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# AUTOMATIC FIRE DETECTION BY CHANGING REGION ANALYSIS BASED ON GEOGRAPHIC INFORMATION

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## ABSTRACT

This paper proposes a new method for automatic fire detection in cities using image processing techniques. Images are obtained successively at regular intervals from monochrome TV cameras which are suitably fixed on roofs of tall buildings.

Fire detection is carried out by identifying smoke in the daytime and fire flames at night. The major feature of the proposed method is to employ a fire identification strategy which is applicable to both smoke and fire flames and efficiently uses geographic information for identifying fire location.

The strategy is as follows; changing regions are extracted as fire region candidates by image subtraction operation. Motion analysis based on changing region tracking is carried out. As a result, actual fires are discriminated from disturbing events such as swaying trees, moving cars, etc. It is thought that smoke or fire flames might be detected in fragments due to noise. Fire spreading inference based on geographic information is adopted for top down grouping in changing region tracking.

Experimental results have shown the effectiveness of the proposed method.

## 1.Introduction

The Geographic information systems (GIS) have come into practical use in many fields, for example, utility (water, gas, electric power) supply management, urban planning, etc.[1]. The main reason for the wide use of GIS is the rapid improvement in computer capability, such as processing power and storage data capacity.

By the way, interest in the prevention of disasters has been increasing recently in Japan due to fear that a big earthquake will happen. Several projects on urban disaster management systems as an application of GIS have been progressing by governmental organs. One of the problems in an urban disaster management system is how to manage fires which simultaneously break out at multiple locations after a big earthquake.

This paper proposes a new method for automatic fire detection in cities as a key technique for the urban disaster management system. Fire detection is carried out by identifying smoke in the daytime and fire flames at night from images in the visible band. Fire location is calculated by matching a part of the image with an area code described in a geographic database.

Roughly speaking, there are two ways for fire detection. That is, from images in the visible band using ordinary ITV cameras and from images in the infra-red band using thermal sensors or similar devices. The former has an advantage from the viewpoint of cost and maintenance. There are several studies on fire detection using thermal sensors. However, reports on automatic fire detection which deal with both smoke or fire flames in the visible band are very few [2]. Furthermore, they do not discuss about the problem of fire location identification.

The major feature of the proposed method is to employ a fire identification strategy which is applicable to both smoke and fire flames and efficiently uses geographic information for identifying fire locations. The basic idea of the proposed method is described in Section 2. The fire detection method is explained in detail in Section 3. Some preliminary experimental results are show in Section 4.

## 2.Basic idea

It is considered that fires can be detected as follows from images in the visible band.

(a)In the daytime, smoke analysis is the best approach for fire detection, since smoke is always associated with fire and becomes quickly visible even if the fire source is occluded.

(b)Although smoke is not clearly visible at night, the detection capability of fire flames becomes high. Thus, fire flame extraction is effective for fire detection at night.

Smoke and fire flames cannot be specified by shape nor gray level. Therefore, it is difficult to detect them by the conventional thresholding techniques. Two stages of processing have been newly designed for high fire detection accuracy. The basic idea of the method is described below.

(1)Changing regions are extracted as fire region candidates by image subtraction operations between two successive images. The extracted regions possibly include false ones caused by disturbing events. These are trees swaying in the wind and moving objects such as cars or persons in the daytime, and object illuminations such as neon lights and moving car-headlights at night, etc.

(2)Motion analysis based on changing region tracking is carried out to discriminate between fire and disturbing events. In the tracking, grouping is done by making correspondences among connected components in the difference image, where changing regions caused by the same event are linked as one group. It is thought that smoke or fire flame regions cannot be grouped successfully only by fusing based on a logical OR operation between difference images.

