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STUDY ON THE VIDEO SMOKE DETECTION SYSTEM

Lawrence S.M. Chiu
Department of Building Services Engineering, The Hong Kong Polytechnic University, Hong Kong, China

ABSTRACT

Digitalized system has become more and more popular in the building services field and the scale of Video Smoke Detection (VSD) system is continuously enlarging in the area of fire detection. Different fire specialists are developing VSD system with the fastest response time and earliest alarm detection. In this paper, the basic detection method has been constructed with the guidance of gray level histogram theory. In other words, the image captured by the system can be read as different gray level binary numbers. Those numbers can then be thresholded and the data obtained can be treated as a database of the detection system for further development of a faster and more accurate VSD system.

1. INTRODUCTION

In fire detection, the main topic of concern will be the early response and the early alarm of the detectors. However, the traditional smoke detection system has some disadvantages such as the slow response rate of heat detectors and false alarms due to over-sensitive smoke detectors. Point type detectors measure the amount of smoke that reaches them, while smoke detectors are effectively functional in only small closed spaces. In larger or open areas, the air flow may be strong enough to dilute the concentration of the smoke [1]. This resulted in a fast-growth of smoke detection based on the image processing method. In this system, Closed Circuit Television (CCTV) cameras or other good quality web-cams monitor the specific area; the signals from each camera are analysed electronically to detect the presence of smoke by the obscuration of part of the camera's field of view that it creates. Detection therefore relies on the illumination of the field of view by normal lighting or specially installed infra-red light sources [2]. Referring to Table 1, the video smoke system (the last column) can perform in a very fast response rate, with a lowest level of false alarm rate and in a more reliable way [3] when comparing to the traditional detection system.

People started studying the VSD system since the mid-1990's. Most of them would use the existing CCTV system with charged-couple device (CCD) camera to connect with their detection software, as this would reduce the cost of the system and they would base on the method similar to the Video Motion Detection to detect smoke. It was apparent that video motion techniques used in the security environment would not adequately meet the requirements for a reliable smoke detection system. So the manufacturers developed new software that was tested and produced by millions of experimental trials. Data gathered from the trials emphasised the particular characteristics of smoke in relation to time, volume, colour and dispersal [4].

A survey of the existing VSD systems was done that suppliers such as ASCOM, VINDICATOR, FASTCOM and ISL could provide a detection system of 8 cameras input and 16 signals output. Unfortunately, the price of the system software is at least around HK$200,000; obviously, this is quite difficult to make this system a very popular one. According to BS 5839-1: 2002, the Code of practice of fire detection and fire alarm systems for buildings, VSD systems should be capable of detecting smoke reliably wherever there is no normal lighting in the building and lighting provided specifically to aid the detection of smoke should not depend on or connect to the main power supply because some of the case is cutting the main power after a fire occurred. Only a very small proportion of paragraphs mentioned about the VSD system. This gives very much room for developing your own smoke detection method.

2. METHODOLOGY

Commonly used techniques like Histogram comparison, Temporal based method, and Rule based method to detect smoke are quite reliable [5]. Histogram method could show several parameters such as luminance level, gray level and RGB ratio. For example, image was grabbed every second, and then by comparing the first and second image; the difference number of pixels could be counted, and this data is one block in the Histogram. After several iterative comparisons, a tendency curve could be tracked. If smoke is produced, there would be a great difference in the number of pixels, and the data bar would be higher than the normal one. That means the new data would be out of the tendency curve boundary, and this could be an alarm.

Table 1: Comparison of traditional smoke detection system and VSD system

Detection	Heat	Smoke	Flame	Particle	Gas	Video smoke
Response speed	Slow	Fast	Very fast	Fast	Medium	Very fast
False alarm rate	Low	Medium	High	Medium	Medium	Low
Cost	Low	Medium	High	High	High	Variable
Application	Confined spaces	Open or confined spaces	Highly flammable material storage	Open spaces-high value	Controlled spaces high value	Large and open spaces

Another parameter is plotting a characteristic curve of Pixel counts verses the Gray level. In the case of 8-bit gray-scale images, there are 256 gray-scale levels, Black colour pixel has a gray-scale of 0 and White colour pixel has a gray-scale of 255. If there is an obscuration or smoke showing in the screen, the gray level would be changed and there would be a great number of pixels counted in the low luminance portion (between 20 to 75) of the histogram. If there is a fire occurred, there would be a high luminance portion (between 200 to 250) in the histogram [6]. But for a 24-bit RGB image as shown in Fig. 1, the pixel of the image could be described: Red (255, 0, 0) or Yellow (255, 255, 0), a different form of histogram could be shown; the data may be based on the occurrence of Red, Green and Blue or R/G ratio [7].

