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Smoldering Fire Detection by Image-processing

Abstract

Since fire detectors are not installed in all buildings, too many victims and property damages are caused in building fires every year in the world. One reason of non-installation is the fire detectors currently on sale are not always reliable mainly due to the so-called false alarms. Therefore the author has been examining many possibilities of new reliable fire detection system, including a possibility of multi-element fire sensor. At the AUBE'99 in Duisburg, the author reported another newly developing fire detection system using a thermal video camera system, related to the heat image due to fires, where the author proposed a method to eliminate non fire sources. In this report, the author has further advanced the image processing method to detect smoldering fires, together with the verification of software by experiments. And it has been indicated that this system is very effective in detecting smoldering fires very early and reliably.

1. Introduction

Too many victims and property damage are caused in building fires every year in the world. It is well known that fire detectors can reduce building fires, but unfortunately fire detectors are not always widely installed in buildings. One reason is the problem of price of fire detectors and installation. Another reason is the fire detectors currently on sale are not always reliable mainly due to the so-called false alarms, since most current fire detectors are based on a too primitive sensing element and logic. The author has longly studied the method of how to reduce the false alarms of fire detectors. One possibility developed by the author is to use the newly developed three sensing element fire detector (including new CO sensor) and artificial intelligence logic to judge between a real fire and a false fire[1]. It has been found that this new fire detector is very effective to reduce false alarms, therefore increasing the reliability of fire detection. The new three-element fire detector has, however, still a problem of price to manufacture particularly on CO sensing element at present. Therefore, the author has been examining other possibilities of new reliable fire detection systems also.

At the AUBE'99 in Duisburg, the author reported another newly developed fire detection system using a thermal video camera system, which is related to the analysis of heat images[2]. This newly developed fire detection system is particularly effective in detecting smoldering fires. As well known, it is comparatively easy to detect flaming fires by infrared or ultraviolet sensors or CCD cameras[3], particularly in the air conditioned rooms. On the other hand it is not always easy to detect smoldering fires, since there is no ways to detect smoldering fires by remote sensors at present. Although there have already been some studies to detect forest fires using infrared cameras[4], those methods are not always in common. Thus there is a possibility that the detection of a smoldering fire is delayed. Keeping this in mind, studies to develop a method to detect smoldering fires has been made, by introducing a thermal video camera. Thermal images are resistive against the influence by the airflow from the air conditioners or high-temperature layer in the room. To improve the disadvantage of current smoke detectors in smoldering fire, the author has been developing a new fire detection system using thermal images. In this report, the author deals with image processing software for smoldering fire detection, together with the verification by experiments.

2. Algorithm of Image Processing to Detect Smoldering Fires

2.1 Preprocessing of thermal images to eliminate noises

In order to detect fires correctly, it is important to eliminate false signals by preprocessing of thermal images. Generally video signals often import unwanted noises due to miscellaneous sources, including electric ones and thermal ones. There are many sources, which emit thermal radiation, for example by thermal reflection or something warm. Therefore, those noises should be removed. The procedure employed here to eliminate noises is as shown in Fig.1. Details are as follows.

(1) An infrared thermo-graphic camera (picture (a) in Fig.1), with semiconductor imaging cell consisting of 256 x 256 resolution, imports 30 images per second.

(2) With 30 pictures per second, six imported thermal images per minute are stored into a computer memory as 8-bit data (picture (b) (a part of picture (c)) and picture (c) in Fig. 1). Figs. 1(b) ,(c),(d),(f),(g) are related to electric radiant heater as an example.

(3) By comparing a preset threshold value, 8-bit data are transformed into binary data

(picture (d) in Fig.1). A threshold is placed between high and low temperatures. Many threshold values were tested. It was found that the thermal value of 200˚C was best. And then all thermal data are transformed into binary. If a pixel value is larger than a preset value, the pixel changed into “1” and if smaller, changed into “0”. However original 8-bit data are also kept for another purpose, to be explained later.