Here, a top down method is adopted to effectively group fragmentarily detected fire regions (changing regions). It is possible to forecast a fire spread pattern using some rules or models based on geographic information such as locations and attributes of buildings, roads, etc (see Fig.1). Top down grouping is performed from fire spreading inference. The final decision whether the changing regions are actual fires or not is accomplished under the assumption that: a fire region monotonously spreads globally with time, while disturbing regions caused by noise or unexpected events appear in limited areas. That is, actual fire regions can be discriminated from false regions from changing patterns. In the case that disturbing events are known in advance, these can be eliminated by defining mask areas.

## 3.FIRE DETECTION METHOD

The method assume the following.

(a)Monitoring cameras are suitably fixed on the roofs of tall buildings at several points.

(b)Images are obtained successively at regular intervals.

(c)Geographic information for buildings, roads, trees and neon lights is given for the input images from the monitoring cameras. That is, each pixel of the input image corresponds to its geographic data in advance.

The method consists of five steps. It is designed to give warning to the user when a fire is first detected.

**(Step 1) Image input and condition checking**

A current image is input, and a noise reduction operation is carried out. It is decided whether smoke or flames should be detected by checking the average density of the input image.

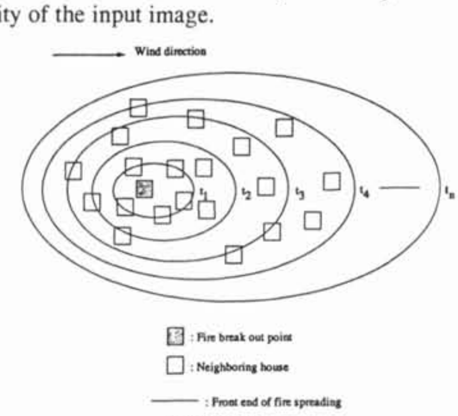


Fig.1 Conceptual illustration of fire spread pattern forcasting

**(Step 2) Changing regions extraction**

A difference image is obtained by an image subtraction operation between the current image and the previous image. The difference image is thresholded by G (parameter). This threshold level is dynamically set according to the image brightness. Then, connected regions are extracted by a labeling operation[3]. The resultant image and each connected region are called "a labeled difference image (LDI)" and "a changing region (CR)", respectively. The CRs are fire region candidates.

**(Step 3) Grouping**

Moving object analysis is carried out by making correspondences among the LDIs which are obtained successively (this operation will be called "grouping" from now on). The result is represented in terms of an accumulative LDI (called ALDI) and grouping information table.

(a)ALDI

An ALDI is a labeled image in which CRs in each LDI are accumulated. Each labeled region of an ALDI (called a LR) is linked to a unique group which corresponds to a changing event. Each group has a LR ( or more than one in some cases) which is the first LR when its group is generated. This is called a "seed". If a seed is caused by a fire, it means the location of a fire break out. (see Fig.2-a)

(b)Grouping information table

The grouping information table stores the group ID, the area and boundary data of each group, the time elapsed since the group was generated, and the history of the grouping process (seed and link information among LRs). (see Fig.2-b)

The procedure for constructing a current ALDI from a previous ALDI and a current LDI will now be explained.

**(Step 3.1) Each CR in the current LDI is linked to one of the groups in the previous ALDI based on the overlapping relation.** There are two cases.

Case3.1.1: The case that CRs overlap with LRs belonging to a single group.

Each CR in the current LDI is added to the current ALDI as a new LR. Then, the new information for the LR is added to the history information for the group to which the LR belongs, and the region information is updated.

Case3.1.2: The case that CRs overlap with LRs belonging to several groups.

The group which was generated the longest time ago is selected as the representative group. The table information for the representative group is updated by merging the data for the other groups into the representative group.

**(Step 3.2) Top down grouping by fire region spreading inference is tried for the CRs in the current LDI which do not overlap with the LRs in the previous ALDI.**

**(Smoke spreading inference)**

It is assumed that a smoke region strongly spreads in the wind direction (upward when it is not windy). Here, the current smoke region under the assumption that each group corresponds to a smoke region is calculated as follows (see Fig.3). First, Ymin and Ymax, which is the minimun (maximun) y coordinate of the smoke region, are calculated for regions belonging to the same group. Next, the area between Ymin and Ymax is horizontally divided into several blocks by a interval I (parameter). Then, Xmin and Xmax are calculated for each block. The current smoke region is defined by (Ymin,Ymax) and individual (Xmin,Xmax) s. The border where the smoke region will spread in a constant time is predicted by enlarging the current border. How much and how fast the smoke will spread can be experimentally determined in accordance with the velocity and direction of the wind.

