Dust Monitoring and Processing System Based on Stepped Distributed Algorithm

Pei Zhang, Xiaolin Ma*, Lihui Zhang and Zeyu Guo
School of Information Engineering, Wuhan University of Technology, Wuhan, Hubei 430070, China
*Corresponding author: maxiaolin0615@whut.edu.cn

Abstract. With the rapid development of modern industry, productive dust is almost everywhere in factories, becoming a major hidden danger to industrial production safety. This project will realize real-time monitoring of factory dust, automatic dust removal, and human-computer interaction. Users can set the dust concentration threshold by themselves. The sensor will monitor the dust concentration in real time and upload the processed data to the cloud platform. If it exceeds the preset Threshold value, the nearby dust removal equipment is activated to remove dust in time. In this paper, for the monitoring and dust removal control of dust concentration in the air, the ladder distributed algorithm is used to save energy under the premise of achieving the dust removal function.

Keywords: ladder distributed algorithm, dust concentration, dust removal, real-time monitoring.

1. Introduction
The stepped distribution algorithm used in this paper aims to process the dust concentration data between the finite nodes in the space by using the superposition fitting method to predict the dust concentration distribution in the entire space and then adjust the output power of each node to achieve the corresponding When the dust removal effect, the dust removal power reaches the lowest. This application has guiding significance for the use of dust processing and other mixing scenarios.

2. Design background
With the rapid development of modern industry, productive dust is almost everywhere in factories, becoming a major hidden danger to industrial production safety. Dust will reduce product quality and machine accuracy, and workers who work in a dusty environment for a long time will cause great harm to the body. Excessive concentration may even cause an explosion. In order to reduce the harm of dust, the Chinese government has promulgated a series of regulations and decrees, such as the "Decision on Preventing Silica Dust in Factory and Mining Enterprises" and so on. According to these policies and decrees, Chinese factories and mines have done a lot of work on dust prevention and dust removal [1].
At present, a variety of dust monitoring instruments have been developed at home and abroad, such as dust samplers, direct reading dust meters, dust concentration sensors, etc. [2], especially the
appearance of dust concentration sensors, which solves the problem of not being able to monitor the dust concentration of factories in real time. At present, the light scattering method and light absorption method are mainly used to monitor the dust concentration in the market. Although the dust monitoring system has been widely used, the task of reducing dust hazards in my country is still quite arduous. Correct monitoring and handling of dust can eliminate safety hazards, improve production efficiency and product quality, increase economic efficiency and protect workers’ health. [3] This project will realize real-time monitoring of factory dust, automatic dust removal, and human-computer interaction. Users can set the dust concentration threshold by themselves. The sensor will monitor the dust concentration in real time and upload the processed data to the cloud platform. If it exceeds the preset threshold value, the nearby dust removal equipment is activated to remove dust in time.

3. Dust concentration monitoring

The mathematical model for studying dust diffusion is mainly Fick’s first law of diffusion. This model is based on the assumption that the velocity distribution of the flow field has nothing to do with the existence of discrete phases. That is to say, during the dust diffusion process, no dust particles will occur between air particles. Transfer, the spread of dust is entirely due to the result of air mixing with dust. Establish a Cartesian (x, y, z) coordinate system, the coordinates are perpendicular to the ground. The formula derived by ignoring the influence of gravity on solid particles

\[
C(x, y, z, H) = \frac{Q}{2\pi u\sigma_y\sigma_z} \exp\left(\frac{-y^2}{2\sigma_y^2}\right) \times \left\{\exp\left[-\frac{(z-H)^2}{2\sigma_z^2}\right] + \exp\left[-\frac{(z+H)^2}{2\sigma_z^2}\right]\right\}
\]

In the formula: \(C(x,y,z,H)\) is the source strength \(Q(\text{mg/s})\), the concentration caused by the emission source of height \(H(\text{m})\) at the leeward side space point \((x,y,z)\), unit It is \(\text{mg/m}^3\); \(u\) is the average wind speed of the atmosphere in \(\text{m/s}\); \(\sigma_y\) and \(\sigma_z\) are the horizontal and vertical diffusion parameters, in \(\text{m}\).

By measuring the position of the dust concentration detection node in space, the position information of the dust concentration detection node is calibrated \(xy(\text{m})\), and the height of \(z\) is
uniformly calibrated to 1m, and the two-dimensional image of the node distribution is established as shown in Figure 1.

Each node monitors the dust concentration information in real time, and uses monitoring node 1 as the root node of the dust concentration to calculate the concentration in the current space and draw the dust concentration distribution map with the above formula. The dust concentration information obtained by the other 12 nodes is drawn by theoretical calculation. Doing compensation for the concentration distribution diagram of the dust, thereby improving the accuracy of the dust concentration distribution diagram. The algorithm block diagram is shown in Figure 2. The obtained dust concentration distribution diagram is shown in Figure 3.

