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Convolutional Neural Networks based Fire Detection in Surveillance Videos

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Abstract: The recent advances in embedded processing have enabled the vision based systems to detect fire during surveillance using convolutional neural networks (CNNs). However, such methods generally need more computational time and memory, restricting its implementation in surveillance networks. In this research article, we propose a cost-effective fire detection CNN (YOLO Object Detection) architecture for surveillance videos. The model is inspired from GoogleNet architecture, considering its reasonable computational complexity and suitability for the intended problem compared to other computationally expensive networks such as "AlexNet". To balance the efficiency and accuracy, the model is fine-tuned considering the nature of the target problem and fire data. Experimental results on benchmark fire datasets reveal the effectiveness of the proposed framework and validate its suitability for fire detection in CCTV surveillance systems compared to state-of-the-art methods. We plan to overcome the shortcomings of the present systems and provide an accurate and precise system to detect fires as early as possible and capable of working in various environments thereby saving innumerable lives and resources.

Keywords: Convolutional Neural Networks (CNNs), GoogleNet architecture, Fire Detection, CCTV Surveillance Systems, etc.

I. INTRODUCTION

Fire detection is crucial task for the safety of people. To prevent damages caused by fire, several fire detection systems were developed. One can find different technical solutions. Most of them are based on sensors, which is also generally limited to indoors. However, those methods have a fatal flaw where they will only work on reaching a certain condition. In the worst-case scenario, the sensors are damaged or not being configured properly can cause heavy casualty in case of real fire. Those sensors detect the particles produced by smoke and fire by ionization, which requires a close proximity to the fire. Consequently, they cannot be used for covering large area. To get over such limitations video fire detection systems are used. Due to rapid developments in digital cameras and video processing techniques, there is a significant tendency to switch to traditional fire detection methods with computer vision-based systems.

Video-based fire detection techniques are well suited for detecting fire in large and open spaces. Nowadays, closed circuit television surveillance systems are installed in most of the places monitoring indoors and outdoors. Under this circumstance, it would be an advantage to develop a video-based fire detection system, which could use these existing surveillance cameras without spending any extra cost. This type of system offers various advantages over standard detection methods. For example, the cost of using this type of detection is cheaper and the implementation of this type system is greatly simpler compare to those traditional methods. Secondly, fire detection system responds faster compared to any other traditional detection methods because a vision based fire detection system does not require any type conditions to trigger the devices and it has the ability to monitor a large area.

II. RELATED WORK

According to K. Muhammad, R. Hamza, J. Ahmad, J. Lloret, H. H. G. Wang, and S. W. Baik, 2018 [1] This paper proposes a secure surveillance framework for Internet of things (IoT) systems by intelligent integration of video summarization and image encryption. First, an efficient video summarization method is used to extract the informative frames using the processing capabilities of visual sensors. When an event is detected from key-frames, an alert is sent to the concerned authority autonomously. As the final decision about an event mainly depends on the extracted key-frames, their modification during transmission by attackers can result in severe losses. To tackle this issue, we propose a fast

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probabilistic and lightweight algorithm for the encryption of key-frames prior to transmission, considering the memory and processing requirements of constrained devices that increase its suitability for IoT systems. Our experimental results verify the effectiveness of the proposed method in terms of robustness, execution time, and security compared to other image encryption algorithms. Furthermore, our framework can reduce the bandwidth, storage, transmission cost, and the time required for analysts to browse large volumes of surveillance data and make decisions about abnormal events, such as suspicious activity detection and fire detection in surveillance applications.

According to K. Muhammad, J. Ahmad, and S. W. Baik, 2017 [2], Fire disasters are man-made disasters, which cause ecological, social, and economic damage. To minimize these losses, early detection of fire and an autonomous response are important and helpful to disaster management systems. Therefore, in this article, we propose an early fire detection framework using finetuned convolutional neural networks for CCTV surveillance cameras, which can detect fire in varying indoor and outdoor environments. To ensure the autonomous response, we propose an adaptive prioritization mechanism for cameras in the surveillance system. Finally, we propose a dynamic channel selection algorithm for cameras based on cognitive radio networks, ensuring reliable data dissemination. Experimental results verify the higher accuracy of our fire detection scheme compared to state-of-the-art methods and validate the applicability of our framework for effective fire disaster management.