**(Fire flame spreading inference)**

The fire flame spreading pattern can be inferred by using a fire growth pattern forecasting model (for example, Hamada model is one of the models, which is authorized in Japan). This model can predict the spread region in some time scale with the direction and velocity of the wind and the geographic information such as buildings and roads in the area.

The same processing as (Step 3.1) is carried out for the CRs which are included in the inferred spread

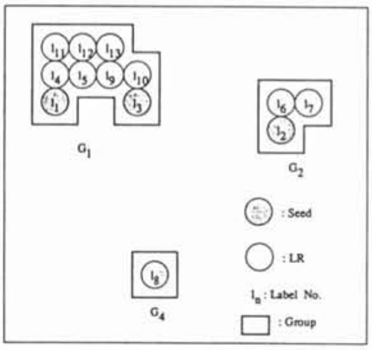


Fig.2(a) Example of ALDI

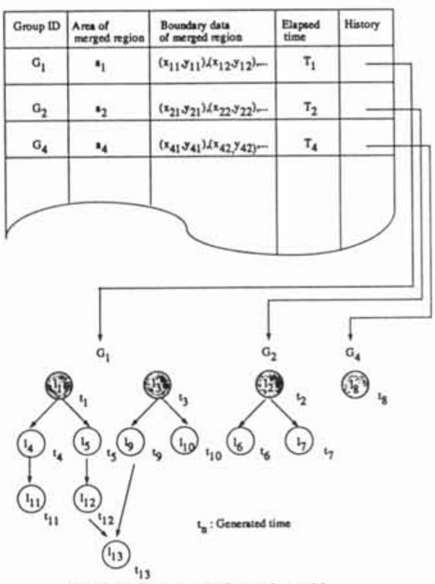


Fig.2(b) Grouping information table for ALDI shown in (a)

region.

**(Step 3.3) For the CRs in the current LDI which are not dealt with in the above processings, the overlapping relation with mask regions which are defined in advance is checked.**

Case3.3.1: The case that CRs don't overlap with the masked region .

Each CR is regarded as a new fire region candidate, and it is added to the current ALDI and registered in the grouping information table.

Case3.3.2: The case that CRs overlap with the masked region .

The CRs are assumed to be noises or false fire regions such as cars, trees, neon lights, etc. Therefore, nothing is done for the current ALDI and the grouping information table.

**(Step 4) Decision**

Decision whether it is a fire-region or not is made based on the area and the time elapsed for each group. There are three cases.

Case4.1: The case that the area is larger than A (parameter) .

These groups are regarded as fire regions. The corresponding address of the seed location is retrieved from the data-base. This information and a warning are output.

Case4.2: The case that the area is smaller than A and the time elapsed are larger than T (parameter), respectively .

These groups are regarded as noises. The LRs in the current ALDI and information in the grouping information table are eliminated.

Case4.3: Cases other than the above two cases .

It is difficult to make any decision at the present time. Thus, nothing is done.

**(Step 5) The current ALDI is stored as the previous ALDI, then go to (Step 1).**

The above method has four parameters G, I, A and T. These parameters should be determined experimentlly.

