Time Variation of Smoke Behavior and Image File Size

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1 Introduction

Research targeting smoke involves visualizing its shape to understand the characteristics of a fire. The images obtained through visualization are two-dimensional data. When two-dimensional data are analyzed, the positional information is in the *x*- and *y*-directions, and the pixel information, in the case of color, is a three-dimensional vector of red, green, and blue. Based on this information, feature extraction and analysis are performed using a series of five-dimensional vector data. Furthermore, by determining the sum of the smoke densities, a scalar value can be obtained as an indicator on the screen. However, this operation is labor intensive.

When an image is recorded, the file size of each image represents the amount of information that it contains, assuming that the device records the minimum amount of necessary information. This information is expected to remain constant if the image remains unchanged. When images are analyzed, it is necessary to process a large amount of information to track the temporal changes in vectors and scalars, whereas the temporal changes in phenomena can be examined using file size as an indicator.

Terada conducted experiments [1] in which two sheets of gauze were stacked on top of each other to form the combustion surface, and a gap of a few millimeters was placed at the bottom of the combustion surface. When the combustion surface was at a slope of approximately 10°, the flame spread faster downward. On a 35° slope, the flame mainly spread downward.

In a study by Daitoku et al. [2], the flame spread was examined using the slope angle of the filter paper relative to the horizontal plane.

The purpose of this study was to confirm whether there is a correlation between changes in a phenomenon and changes in the file size of an image. The flame spreading along the thin combustion material was observed from the side.

2 Experimental equipment

An outline of the experimental apparatus is shown in Figure 1. It consisted of a light-emitting diode ring light, a close-up lens, an experimental stage gypsum board, and a camera. Dark-field photography was used to visualize the smoke generated by combustion. The experimental setup is shown in Figure 2. Spacers were placed on a sloped gypsum board, and combustible material was attached to the spacers. The gypsum board was 5 mm thick and 160 mm square on each side. For the combustible material, a

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100 × 100 mm square of 0.25-mm-thick filter paper was used. The spacer was made of aluminum (30 × 30 mm and 3 mm thick). The spacers were placed at the four corners of the filter paper. The experimental conditions were a gap height of 3 mm and a slope angle of 35°. Ignition was performed near the center of the filter paper. The spread of the flame was photographed from the side of the experimental apparatus.