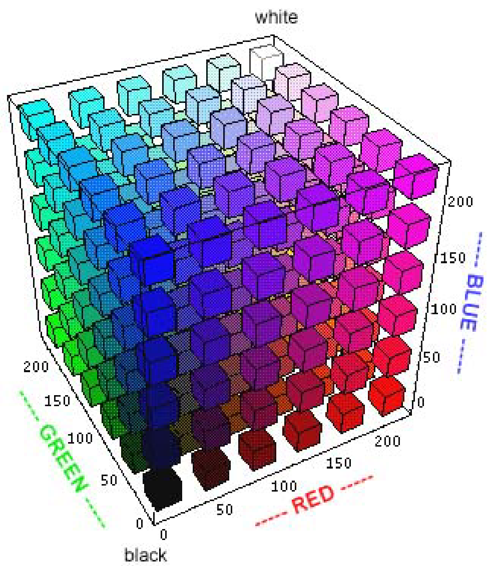

Fig. 1: Colour component of a graphic pixel [7]

Pattern recognition would be a very useful method to prevent false detection of strong light produced by a torch, a car lamp or an electrical appliance, as this method could trace the edge image of the smoke or the fire, and a characteristic curve could be plotted. Real fire would change its shape rapidly in a very short time, so by comparing the curves obtained in the pattern recognition, the curve with respect to time would increase tremendously, and something like the curve is shifting upward. The pattern recognition observed data from time to time is a kind of temporal based method, in other words, it is observing the pattern changes within a certain time form. Rule based method is actually a combination of the methods mentioned above, as this method relies on different parameters and the data input to the system beforehand.

Before using these methods, a computer simulation and a fire test have been taken. Based on the experimental result, an appropriate VSD system can be developed. The computer simulation test is undertaken by running a programme included in "Fire-i" controller software, which could do the frame capture continuously at a certain minute or even every second. A notebook computer is connected with an IEEE 1394 based FIREWIRE digital web-cam to generate the video frame capture function. The captured picture is in Black and White of size 640 × 480, and is stored as a BMP file. The picture size can be described in this way:

Size of file in bits = Height × Width × Resolution^2 × Bit depth

If the BMP picture has a resolution of 640 × 480, the file size is approximately 300 Kbytes. On the other hand, the higher the resolution, the bigger the file size. So the size and speed of the hard disk of the processing computer would be critical in running and loading the images smoothly.

The fire smoke test consists of three parts: (1) burning 30 ml propane, (2) burning a 2 × 3 × 1.5 cm wood crib, (3) burning a smoke pellet. The setting of the equipment is shown in Fig. 2. The whole process from ignition to put out is recorded every second in the computer. The pictures captured would be analyzed by HISTOGRAM.exe [8], and output as a characteristic curve.

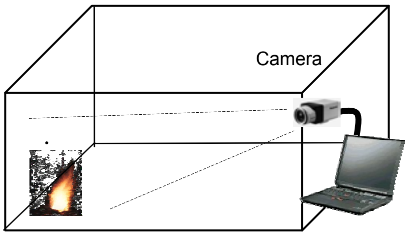

Fig. 2: Video capturing experiment in a fire chamber

The peak values in the output histogram could be set as a threshold, for example, the gray level 57 has occurred 400 times, and gray level 205 has occurred 2000 times. With those values, a database could be set up. So, whenever a similar picture with similar value appeared and match with the database value, a fire can be confirmed. The architecture of the research experiment is shown in Fig. 3.

3. RESULT

The most successful part of this first stage of research is the compilation of the source code of Histogram counting and pixel colour describing. The bunch of source data was compiled by the software Turbo C compiler, and finally generated as an execution programme. The data are shown in a .txt file as shown in Figs. 4 and 5.