(4) High temperature pixels surrounded by low temperature pixels are defined as “high temperature cluster”. Fig. 1(e) shows how to define the high temperature cluster. Number of pixels and centroid of each high temperature cluster within the thermal image are measured, by judging the connection way between the neighboring pixels. High temperature clusters are extracted from the binary image using the well known “eight-neighborhood connected component processing method”[5]. After that, the identification number is labeled to each high temperature cluster. Then calculated is the number of pixels and centroid as shown in Fig. 1(f).

(5) Next processed is the removal of thermal noises by the way that smaller clusters are ignored. Thermal noises are eliminated in the pixel domain, by counting the number of pixels consisting of a cluster and comparing the preset value. Here a cluster consisting of 10 pixels is eliminated (pictures (g) in Fig.1).

2.2 Image processing to eliminate non-fire cluster

(1) Follow up of increase and decrease of high temperature clusters

Here, non-fire clusters are defined as the tools such as cooking stove, room heater and smoothing iron, which remain at almost the same size with time. Other sources can not be considered, since the temperature of 200 ˚C is too high in normal conditions. Therefore each cluster size is followed up on the basis of discriminating separation or fusion of high temperature cluster from time series images, and the time varying size and location are calculated. Detailed following up procedure is as follows, needed is the information, such as identification number of each cluster, number of pixels, centroid and intensity (namely 8-bit image data as mentioned above) of all pixel obtained from extraction process mentioned in section 2.1-(4) for each image. This information is named “Cluster ID Information”. In the smoldering fires, time dependent shift of the centroid is very small. It is easy to identify the moved clusters using the Cluster ID Information between two deferent images.

(2) Discriminate separation or fusion of high temperature cluster

In this method, the discrimination between the real smoldering fire and the non-fire is based on the time-dependent variation of the centroid and size of the high temperature cluster. Differently from non-fires, the centroid and size of the high temperature cluster are highly time dependent. If two separate clusters reach close to each other and merge in one cluster, the centroid location and cluster size will suddenly be changed. Similarly to this, if one cluster separates into multiple clusters, the same situation will happen. In Fig. 2, one example of fusion of 6 clusters in Fig.2(b) into 3 clusters in Fig.2(d) is shown, namely clusters C and D in Fig.2(b) fused into the cluster H in Fig.2(d). Details are shown in Table 1.

Here many trials were made to identify which clusters fuse into one cluster and employed method is a simulation to search most appropriate combinations on the centroid shift and pixel numbers. In the case of clusters C and D in Fig.2-(b) fused into the cluster H in Fig.2-(d), the centroid location of cluster H is 355 in X direction and 228 in Y direction while the average centroid location of cluster C and D is 354 in X direction and 228 in Y direction, as shown in Table 1. Both are very close and it was judged that clusters C and D fused into cluster H. Based on the procedure mentioned above, a software to detect smoldering fires and to eliminate non-fires is developed using C language.

3. Verification of the Software by Detection Tests of smoldering fire

Using the newly developed software, based on the procedure mentioned in section 2, experimental verification tests were repeatedly made. Here particularly focused in the tests are the elimination of the heat from cooking instruments or room heater, and also the accurate detection of the smoldering fires. It was found that heat from cooking instruments or room heater could easily be discriminated by the calculation of centroid coordinates and the size of high temperature cluster. The threshold value was varied from 100 ˚C to 300 ˚C. If the threshold value is too low, too many clusters appeared. And if it is too high, the cluster size differs only a little with time. Then the value employed here was 200 ˚C as most appropriate value.