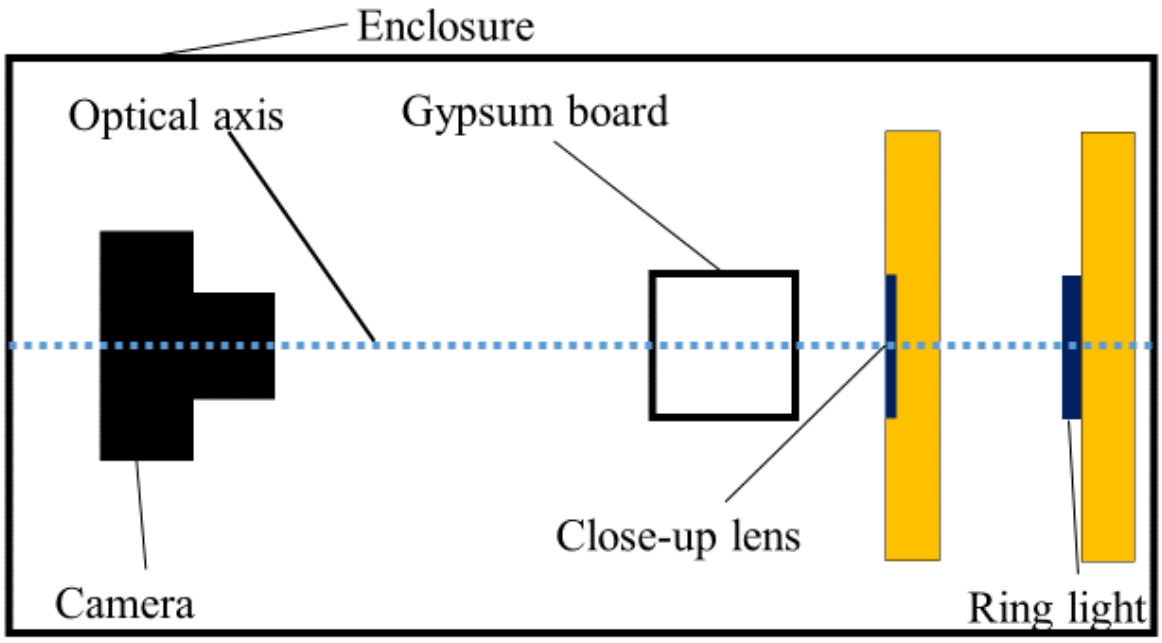

Figure 1: Outline of experimental apparatus

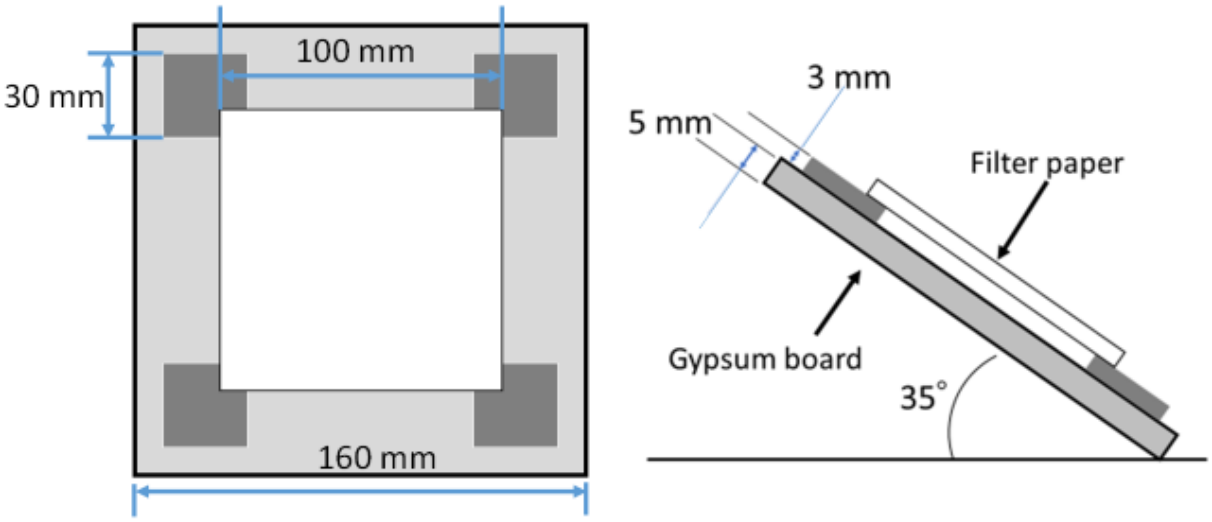

Figure 2: Outline of experimental setup

3 Experimental results and discussion

The videos recorded were divided into still images. The relationship between the file size and the sum of the luminance values of the image was examined. Figure 3 shows the variation in file size and the sum of the luminance values of the image. In this figure, ignition, flame spread, and extinction are shown. The ignition period ranged from 0 to 9 s. The flame spread period ranged from 9 to 51 s. Extinction occurred from 51 to 74 s. There were three main periods. Period A was defined as 0–9 s, Period B as 9–51 s, and Period C as 51–74 s. Images for each period are shown in Figure 4. The images were rotated to make the slope horizontal for comparison.

Period A shows smoke appearing in the gap between the filter paper and the gypsum board immediately after the start of the experiment. Then, the smoke flowed downward through the gap, becoming denser. When a hole formed in the filter paper, the behavior changed, and it began to vibrate. The changes in file size and the sum of the luminance values of the image showed peaks in the rate of increase at 1 s and a peak in the rate of decrease at 5 s.

In Period B, the spread of the burning filter paper and the vibration of smoke in the gap were observed. Compared with Periods A and C, Period B showed a gradual change in brightness. The vibration of the smoke and curling of the filter paper were observed. At this time, there were variations in the bright area caused by the spreading of smoke and the dark area caused by the peeling of the filter paper, but there were no significant changes.

During Period C, it was confirmed that the smoke continuously changed from approximately 51 s. At 54 s, the smoke was increasing. At 58 s, the appearance of the smoke changed compared with its appearance at 54 and 56 s.

The sum of the luminance values fluctuates with time, and the file size fluctuates with time simultaneously. Figure 4 shows a scatter plot of the file size and the sum of the luminance values for the three periods. The correlation coefficients are listed in Table 1.