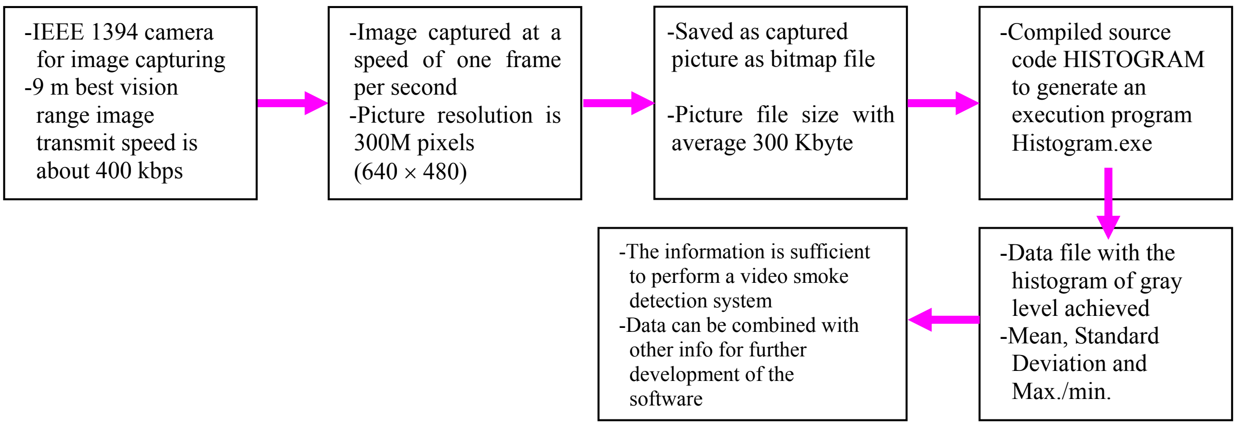

Fig. 3: Flow chart of the VSD system

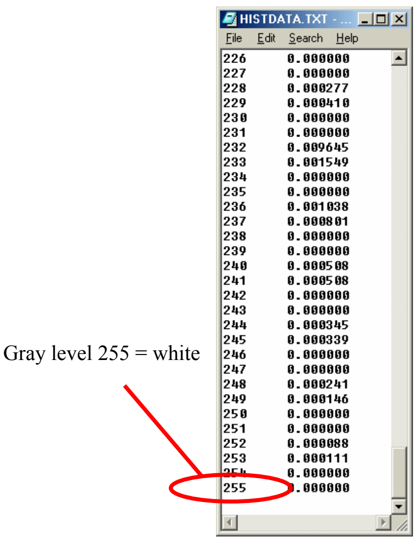

Fig. 4: Histogram of total gray level

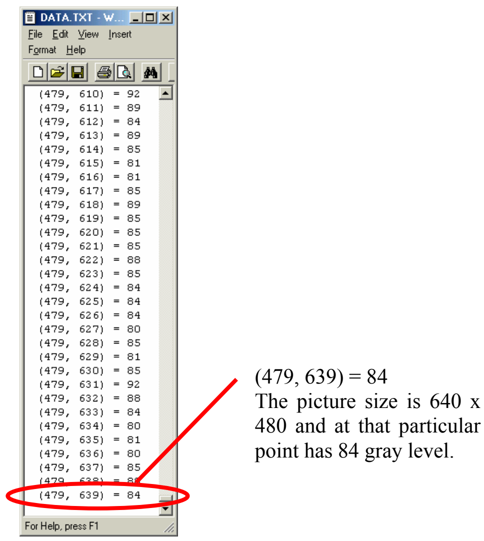

Fig. 5: Colour level of each pixel

Those obtained data are useful for plotting characteristic curves. Pictures are taken in a fire test in a well-equipped fire chamber in the Department of Building Services Engineering, The Hong Kong Polytechnic University, and the respective histograms are shown in Figs. 6 to 8.

It can be seen in Fig. 6 that, at the very beginning of the experiment, the environment is clean, and the corresponding histogram shows that most the values appeared in the range of gray level 50-98. In the chamber, white colour pipe duct is put deliberately, making a colour difference with the background, therefore, in the range of 240-250, the brighter gray level is observed in the histogram. When a fire is ignited, as shown in Fig. 7, the values in the range 100-150 obviously increased, because of the bright luminance of the fire source. The three consecutive pictures shown in Fig. 8 on burning the smoke pellet are a very good demonstration. The whole pattern of the graph is shifting to the right side of the histogram, and the last picture could show the high occurrence in the gray level of 140-160, because high proportion of white smoke is produced at that stage. This proves that in a very short time the system reacts well and outputs relevant data.