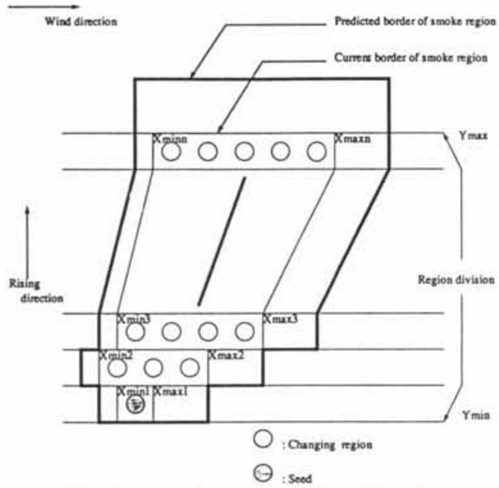


Fig.3 Spreading inference example for smoke region

## 4.Experimental Results & Discussion

Some preliminary experimental results are shown here. First, it is proved that fire regions cannot be successfully detected only by simple thresholding (even if color information is used). Figure4 shows a result of simple thresholding an image which contains an actual smoke region. Here, a fire was made to break out intentionally as an experimental fire. In the resultant image, several regions which were not included in the smoke region were detected.

Next, the reliability of the assumption that a disturbing region appears in a limited area is examined. Figure5 (a) shows a real night scene. In the figure, high-light regions correspond to neons or room-lights in tall buildings. Nine successive difference images were calculated for ten sampling images from the same fixed camera. A logical OR operation was carried out for the successive difference images. The result is shown in Figure5 (b). The figure shows that the merged regions are restricted in the detected locations. Similar experiment for images in the daytime were carried out to examine the changing regions for trees swaying in the wind. The result also showed the reliability of the assumption.

If the locations of disturbing changing regions such as neons, trees, etc. are known in advance, a mask image can be prepared corresponding to each camera. However, there may be unexpected events. For example, false changing regions by changing sunshine condition or noises caused by camera movement in a strong wind may occur. The proposed method under assumption that a fire region monotonously spreads globally with time will discriminate between true fire regions and false changing regions caused by an unexpected event.

## 5.CONCLUSIONS

A new method for automatic fire detection with top down grouping for changing regions has been proposed. Some preliminary experimental results were shown to prove the effectiveness of the basic idea. The proposed method will be applied to urban disaster management systems especially for managing fires which simultaneously break out at multiple locations after a big earthquake.

Further evaluations of the method, i.e. more experiments for real scenes in a free environment, are future work to be done.


## ACKNOWLEDGMENT

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## REFERENCES


[1]"Special GIS Issue", Photogrammetric Engineering & Remote Sensing, vol.8,no.10,Oct.1987.

[2]V.Cappellini et al.,"An intelligent system for automatic fire detection in forests",Proceedings of Third International Conference on Image Processing and Its Applications,pp.563-570,July.1989.

[3]A.Rosenfeld and A.C.Kak,"Digital Picture Processing",Academic Press,New York,(1976).

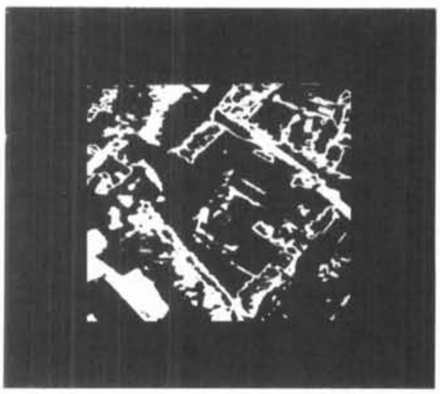
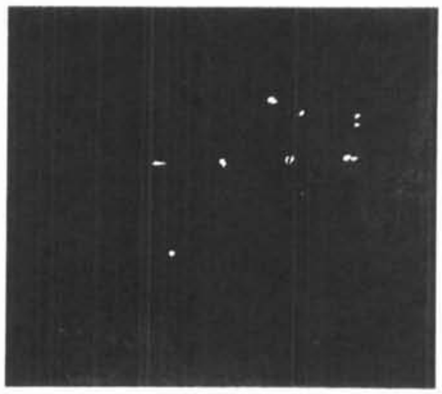



Fig.4 Example of simple thresholding result

(a) Night scene



(b) Result of logical OR operation for several successive difference images

Fig.5 Example of false fire flame regions