T \Delta U_{ss}(k) \tag{1}$$

where j is the smoke emission, i – the total number of floors in a high-rise building, C – the estimated emissions of mechanical flue gas from historic high-rise building corridors, $U_{ss}(k)$ – the time domain of mechanical smoke emission control for corridors of historic high-rise buildings [6], T – the current scale of mechanical smoke emission in high-rise building corridors, and V – the current evaluation function of mechanical smoke emission in high-rise building corridors.

When controlling the mechanical smoke emission in the corridor of high-rise buildings, set m for real-time tracking of emissions, p stands for actual emissions and Q is the dynamic change state of mechanical smoke emission in high-rise building corridors, determine the [7] of emission characteristics l_{mm} by:

$$l_{mm} = \min_{\Delta U_{ss}(k)} j \times \frac{m \forall p}{Q_0} \tag{2}$$

Mechanical smoke motion model of high-rise building corridor

Before the control of mechanical smoke emission in high-rise building corridors, it is necessary to analyze its motion characteristics, and on the basis of determining the mechanical smoke emission in high-rise building corridors, a motion model of mechanical smoke emission in high-rise building corridors is constructed [8-10]:

$$\rho \frac{\partial (T)}{\partial t} + \rho \frac{\partial (T)}{\partial x_i} = \frac{\partial}{\partial x_i}\left(\lambda \frac{\partial T}{\partial x_i} \right) + q_r \tag{3}$$

$$\rho \frac{\partial k}{\partial t} = \rho \frac{\partial D}{\partial x_i} \tag{4}$$

where ρ is the density of the gas, q_r – the radiant heat flux vector, k – the air thermal conductivity [11], D – the original mass transfer coefficient, t – the smoke extraction time, and x_i – the independent variables of smoke exhaust motion model.

The model of space flue gas motion in high-rise building corridor is analyzed. The conservation equations of kinetic energy and energy are:

$$\frac{\partial}{\partial t} + \Delta \rho u = 0 \tag{5}$$

$$\frac{\partial}{\partial t}(\rho Y_1) + \Delta \rho Y_1 u = \Delta \rho D_1 \Delta Y_1 + m_1 \tag{6}$$

$$\rho \frac{\partial}{\partial t} + (u\Delta)u + \Delta p = pg + f + \Delta \tau \tag{7}$$

$$\frac{\partial}{\partial t}(ph)+\Delta phu=\frac{Dp}{Dt}-\Delta q_r \tag{8}$$

where u is the density of the gas, Y_1 – the mass fraction of components, D_1 – the mass transfer coefficient, m_1 – the mass-flow rate, p – the gas pressure, g – the local acceleration of gravity, f – the external forces on the gas, τ – the viscous force tensor, and h – the entropy.

After determining the movement model of mechanical smoke in high-rise building corridor, its movement mode and quality are analyzed, and its emission control is carried out. In this paper, the multi-task convolutional neural network algorithm in the artificial intelligence algorithm is used for emission control [12-15].

Multi-task convolutional neural network based mechanical flue gas emission control method for high-rise building corridor

Multi-task convolutional neural network, which can directly input the relevant data of the research object, is a more efficient method in the field of recognition and control. Multi-task convolutional neural network makes use of weight sharing, local sensing field and pooling to keep data distortion, scaling and displacement constant, which can be effectively applied to the mechanical smoke emission control of high-rise building corridors [16-19]. The multi-task convolutional neural network mainly includes input layer, convolutional layer and lower sampling layer, and realizes target recognition through multi-layer supervised learning network.

