Intelligent Identification and Emissions Estimation of Harmful Gas Based on Background Segregation Algorithm

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Abstract: Environmental protection has become an important issue in modern enterprises, usually involving harmful liquid and harmful gas to be detected. In order to address this issue, we propose a new intelligent algorithm to identify and estimate the emission based on the color and smoke. To be specific, the three-frame difference method is used to achieve the background segregation, and the area of the smoke is separated after the images are proceeded by a mask. The color dictionary is employed to determine what color it is. Then, the background separation algorithm and the physics knowledge are used to establish an estimation model. In the experiment, we use the proposed approach to estimate harmful gas emissions in the real-world production process of enterprises. Results validate the effectiveness and efficiency of the proposed algorithm, in terms of the prediction accuracy.

1 INTRODUCTION

Security is an important issue in the production process of modern enterprises. It is a basic way to alarm in time in a dangerous situation, because there are a large number of necessary chemical reactions, which will produce much smoke in the producing process. According to the color of smoke, it can be judged whether it is a toxic gas. According to the area and volume of the smoke, it can be estimated how much gas has been generated. Accordingly, we can activate an alarm by combining these two conditions. First, we can use background separation algorithm to separate the smoke into a set of pictures with different features, and calculate the area of smoke . Then, the color can be obtained by a mask. Finally, we use an estimation model to calculate the volume of gas. The video after the background separation can be used to display in a page, and then the user can see the shape and position of the smoke. The combination of these two methods can detect harmful gases to ensure a safety.

Therefore, this paper proposes an intelligent smoke detection algorithm and design a smoke detection system based on it. Especially, the proposed algorithm is able to detect the color and area of smoke, and judge whether it requires an alarm. In fact, we use the video as experimental data and extract a set of pictures from the video frame by frame. In order to obtain the background separation, we use the frame difference method, which has exhibited a powerful real-time performance. After background separation, the area algorithm is used based on the video data to find out the proportion of white, which is the percentage of smoke in the image. Based on the above, this paper combines the knowledge of both physics and mathematics to establish a set of mathematical models, which are to calculate the volume. In the process of production, the camera is fixed and the area being photographed is also fixed. As long as the total percentage of smoke is required, the area can be accurately calculated. When detecting the color, this system uses a color image separated by the background separation masked. Generally, the proposed algorithm judges the main color via a customized color dictionary, because different production processes produce different colors. Especially, the color dictionary can add various colors according to different production. Finally, this paper is implemented in Python, supported by OpenCV, and Python+OpenCV reduces code complexity.

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2 BACKGROUND SEPARATION BASED ON FRAME DIFFERENCE METHOD

Background separation is the key process to realize the system function, which it is used for the display in a page, thereby it is necessary and irreplaceable. There are two methods to obtain the background separation of video. The first one is based on the Mixture Gauss Principle. Especially, the background segmentation can be realized by using three background dividers including KNN, MOG2, GMG, which are provided by the Background Subtractor class in OpenCV. This method can obtain a high detection rate by using a concise process. However, it also has some shortcomings. For example, it would consume too much system resources due to its inherent principle of the implementation. When a static object moves suddenly, some redundant objects can be partitioned out. Therefore, this method makes the actual system perform poorly in some real-time application scenarios. The second one is based on the frame difference method. In this approach, the frame difference method can effectively solve the problem of low real-time performance. However, due to the fact that the boundary of smoke surface is usually not clear, the separated image may encounter the dilemma of burning into ghosting. In order to address the above problem, we use three frame difference method for background segmentation in this paper.

Assume that the current frame is S(t), the previous frame is S (t-1), and the next frame is S(t+1) Then, the image I_1 is obtained by S(t) and S(t-1) after using this algorithm, and the image I_2 is obtained by S(t+1) and S(t). We can obtain that $I = I_1 \quad I_2$ is the final image. After that, the picture is processed by the morphology, which can eliminate ghosting. In order to reduce the image noise and to highlight the edge features, we refer to the idea of multi-objective optimization and global optimization. The purpose of these methods is to find an appropriate way to obtain a satisfactory detection accuracy.

3 CALCULATION OF SMOKE AREA BASED ON BINARIZATION METHOD

The existing methods usually use the image contour to calculate the area of smoke, which needs morphological processing. These methods detect the image contour by using the edge detection function, and calculate the area of each contour by using self-defined area function, and then accumulate it. Because the camera captures only one angle of smoke, the smoke area refers to the cross-sectional area seen from the camera angle. The camera is installed above the position of smoke. In this paper, the area is calculated by a binarization method, and the final image is obtained by morphological processing. The morphological processing is orient to a binary image and it uses median filter to clear the noises. Then, the picture is traversed and the number of white pixels is recorded. Note that, the length h and width w of the picture are calculated by the called shape method. The total number of white pixels is recorded as $whitenum$. The proportion of white pixels in whole image can also be called the proportion of smoke, represented as Eq.(1). Because the camera is fixed, the area of smoke can regard as $whitenum$, multiplying area photographed.

$$area = whitenum/(h * w) \qquad (1)$$

Compared with other algorithms, this method has less codes and a more simple logic. This means the code complexity is simplified by this method in background separation.

4 SMOKE VOLUME ESTIMATION MODEL

The smoke is discharged from a small outlet and it gradually spreads outward and upward. In order to estimate the volume of smoke, the shape of smoke can be roughly regarded as a cylinder. The camera is installed on the top position of the smoke, so the bottom area height varies with time. When installing monocular camera condition, the height of smoke can't be measured by image recognition, which requires a mathematical model to estimate the relationship between smoke emission and bottom area.