According to J. Choi and J. Y. Choi, 2016 [3] In this paper, the integrated framework for 24-hours fire detection with a camera is proposed. The framework consists of four novel modules: an integration module, a flame detector with a visible-light camera, a flame detector with an infrared-ray camera, and a smoke detector. According to the state decided by the integration module, different detectors are selected to find fires. The flame detector with a visible light camera determines flame patches from candidates through the cascaded classifiers, based on the color, shape, and randomness of flames. The flame detector with an infrared-ray camera finds flames, using the random movement of blob candidates. The smoke detector recognizes the smoke regions by utilizing the colors and the transparent property of smoke. The three detectors and the integrated framework are tested with numerous videos, which validate the generality and the robustness of the proposed framework.

According to J. Choi and J. Y. Choi, 2015 [4] Fire detection is one of the most interesting issues for surveillance. The existing approaches for the fire detection suffer from a high false positive ratio. To solve the problems, we present a patch-based fire detection algorithm with online outlier learning. In the proposed algorithm, the candidates of fire are obtained in the form of patch, while the classical candidates have been based on pixels or blobs. Because the patches of fire have more distinctive shape than the entire fire, the shape classifier can recognize the candidates correctly from fire-like outliers. In addition, we propose an online outlier learning scheme which handles the irregularity of fire based on the repeatability of shape in time. The proposed algorithm is experimented with new challenging dataset, consisting of 50 positive videos with fire and 44 negative ones with fire-like outliers. By evaluating on the dataset, we validate the performance of our algorithm qualitatively and quantitatively.

According to P. Foggia, A. Saggese, and M. Vento, 2015 [5] In this paper, we propose a method that is able to detect fires by analysing videos acquired by surveillance cameras. Two main novelties have been introduced. First, complementary information, based on color, shape variation, and motion analysis, is combined by a multi-expert system. The main advantage deriving from this approach lies in the fact that the overall performance of the system significantly increases with a relatively small effort made by the designer. Second, a novel descriptor based on a bag-of-words approach has been proposed for representing motion. The proposed method has been tested on a very large dataset of fire videos acquired both in real environments and from the web. The obtained results confirm a consistent reduction in the number of false positives, without paying in terms of accuracy or renouncing the possibility to run the system on embedded platforms.

III. PROPOSED ALGORITHM

A. *Design Considerations:*

Majority of the research since the last decade is focused on traditional features extraction methods for flame detection. The major issues with such methods are their time consuming process of features engineering and their low performance for flame detection. Such methods also generate high number of false alarms especially in surveillance with shadows, varying lightings, and fire-colored objects. To cope with such issues, we extensively studied and explored deep learning architectures for early flame detection. Motivated by the recent improvements in embedded processing capabilities and potential of deep features, we investigated numerous CNNs to improve the flame detection accuracy and minimize the false warnings rate.

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An overview of our framework for flame detection in CCTV surveillance networks is given in Fig.1.

In this proposed system, we propose a method that is able to detect fires by analysing videos acquired by surveillance cameras. Two main novelties have been introduced. First, complementary information, based on color, shape variation, and motion analysis, is combined by a multi-expert system. The main advantage deriving from this approach lies in the fact that the overall performance of the system significantly increases with a relatively small effort made by the designer. Second, a novel descriptor based on a bag-of-words approach has been proposed for representing motion. The proposed method has been tested on a very large dataset of fire videos acquired both in real environments and from the web. The obtained results confirm a consistent reduction in the number of false positives, without paying in terms of accuracy or renouncing the possibility to run the system on embedded platforms.