Multi-task convolutional neural network convolutional layer feature neurons are connected with local receptive fields of other layers, and convolutional operations are carried out to realize feature extraction of flue gas data. The convolutional layer formula in the convolutional neural network is:

$$x_j^l = f\left(\sum\nolimits_{i\in M_j} x_i^{l-1}\times k_{ij}^l\right) \tag{9}$$

where land k represent the number of layers and convolution kernel respectively, M_j and b_j – the receptive field of the input layer and the bias of each output layer. In the convolutional neural network, the upper layer of the convolutional layer can form features and initial data for the convolutional layer and the lower sampling layer. Multiply and sum the local receiver field and the convolution kernel point, and then add it to the bias to realize the calculation of the convolutional layer. The internal parameters of the convolutional kernel of the convolutional layer are trainable, and the initial bias value of the convolutional layer is set to zero during the convolutional operation.

When multi-layer convolutional neural network uses the lower sampling layer to obtain characteristic values of different regions of flue gas emissions, it is required to make statistics and analyze the characteristics of the region, and reflect the overall characteristics of the region through the new features. The analyzed region is the pooling domain of convolutional neural network, and the process of statistics and analysis of this region is the pooling process of convolutional neural network.

After the input flue gas emission data amount is pooled through the convolutional neural network, it is assumed that the characteristic data remain unchanged, and the pooled size is set to be n, and the characteristic data after the pooled operation is $1/n$. The following sampling layer formula of convolutional neural network is:

$$x_j^l = f\left[\beta_j^l down(x_j^{l-1})+b_j^l\right] \tag{10}$$

where b represents the flue gas emission correction factor and *down*() and β are the pool function and the weight coefficient, respectively.

Experimental analysis

Experimental environment

In order to verify the effectiveness of the proposed method in the control of mechanical smoke emission in high-rise building corridors, a simulation experiment was conducted. Experiment in somewhere, to simulate the 20th floor of a high-rise building with artificial smoke as experiment material, its use in the layer, the layer corridor area of 50 m^2, artificial smoke will be prepared at a particular time period is dispersed, analysis of the simulated a high-level building corridor, the change of the mechanical smoke movement, and obtain the data, after the experiment data acquisition through MATLAB platform for processing, using Windows XP system, its operation for 16 GB memory.

Experimental indicators

In order to verify the advantages of this method, the experiment adopts the method of comparison, the method in this paper, the method of [5], and the method of [6], compare the three methods in corridor in the sample building mechanical time consuming of flue gas emission control precision and control for experimental index, in order to ensure the accuracy of the experiment, the experimental data are repeated analysis and processing, with the highest precision to ensure the effectiveness of the experiment.

Experimental result

Accuracy analysis of mechanical smoke emission control in high-rise building corridor by different methods

In order to verify the control accuracy of mechanical smoke emission in high-rise building corridors with the proposed method, the control accuracy of the method in this paper, the method in [5] and the method in [6] were compared. The experimental results are shown in fig. 1.

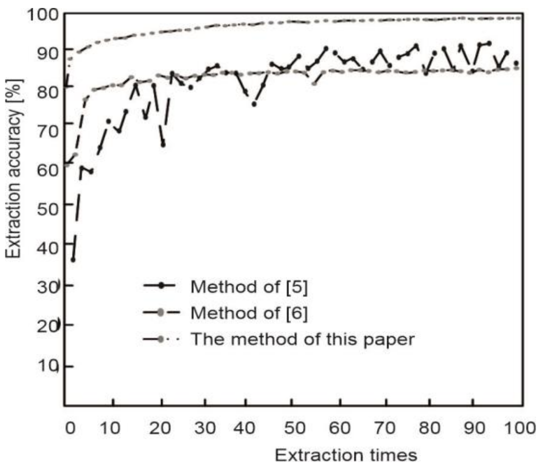

Figure 1. Precision analysis of mechanical smoke emission control in high-rise building corridors by different methods

It can be seen from the analysis of fig. 2 that, under the same experimental environment, the control precision of the method in this paper, the method in [5] and the method in [6] is constantly changing with the change of the number of experiments. When the number of iterations is 20, the control accuracy of the method in this paper is about 93%, that of the method in [5] is about 63%, and that of the method in [6] is about 80%. When the number of iterations is 50, the control accuracy of the method in this paper is about 98%, that of the method in [5] is about 82%, and that of the method in [6] is about 81%. Compared with the control precision of proposed method increased by nearly 20% and 30%, respectively, this is because the proposed method analysis of high-rise building corridor before to control the mechanical principle of flue gas emissions, set the high-rise building corridor mechanical smoke emission threshold, the complete set high-rise building corridor prediction of the mechanical smoke emissions, laid the foundation of the later control, thus improve the control precision of the method in this paper.

