A Means of Obtaining Criteria for the Activation of Video Based Smoke Detection


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Abstract-- The ability to detect smoke and fire in an early stage plays important roles for securing life safety of building occupants. Smoke and fire detectors installed in today's building are considered as point detectors. In case of fire, dependend upon the location of the fire origin, it may take sometimes for the room temperature to rise to the detector setting point or for the smoke to reach the detector. In recent years, the application of image processing algorithms for automatic video smoke detection continued to gain a momentum due to its capability to overcome the major drawbacks of the traditional smoke and fire detection methods. This paper explains the laboratory experimental works on smoke optical density measurement and video image processing of early smoke plume release. Using an NYA 1.5 mm² PVC coated - cable fire experiment, a comparison of the usefulness of convensional smoke detector and video based smoke detection using CCD camera were also discussed. Both approaches provide a means of obtaining criteria for the activation of video based smoke detection which may apply both smoke area, volume and smoke density. The cable fire experiment is a promising method for comparing the video based system with conventional video detector.

Index Term-- Detection, smoke, video based smoke detector, cable fires.

I. INTRODUCTION

The ability to detect smoke and fire in an early development stage plays important roles for fire safety of building occupants [1,2]. In an emergency condition, an earlier detection means more time for the tenant to leave the premises safely. As most of the household objects will generate smoke before they catch fire, thus it is still reasonable to employ smoke detection as early alarm of fire accident. Besides the continuous improvements on the performance and the reliability of the conventional point detectors, the application of video smoke image processing algorithms continued to gain a momentum. Video based smoke detection may provide solutions to overcome the major drawbacks of the traditional smoke and fire detection methods. The new method provides more information about fire, such as location, size, growth rate, and the ability to be applied in large room with complex geometry [1-6].

Nevertheless, it is still not very clear on what basis the threshold value of detection system for image processing should be set to meet the safety requirement.

In order to provide more meanings on its correlation with fire engineering, the development of research in the field of video smoke detection must be coupled with research on measuring the dynamics of smoke, both in terms of smoke movements, as well as from the physical properties of the smoke itself. These are important issues in developing the threshold values to avoid false warnings, or even smoke was not detected. Therefore conducting in situ measurement of early smoke plume density and direct comparison with the conventional one are critical for obtaining criteria for the activation of video based smoke detection. The threshold values should be set in conjunction with smoke density and its dynamics behavior.

The dynamic of smoke plume released from the fire origin is affected by the initial momentum of the plume. As pyrolysis and combustion products the initial smoke temperature are higher than the ambient air temperature. Positive buoyant force propels smoke to rise. During the rising process, due to the entrainment of surrounding air with lower temperature, the smoke temperature decreases while the ambient air temperature increases leading to the reduction of the plume buoyancy. And at a certain height, the plume buoyancy equals zero called as neutral buoyancy point. But due to the inertia effect, the smoke plume continues to rise until the buoyant force becomes negative and the plume stops at a maximum height to form a mushroom shape [7].

The majority of the detection algorithms for flames or smoke detections are by analyzing vision related features such as area, color, motion, and spatial and temporal fire disorder, etc. These features are affected by the thermal properties of materials, including their initial smoke region development. Recently, the authors and co-workers [8] suggested that thermal properties of the materials, i.e. thermal diffusivity greatly affected the time of smoke appearance as well as the maximum density of smoke.
Despite the excellent progress in methods and techniques for video smoke detection, as pointed by Verstockt, S., et al. [2], the absence of ground truth data, the (sometimes) extensive use of heuristic thresholds, and the lack in standardized evaluation criteria, make experimental verification, and in particular the comparison of algorithms, an error-prone and time-consuming task.

This paper provides a means of obtaining criteria for the activation of video-based smoke detection. As the scope of this paper, both smoke area and smoke optical density values are becoming the candidates for the basis of setting the thresholds for the activation of smoke detector. The cable fire experiment was employed as a simple method for comparing the performance of video-based system with conventional video detector. These works are also intended to explore how detection system from image processing could be verified with a system that already reliable and widely used such as conventional smoke detector. Smoke detector was tested together with the video-based smoke detection system in order to identify the safety limits in terms of smoke area and opacity.

