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An intelligent video fire detection approach based on object detection technology

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Abstract

Fire that is one of the most serious accidents in chemical factories, may lead to considerable product losses, equipment damages and casualties. With the rapid development of computer vision technology, intelligent fire detection has been proposed and applied in various scenarios. This paper presents a new intelligent video fire detection approach based on object detection technology using convolutional neural networks (CNN). First, a CNN model is trained for the fire detection task which is framed as a regression problem to predict bounding boxes and associated probabilities. In the application phase, videos from surveillance cameras are detected frame by frame. Once fire appears in the current frame, the model will output the coordinates of the fire region. Simultaneously, the frame where the fire region is localized will be immediately sent to safety supervisors as a fire alarm. This will help detect fire at the early stage, prevent fire spreading and improve the emergency response.

1. Introduction

Fire that is one of the most serious accidents in chemical factories, may lead to considerable product losses, equipment damages and casualties. Fire detection at the early stage can effectively prevent the spread of fire and minimize the damage caused by fire. In indoor buildings, smoke detectors and flame detectors are widely used for fire alarm. However, traditional physical sensors have a number of limitations. For example, they require a close proximity to fire sources so that they cannot work for the outdoor scenes [1].

To overcome this problem, some convolutional neural network (CNN) based methods have been proposed and applied for fire detection in various scenarios. However, there are still some limitations during the practical application. Frizzi [2] and Zhang [3] utilized a slide window in each frame to detect fire. The window size is fixed and usually less than the fire size, which may cause the network cannot learn the complete flame characteristics. Wang [4] and Maksymiv [5] used conventional hand-designed feature extractors to extract the region of interest (ROI), then detected fire in the ROI. However, these methods need to extract ROIs and compute patch images via the network for each frame. This will take a lot of time for the detection.

In this paper, we present a new intelligent video fire detection approach based on object detection technology. Object detection regards fire detection as a regression problem to predict bounding boxes and associated probabilities. This method does not use hand-designed features and the bounding boxes are not fixed so that the network can learn the complete flame characteristics. Each frame is only computed once through the network, which will reduce detection time and resource.

2. Method

Flowsheet

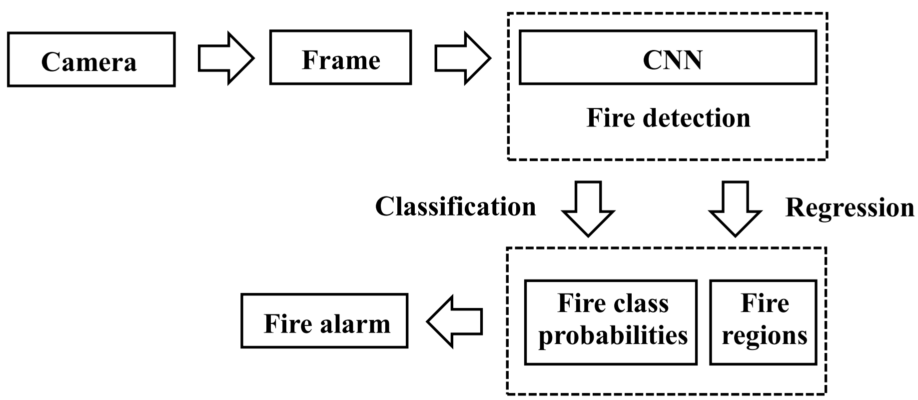

Fig. 1 Flowsheet of the proposed approach.

Fig. 1 shows the flowsheet of the proposed approach. In the application phase, videos from surveillance cameras are processed frame by frame through the trained fire detection model. Once fire appears in the current frame, the model will output the coordinates of the fire region. Simultaneously, the frame where the fire region is localized will be immediately sent to safety supervisors as a fire alarm.

YOLO (You only look one)

In our approach, the key is the fire detection model. There are two classes of method for the object detection task: two-stage and one-stage methods. Compared with two-stage method, one-stage method has faster computation speed. Considering real-time detection, we select YOLO [6, 7] as the fire detection method. YOLO frames object detection as a regression problem to spatially separated bounding boxes and associated class probabilities. YOLO is designed for multi-object detection, however, fire detection is a single-object detection.

Therefore, based on YOLO method, we developed our own method for video fire detection.

3. Experimental results

Fire image dataset

Fig. 2 Annotations of fire regions.

Images that contain fire regions, were collected from some fire image datasets built by previous researchers. Furthermore, via the internet, we augmented our dataset with images of chemical plant fire and other scenarios. The dataset contains 5075 images and the size of the images is not fixed. The proportion of the testing set is 20%, that is, 4060 images as the training set and 1015 images as the testing set. It is important to note that each image may contain several fire regions. Each fire region is annotated by a bounding box for describing its location (see Fig. 2).

Detection results

The fire detection method needs a CNN for prediction. The general function of CNN is a stack of convolutional layers, pooling layers and fully connected layers. Darknet was proposed as the base model of YOLO. For comparison, Darknet and Tiny Darknet were used for the fire detection task.

In the object detection domain, we need to define the true positives and the false positives. If $\mathrm{IOU} > 0.5$ between the predicted box and the ground truth box, the predicted box is true positive;

otherwise, it is false positive. The experiment was done on a computer server with a NVIDIA 1080 GPU. We augmented the testing set (1015 fire images) with 1000 no fire images. The details of the results are listed in Table 1 and Table 2. The accuracy reached 88% and 91% respectively. Compared with Tiny Darknet, Darknet has larger network size but better detection accuracy. Fig. 3 shows several instances of the detection results.

Table 1. Details of fire detection using Tiny Darknet.

		Actual Class	
Predicted Class	Size (63M)	Fire	No fire
	Fire	81.4%	5.1%
	No Fire	18.6%	94.9%

Table 2. Details of fire detection using Darknet.

		Actual Class	
Predicted Class	Size (193M)	Fire	No fire
	Fire	91.2%	9.2%
	No Fire	8.8%	90.8%

(a) No fire images.

(b) Fire images.

Fig. 3 Some instances detected by the trained network.

4. Conclusions

In this article, we present an intelligent video fire detection approach based on object detection technology. Compared with other CNN based classification approaches, our approach is based on YOLO method which predicts bounding boxes and associated probabilities directly. The performance of our approach can meet the needs of real-time fire detection on the precision and the speed.

In the future work, we will focus on reduce the false alarm by adding more negative images (no fire) into the training set. Moreover, a chemical factory may have hundreds of cameras, so developing a parallel fire detection system is also a vital problem for the practical application.

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