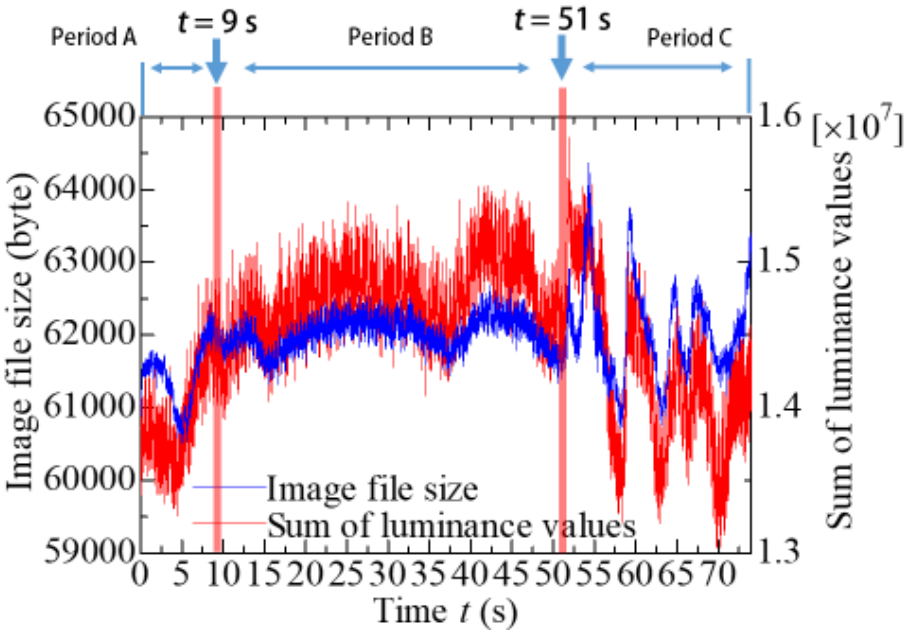

Figure 3: Time variation of file size and sum of luminance values

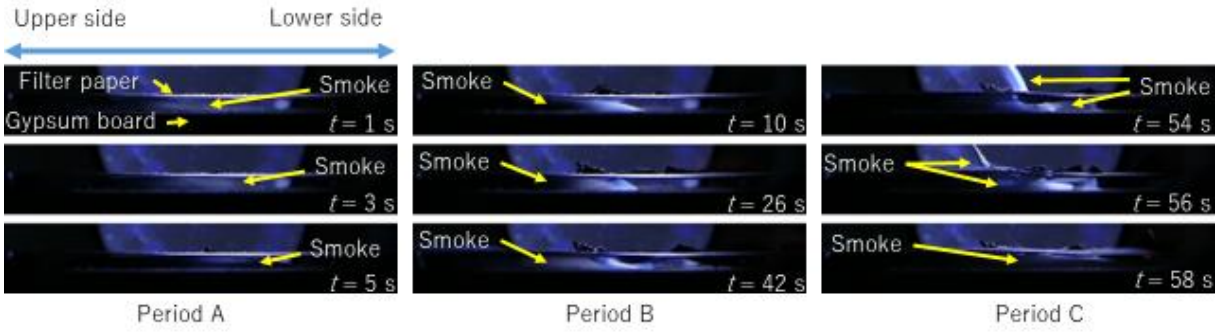

Figure 4: Phenomena in each period

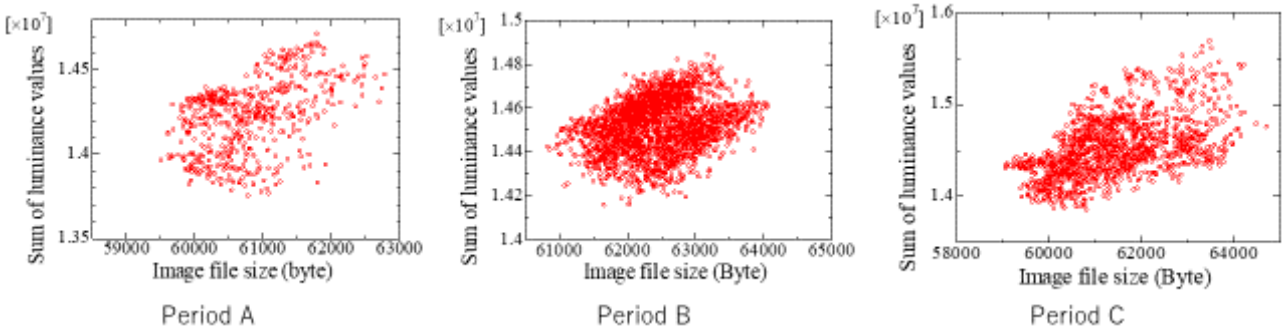

Figure 5: Plots of file size and sum of luminance values

Table 1: Correlation coefficients

	Period A	Period B	Period C
Correlation coefficients	0.456	0.267	0.523

4 Conclusion

The flame spread on the slope was photographed from the side. By taking the file size and the sum of the luminance values and comparing the phenomena, a correspondence was found. The variation in the phenomenon is seen as a change in the sum of the luminance values and file size. When the contrast within an image is high, there may be changes in the file size and the sum of the luminance values in the image, resulting in a higher correlation coefficient.

References

[1] Torahiko Terada (1930). Preliminary Study on Flame Spread along combustible surface, Research Report of Riken 9-7:551–560.

[2] Tadafumi Daitoku, Keiichiro Hiyama, Takashi Tsuruda (2019). Heat and mass transfer of flame spread along a combustible slope. Proceedings of the 27th International Colloquium on the Dynamics of Explosions and Reactive Systems, Paper 200, 2019.