II. VIDEO BASED SMOKE DETECTOR

The users worldwide knows smoke detectors for its sensitivity and trustable. The number of sensitivity of smoke detector is known as obscuration level. Obscuration is the effect that smoke has on reducing visibility. Higher concentrations of smoke result in higher obscuration levels, lowering visibility [9]. Since the smoke is a contaminated hot fluid, smoke movement is acting under fluid mechanics law [9]. Basically, if we can understand the movement of smoke and its characteristic, we can detect the smokes that appear in a compartment or outdoor. Many researcher have been dealing with the new detection ways of fire in a variety point of view, such as from it’s grow rates, sizes, places and indications[3,5,10,11]. One of the algorithm that could be applied to detect the movement of an object was Adaptive Gaussian Mixture Model, brought up by Stauffer C. [12]. This model uses background subtraction to separate the moving object from its background. This algorithm allows the detection system adapted with different intensity of light and colors.

The video-based smoke detector algorithm used in this paper is provided in an earlier paper [13]. This algorithm uses Adaptive Gaussian Mixture Model (GMM) to subtract the moving object as foreground from the background. In addition, this algorithm includes fuzzy inference to classify the moving object as a smoke or rather not. The correlation of smoke area and temperature of the cable jointing was presented in an earlier paper [1].

III. EXPERIMENTAL

This work comprises of (i) optical density measurement and (ii) comparison of conventional and video smoke detection performance. The experimental set-up for optical density measurement comprises of a current regulator apparatus, a DIN 50055 Smoke Density Photometric System [14], a FLUKE® 568 Infrared Thermometer [15], a CCD TV system and an electric current measurement apparatus. The FTT ‘Smoke Density Photometric System’ consists of: light source, light measuring system, and control unit. The light source is a gas filled tungsten filament lamp. Power for the lamp is provided by a regulated power supply housed in the control unit. The light-measuring device consists of: achromatic system of lenses, silicon photo-electric cell, and high gain low noise amplifier. These components are housed in an assembly with a collimating lens. The signal from the Light-Measuring Device is taken to the Control Unit, which is capable of continuously measuring relative light intensity against time as percentage transmission over the ranges to be studied. The system has a linear response with respect to transmittance and an accuracy of better than ±1.5% of the maximum reading. The Control Unit also regulates the damping of the amplifier so that the response times required to achieve 95% accuracy (T95) correspond to the specifications given in the standard. The NYA type cable with an area of 2.5 mm² was used as a heating source. The material tested was PVC material. The optical density measurement was carried out at three levels, i.e. 3 cm, 15 cm and 30 cm above the experimental point.

The second experimental focused on the comparing the response of video smoke detection and conventional smoke detector (Fig. 1). In this experiment, NYA types of cable with a single copper conductor were heated electrically using an overload current. This experiment equipped with a step down transformer of 220V to 10V with adjustable current up to 400A. The current that run through the cable is 24A until the temperature rise occurs and pyrolysis start to destroy the PVC insulation. There are Fluke 568 Series IR thermometer that measures the surface temperature histories at the cable jointing in range 27°C to 240°C. The smoke development was recorded using 3 CCTV camera that record at the same time with distance difference to others. The distance of cable sample to the camera is 80cm, 100cm, and 120cm, with a stable that incline in 30° to the cable sample. The motion segmentation using Adaptive GMM was applied for each video recorded. Two stand-alone photoelectric smoke detectors were place 80cm above the cable sample to verify the dangerous level of the smoke produced. Meanwhile, the smoke area detected was processed further by using an open source image processing software of ImageJ [16].
Fig. 1. Experimental set-up

IV. RESULT AND DISCUSSION

Fig. 2 shows the typical result of the early smoke plume released from the heated material. The smoke optical density was measured at three locations above the source as indicated in Fig. 2. One should realise that the measurement was carried out separately, as at the moment there is only one set of optical density measurement apparatus available. In other word, the measurement was carried out three times using an identical sample. The smoke flow characteristics of the plume varies according to the distance from the source. Initially the flow was in laminar region, and it becomes more turbulent higher regions.