Time consuming analysis of mechanical smoke emission control in high-rise building corridor by different methods

In order to further verify the advantages of the proposed method for the control of mechanical flue gas emission in high-rise building corridors, the control time of the method in this paper, the method in [5] and the method in [6] were compared. The experimental results are shown in fig. 2.

By analysing the data in fig. 2, it can be seen that with the increasing number of experiments, the time consuming of mechanical smoke emission control of high-rise building corridors by the method in this paper, the method in [5] and the method in [6] are constantly changing. When the number of iterations is 20, the time of mechanical smoke emission control of high-rise building corridor based on the method in this paper is about 0.5 seconds, that of the method in [5] is about 7.6 seconds, and that of the method in [6] is about 6 seconds. When the number of iterations is 50, the method of high-rise building corridor mechanical smoke emission control takes about 0.3 seconds, the method of [5] of high-rise building corridor mechanical smoke emission control takes about 6.1 seconds, the method of [6] of the high-rise building corridor mechanical smoke emission control takes about 8.9 seconds, when the number of iterations is 100, the method of high-rise building corridor mechanical smoke emission control takes about 0.1 seconds, the method of [5] of high-rise building corridor mechanical smoke emission control takes about 9.1 seconds, It takes about 10 seconds to control mechanical smoke emission in high-rise building corridors based on the method in [6]. Compared with the proposed method, the control time cost is shorter, which is because the proposed method adopts multi-task convolutional neural network for control, which is faster and has certain advantages.

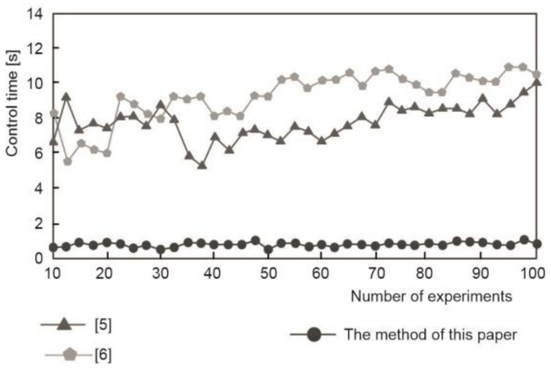

Figure 2. Time consuming analysis of mechanical smoke emission control in high-rise building corridors by different methods

Conclusion

- This article proposes a method for mechanical smoke exhaust control in corridors of high-rise buildings based on multi-task convolutional neural networks. This method analyzes the principle of mechanical smoke exhaust in corridors of high-rise buildings, sets the threshold of mechanical smoke exhaust in corridors of high-rise buildings, completes the prediction of mechanical smoke exhaust in corridors of high-rise buildings, and simulates the mechanism of mechanical movement.

- Analyze the smoke in the corridors of high-rise buildings with FDS, and determine the turbulent motion state of the mechanical smoke in the corridors of high-rise buildings. On this basis, the mechanical smoke exhaust data of high-rise building corridors are input into the multi-task convolutional neural network to complete the mechanical smoke exhaust control of high-rise building corridors.
- The maximum accuracy of mechanical smoke control in corridors of high-rise buildings proposed in this paper is about 98%, which has certain advantages. The mechanical smoke control in corridors of high-rise buildings proposed in this paper takes less than 1s, which is faster than that, and has certain feasibility.

Although the method in this paper has achieved certain results in the time consumption of smoke control, this paper does not consider the energy consumption of smoke control, which is my research direction.

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