4. CONCLUSION

In this first stage of development of VSD system, the system has been tested with histogram method and gray level method, which are very preliminary methods. More trials have to be taken in the next stage, for example, burning more types of fire source to generate different colour and concentration of smoke. Different detection methods are needed to perform, such as edge detection and shape pattern recognition. It could also be input with plume equation, making it a double checking data, ensuring the detected alarm is a real fire and not a false alarm.

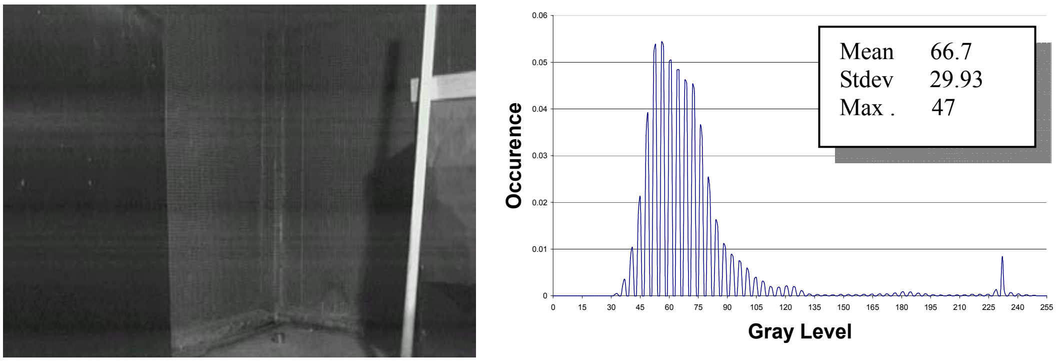

Fig. 6: Original scenario of the testing fire chamber

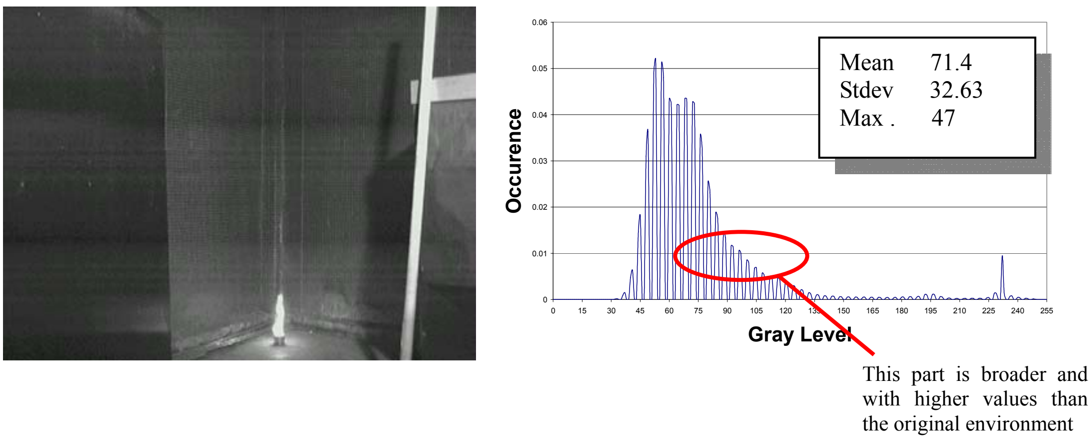

Fig. 7: 30 ml propane ignited for 2 minutes

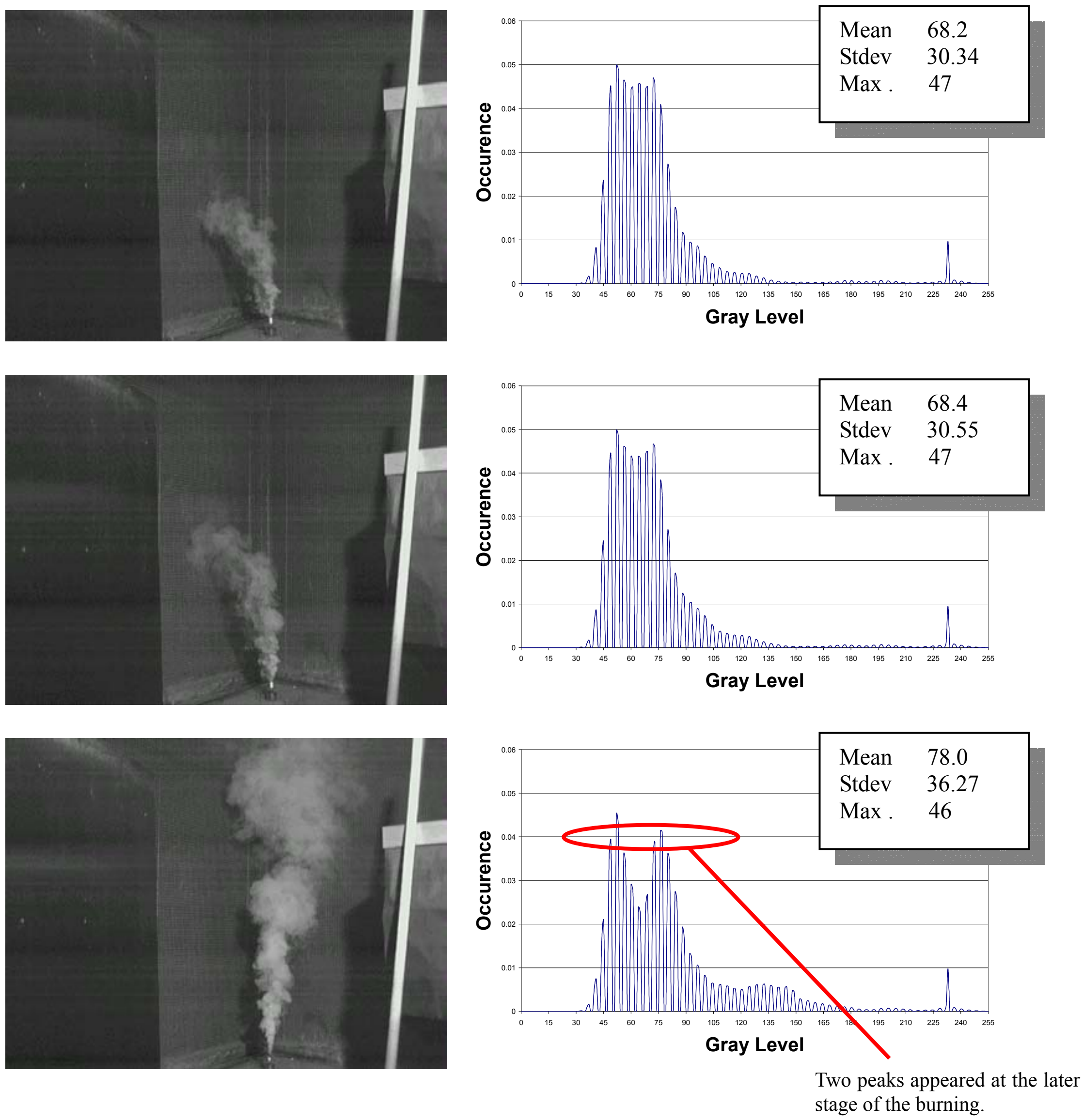

Fig. 8: Three pictures taken at 2 s, 3 s, 34 s after burning a smoke pellet

In order to test the response time of the VSD system, another fire test with different traditional detectors, such as point-type detector, has to be performed. Different lighting level of the experiment has not been done in this stage, as the VSD system would depend largely on the light level of the detected environment, may be this system could only be an auxiliary detection device of Point-type smoke detector. But after this research, it is expected that an independent role of the VSD system could be confirmed.

ACKNOWLEDGEMENTS

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Q & A

Q1: If there are some phenomena which are quite similar to the smoke (maybe some particles with the wind), how could the VDS deal with this situation?

Chiu: The VDS would distinguish the different particle sizes in the air like combustible particles, soot and air entrained. The combustible particles like CO, NO etc. are too small and they cannot be distinguished by the VDS. But the soot or smoke can be distinguished by the VDS clearly by measuring their particle size. Therefore, with a good quality VDS, false detection can be reduced to a minimum.

Q2: When the place which has installed VDS is very dark that normal camera cannot work, can we use the VDS?

Chiu: When using the VDS system, we should integrate it with other fire safety systems like emergency lighting, back-up generator and so on. And due to the main function of the VDS is to detect the fire through the smoke before the fire grows, the lighting level around should be high enough for the normal camera. Whether we need a very expensive camera, like infra-red camera, it depends on the requirement or need dramatically.