Fig. 3 shows the changing high temperature cluster of electric radiant heater as a non-fire test material. In this case, the centroid and the size were almost the same for more than 5 minutes after the initial one minute rapid increase as shown in Figs.3 and 4, where the pixel number was fixed at about 7500 after one minute and at the same time the centroid did not shift. Next examined was a smoldering fire using silk cotton cushion. Fig. 5 shows the changing high temperature cluster of smoldering silk cotton cushion. Fig. 6 shows the time dependent pixel number of smoldering cushion. As shown in Figs.5 and 6 the heated area, namely number of pixels, is rapidly increasing, differently from the case of electric radiant heater. Additional verification tests using other smoldering ropes were made. It has been found that the developed software is very useful to detect smoldering fires and to eliminate non-fires. The detection of flaming fires is comparatively easy, as mentioned earlier. The threshold value of 200 ˚C employed here is not always fixed, but can be flexible depending on the circumstances of rooms, using artificial intelligent processing.

4. Conclusions

In this study an image processing algorism has been proposed to detect smoldering fires and to eliminate non-fires. It is verified that the image processing software works correctly for smoldering stage of silk cotton cushion and experiments using an electric radiant heater.

References

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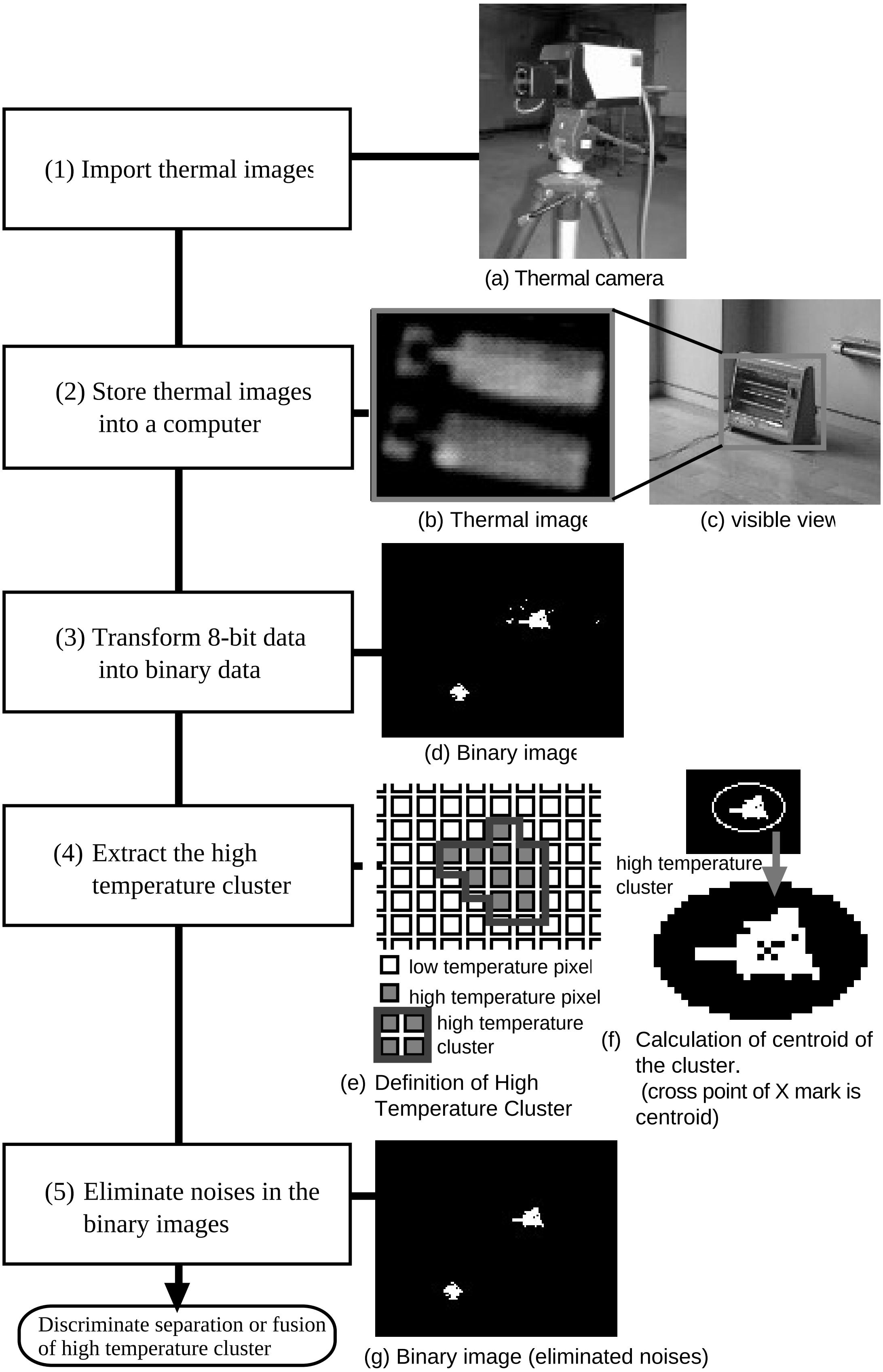
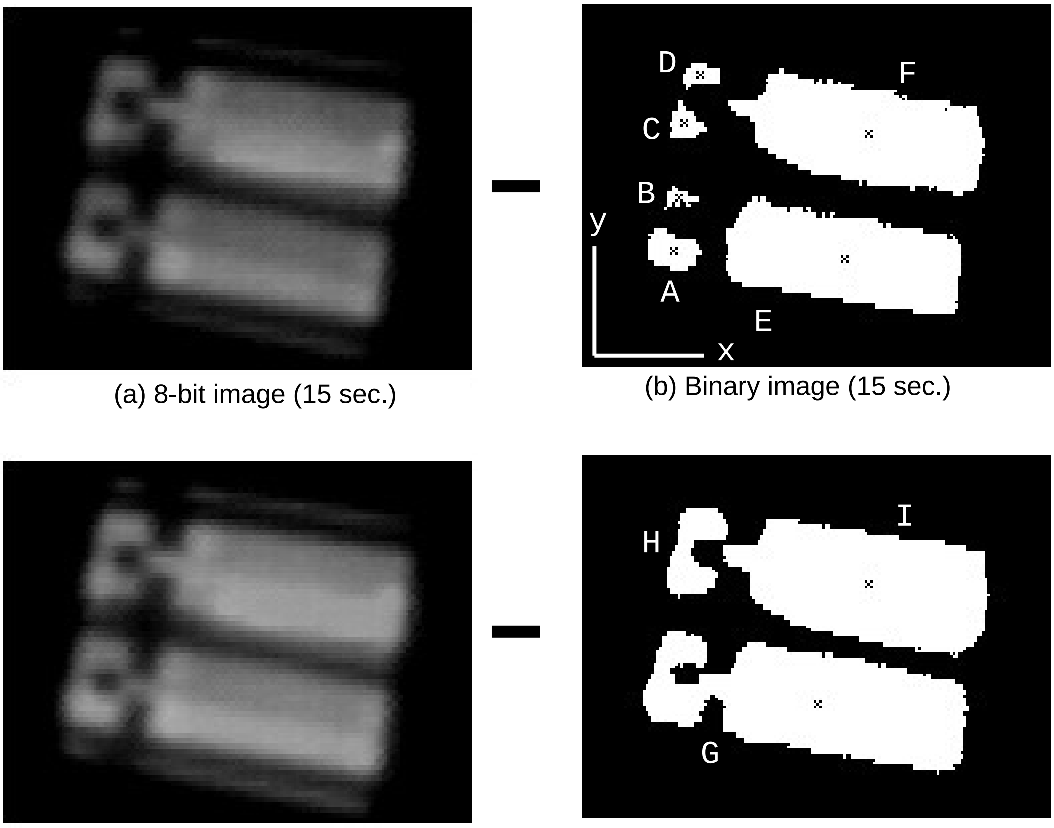


Fig. 1 Algorithm of Image Processing to Detect Smoldering Fires



(a) 8-bit image (15 sec.)

(b) Binary image (15 sec.)