4. Dust treatment
As shown in Figure 4, the space is equally divided into 16 small blocks, and each dust removal node corresponds to a small block. Suppose the height of the space is 3m, and the volume corresponding to each small block is 11.25m³. In order to improve the efficiency of the system, and considering the fact that the dust distribution is often not ray distribution in the case of multiple sources in practical applications, the efficiency of the dust removal node in this system depends on the total amount of dust in the corresponding small block. Through the obtained dust concentration distribution diagram and the corrected concentration distribution function, the volume is integrated to obtain the total amount of dust in the current small block, and the dust removal fan is controlled according to the total output duty cycle to perform dust removal operation.

If the amount of dust in the small block is 112.5mg, the duty cycle of the PWM wave output at this time is also 40%, which is the minimum duty cycle. Whenever the amount of dust in the small block increases by 11.25mg, the duty cycle of the output PWM wave increases by 2%. When the amount of dust in the small block is 450mg, the duty cycle of the output PWM wave is 100%, that is, the fan...
rotates at full speed for dust removal operation. When the threshold is exceeded, the duty cycle of the output PWM wave is 100%, and the fan rotates at full speed for dust removal operation.

![Distribution diagram of dust treatment equipment](image)

**Figure 4** Distribution diagram of dust treatment equipment

5. Experimental results

In the experimental simulation system structure, in order to simulate the environment in the real factory as much as possible, a room of 5m*12m is used to simulate the production workshop, wood powder is continuously injected through small holes to simulate the production of dust, and the air outlet is simulated by a fan.

Put 60mg of dust at the point (0,5) in the xy coordinate system, record the concentration of the monitoring node, and keep other environmental conditions unchanged. Repeat the above operation 5 times. The results are shown in Table 1.

| Table 1: Node concentration record table |
|----------------------------------------|
| **Node** | **Frequency** | **1** | **2** | **3** | **4** | **5** |
| Node 1   | 49.51         | 48.12 | 49.14 | 50.04 | 49.65 |
| Node 2   | 39.84         | 39.87 | 40.1  | 39.54 | 39.17 |
| Node 3   | 34.36         | 35.23 | 35.16 | 34.92 | 35.08 |
| Node 4   | 33.15         | 33.14 | 33.31 | 32.98 | 33.24 |
| Node 5   | 29.46         | 28.94 | 29.11 | 29.45 | 29.87 |
| Node 6   | 27.47         | 27.86 | 28.22 | 27.19 | 27.34 |
| Node 7   | 23.12         | 23.47 | 23.57 | 23.44 | 22.97 |
| Node 8   | 19.65         | 19.62 | 20.13 | 19.74 | 19.15 |
| Node 9   | 18.87         | 18.69 | 19.21 | 19.17 | 18.56 |
| Node 10  | 6.71          | 6.82  | 6.13  | 6.54  | 6.98  |
| Node 11  | 13.39         | 13.2  | 13.01 | 13.74 | 13.46 |
| Node 12  | 7.18          | 6.95  | 7.35  | 7.21  | 6.99  |
| Node 13  | 5.69          | 5.65  | 5.12  | 5.68  | 5.74  |
Put 60mg of dust in (0,5) in the xy coordinate system, and record the duty cycle of PWM output by the dust processing device. The results are shown in Table 2.

| Node | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 14  | 15  | 16  |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| PWM  | 100 | 98  | 92  | 90  | 84  | 92  | 90  | 88  | 74  | 60  | 54  | 48  | 42  | 40  | 40  | 40  |

6. Summary
The number of nodes is limited, but by superimposing and fitting the concentration distribution images obtained at each node in the space, the complete dust concentration distribution plan in the entire dust space can be predicted.

The system learns the distribution of dust concentration in the entire dust space through prediction, and then calculates and adjusts the output duty cycle of each node dust processor, so as to minimize the total power of the system and achieve the purpose of stepped dust removal.

From the perspective of market demand, with the continuous improvement of technological development, people's requirements are getting higher and higher, equipment will become more and more advanced, product structure will be continuously adjusted, functions will be more diversified, and market capacity will continue to expand. Dust treatment system is an important equipment in factories, and the market demand for dust removal systems in my country will continue to increase. With the continuous improvement of people's health awareness and the continuous improvement of factory requirements, my country's dust removal system industry will achieve faster development.

Acknowledgments
This work is supported by the National innovation and entrepreneurship training program for college students with Grant No. S202010497211.

References
[1] Li Weidong, Wang Lianfu, Liu Daowen, Sui Jinjun. Current status and development trend of dust concentration monitoring technology in my country's coal industry [J]. Mining Safety and Environmental Protection, 2005(S1): 66-67+125.
[2] Tang Juan. Current status and development trend of online dust concentration monitoring technology [J]. Mining Safety and Environmental Protection, 2009, 36(05): 69-71+74.
[3] Cheng Xuezhen, Liu Mei, Wang Yongbao, Sun Aiqin, Wang Jidai. Coal mine dust detection and control technology [J]. Mining Research and Development, 2007(06): 78-79+85.