Smoke plume, which is moving upward from the heat source, is affected by the phenomenon of free convection with the term as a buoyant plume. The shape of the buoyant plume is determined by its interaction with the fluid environment. Buoyant force per unit volume was detainted by the drag force, especially viscosity, between the smoke with ambient air. Because of the upward flow, the buoyant force grew smaller and less viscous drag than the environment. The effect of turbulence to smoke flow is shown in Fig. 2. This phenomenon greatly affects the density of the smoke itself. From the measurement of smoke density for material, it can be seen that the higher the smoke movement, which means that the flow has changed from laminar to turbulent, smoke density has declined, both on its maximum value and its development trend. This applies to all movement of smoke without any external interference, or the movement of smoke within a building. In general a near-Gaussian shape of the smoke plume density was observed. This is in good agreement with the Gaussian profiles of mean velocity and smoke density reported in the literatures [7, 17].
The smoke profiles at different heights were influenced by the early momentum of smoke. At the time of initial appearance, the smoke still has a large initial momentum, but in line with increasing altitude, the momentum was reduced and eventually disappeared. The smoke temperature decreases while the ambient temperature increases leading to the reduction of the plume buoyancy [7, 18]. The smoke shape becomes a mushroom-shaped, because at a certain height the smoke will not be able to maintain its shape. Fig. 3 shows that at the higher (maximum) region, the smoke obscuration will have a lower value than the bottom section. This phenomenon occurs in many fire incidents in which the conventional smoke detectors are capable of detecting the presence smoke when the ceiling are filled with high concentration of smoke. The higher concentration of smoke in the ceiling means that smoke concentration near the floor area was thinner. The drawback of the conventional detector can be solved by using video smoke detection. It is expected that vision based detection system will be able to detect the presence of smoke faster than conventional one.

Fig. 4 show typical results of the second experimental set-up. The typical image processing on video was recorded at 1:04 minutes, measured at 80cm, 100cm, and 120cm surrounding the smoke origin. It is clear that smoke is a three dimensional (3D) phenomena. The angle in which the video sequence was recorded will affect not only the smoke area but also its density. Effect of distance between individual cameras with the smoke origin on the area and the intensity of smoke detected were shown in Figs. 5 and 6. If the camera was put nearer to the smoke source, the larger area of smoke covered was expected. Larger area detected is defined as more dangerous, and so is the opposite. Figs. 5 and 6 also showed that whether the cameras were put on a different distance, the timing of the first detection of these three cameras were the same. In addition, the timing that the camera can detect the largest area of smoke is same as the other camera, regardless the numbers of area remain differ.
Fig. 4. Results of typical image processing on video recorded at 1:04 minutes, measured at 80cm, 100cm, and 120cm.

Fig. 5. Correlation between distances of smoke to the camera with area of smoke covered.

Figs. 5 and 6 might indicate that although the distance is different from one camera to the other, the system can maintain to detect at the right time and consistent. Less area will be covered by the most distance camera but the detection time is just as same as the closest camera.

Fig. 6. Colour intensity affected by smoke at different distance of the cameras.
The second experimental focused on the comparing the response of video smoke detection and conventional smoke detector. In this experiment, the smoke was released to the system by a cable heating first seen at 21s after the electric current was applied. The increasing amount of smoke released and as well as its opacity, finally activated the smoke detectors alarm in 46s. This explains that smoke need times to reach the smoke detectors and to meet the obscuration level that will reach the sensitivity of (2.06 ±1.3)\%.

Fig. 7 shows that the three CCD cameras used as input for video based system provided earlier respond to that of the conventional smoke detector. This is due to the video based system can detect almost all movement including the smoke that appears on the system. Meanwhile, the smoke detector rang loudly when a set value of obscuration level on the sensors reached. The reliability of video based system requires careful selection of the threshold values. On the basis of this experimental work, the peak value when the area as well as the intensity rises sharply could be considered to define early detection in cable fires scenario. The cable fire experiment is a promising method for comparing the video based system with conventional video detector. In the future a 3D smoke image analysis is expected to improve the capability and the accuracy of a video smoke detection system.

CONCLUSION

The experiment has been brought to understand how the video based smoke detector can be verified their detection system. Using stand-alone photoelectric smoke detector as a compare, we can conclude that the video based smoke detector can cover the delay time from the smoke appearance to the activated alarm. At a controllable smoke environment, the smoke developed can be detected by its movement and characteristic as the obscuration level by video based smoke detector.

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