(c) 8-bit image (18 sec.)

(d) Binary image (18 sec.)

Fig. 2 Discriminate separation or fusion of high temperature cluster (Number of second is elapsed time from turn on the heater)

Table 1 Centroid and pixel number of clusters in Fig.2 (b) and (d)

Cluster ID	Centroid		Pixel number
	X	Y	
A	347	172	225
B	349	192	55
C	351	220	117
D	357	238	97
E	411	169	2650
F	420	216	2847
G	401	171	3836
A+B+E	405	170	2930
H	355	228	456
C+D	354	228	214
I	420	216	3465
F	420	216	2847

(a) 10 sec. (b) 60 sec. (c) 180 sec.

Fig.3 Growth of high temperature cluster of electric radiant heater
(Number of second is elapsed time from turn on the heater)

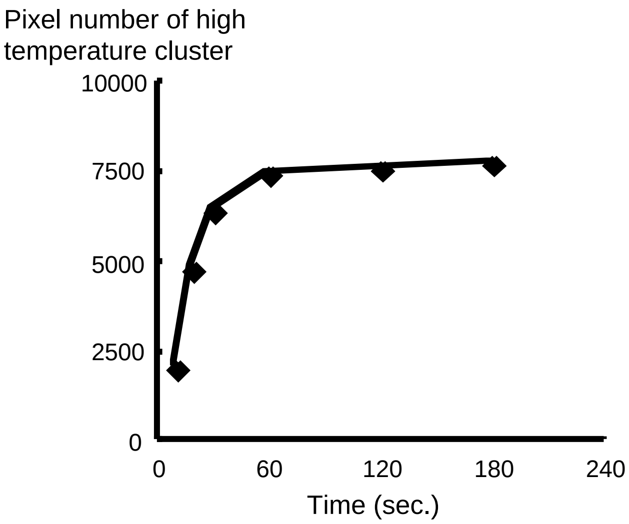
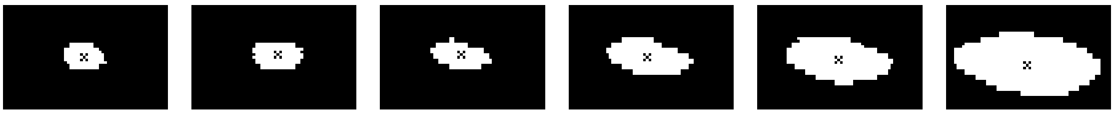


Fig. 4 The time dependent pixel number of electric radiant heater



(a) 10 sec. (b) 60 sec. (c) 120 sec. (d) 180 sec. (e) 240 sec. (f) 360 sec.

Fig.5 Growth of high temperature cluster of smoldering cushion
(Number of second is elapsed time from ignition)

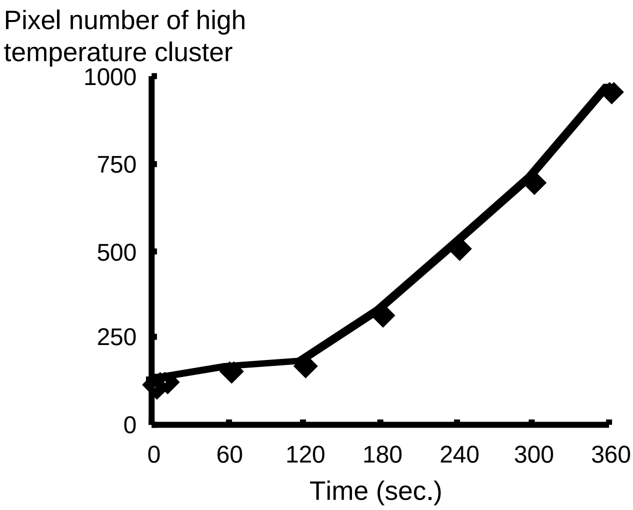


Fig. 6 The time dependent pixel number of smoldering cushion