The height of smoke increases gradually at the beginning of process, then stabilizes, and finally gradually decreases. The changing process is shown in Figure 1. Because of the Fourier's Law, the gas emission can be estimated through the rule of the concentration change. The concentration $C x y z t(, , ,)$ can be expressed as Eq.(2). The trend of gas emission with time is shown in Eq.(3) . Among them, Q is the gas emission, which is a larger number, can equal 10^3 and k is a proportional coefficient.

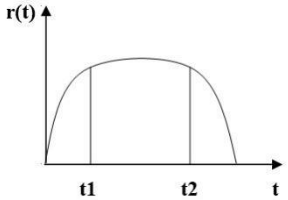

Figure 1: Emissions change with time.

$$C(x,y,z,t)=\frac{Q}{(4\pi kt)^{\frac{2}{3}}}e^{-\frac{x^2+y^2+z^2}{4kt}} \tag{2}$$

$$r=\sqrt{4kt\ln\frac{\alpha Q}{\pi kt}} \tag{3}$$

Therefore, the relationship between smoke area and time can be expressed as (4).

$$area=4kt\pi\ln\frac{\alpha Q}{\pi kt} \tag{4}$$

The function of gas emission and smoke area can be expressed as (5).

$$Q=\frac{\pi kt}{\alpha}e^{\frac{area}{4\pi kt}} \tag{5}$$

In conclusion, the smoke volume can be estimated according to the smoke area.

5 EXPERIMENT ON COMPILING COLOR DICTIONARY

In the experiment, we usually use the masking to cut the area of interest in a given image. Masking in the image processing looks like the process of PCB plate making, which uses a specific picture to shade the image. The used mask is a two-dimensional matrix array. We can get final image by using various operations. The masking process is as follows.

$$\begin{bmatrix}0 & 10 & 0\\ 20 & 30 & 40\\ 55 & 0 & 50\end{bmatrix} \;\&\; \begin{bmatrix}0 & 0 & 0\\ 1 & 1 & 1\\ 0 & 0 & 0\end{bmatrix} \longrightarrow \begin{bmatrix}0 & 0 & 0\\ 20 & 30 & 40\\ 0 & 0 & 0\end{bmatrix}$$

Figure 2: Mask operation process.

"&" is a common and simple operation, which can use masks and original images to get the target area. When judging the color of smoke, it is not necessary to cut the smoke completely, only the part which contains a large amount of smoke. The position of smoke discharged from the production workshop is fixed. Through the experiment, we selected the region of 100 pixels around area where the smoke is discharged, and use it as the mask, we set mask to 1, the rest of the position is 0.

Some color detection methods by extract smoke area, and normalize it to RGB space. Then, analyzing the data of each color component. The way in this paper of judge color through a customized color dictionary. First, we define the upper bound and lower bound of the color. The color dictionary is constructed in RGB mode. The RGB value of the upper bound and lower bound of color can be found in the drawing software. Then, add the upper bound and lower bound of a color to a list. Finally, take black as an example, the following code defines a color.

```
lower_black  =  np.array([0,  0,  0])
upper_black = np.array([180, 255, 46])
color_list           =           []
color_list.append(lower_black)
color_list.append(upper_black)
dict['black'] = color_list
```

Traverse one picture, record the value of each color pixel in the color dictionary, and compare the number of each color pixel. The color of largest value is the color of this picture.

6 EXPERIMENT RESULTS

In chapter two, we analysis some advantages in our algorithm that others do not have. We found a video on the Internet, and the comparison of experimental results is as follows.

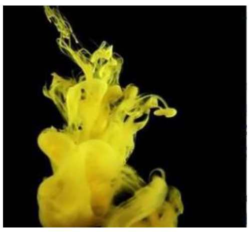

Figure 3: Original image.

Figure 4: MOG2

Figure 5: GMG.

Figure 6: Frame difference method.

It can be found that MOG2 method has a very poor effect and can hardly separate the smoke. GMG method can separate smoke contour roughly, but still can't separate all the smoke. In contrast, using three frame difference method to extract the foreground can separate all the smoke, even slight smoke can be extracted, which ensures accuracy for later calculation of smoke area.

According to the experimental results in in terms of the separated pictures and the resultant data, the accuracy of color recognition can reach more than 99%. The deviation between gas emission and actual gas is shown in the following figure. It can be seen that most of the estimated values are bigger than the actual values, because the prediction model is calculated with the maximum bottom area, so the value is bigger than actual data, but such errors do not affect the volume estimation.

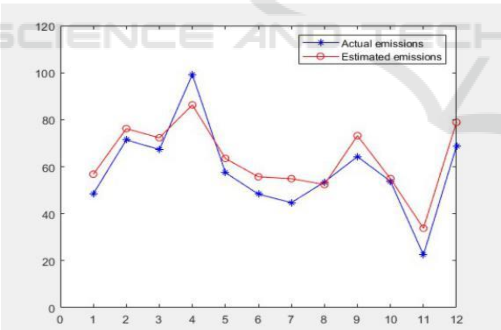

Figure 7: Comparison between gas emission estimation and actual gas production.

From the above, we can get the following observations:

(1) The frame difference method can generate a better effect on these image set.

(2) The proposed mathematical model can realize the estimation of smoke emission under the condition of monocular camera, and it has a merit of saving the cost.

7 CONCLUSIONS

In the processing of production, the traditional smoke alarm system only detects whether there is smoke, but can't judge the toxicity and emissions of smoke, which is ineffective to improve the accuracy of alarm. In this paper, we propose an intelligent algorithm to identify and estimate the emission based on the color and smoke. In the experiment, the proposed algorithm is used to estimate harmful gas emissions in the real-world production process of enterprises. The experimental results show that our algorithm can identify the smoke more accurately, and judge the color and emission more effectively This means our algorithm obtain a desired performance, and it also provides a new idea to identify the same type of defects.

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