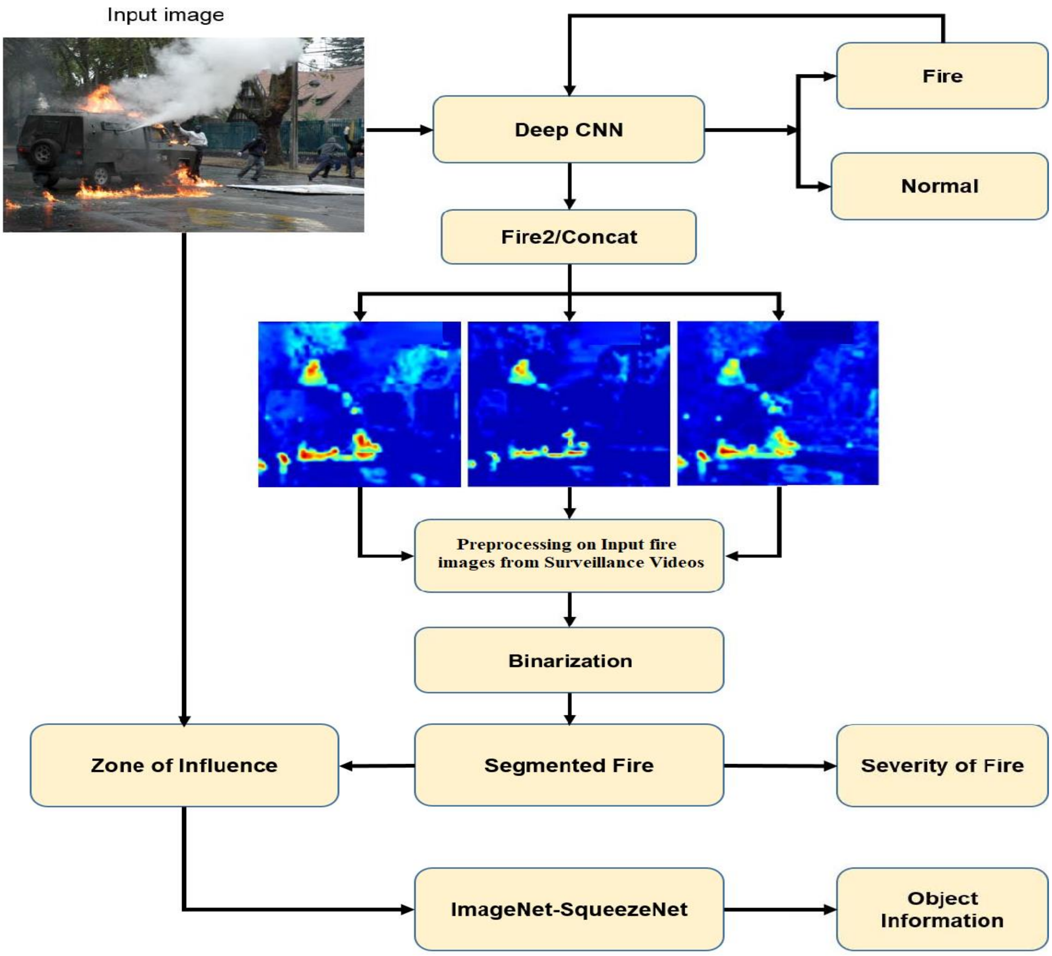

Fig.1: Proposed System Architecture

The performances of algorithms are estimated by two measures: detection ratio and false positive ratio. The detection ratio is obtained by dividing the number of correctly detected fire videos by the number of the tested fire videos. The detection of a video is determined when one or more fire alarms are detected from the fire video. The false positive ratio is evaluated by dividing the number of wrongly detected negative videos by the number of the tested negative videos. Because a negative video becomes a wrongly detected negative video even with one false alarm, the measure is very challenging for fire detection frameworks. As the algorithm shows high detection ratio with a low false positive ratio, the performance of the algorithm becomes good. With a ROC curve of detection ratio and false positive ratio, the performances of algorithms can be compared by the area under the curve.

B. *Description of the Proposed Algorithm:*

CNN is one of the main categories to do image recognition, image classification. Object detection, face recognition, emotion recognition etc., are some of the areas where CNN are widely used. CNN image classification takes an input image, process it and classify it under certain categories (happy, sad, angry, fear, neutral, disgust). CNN is a neural network that has one or more convolutional layers. The proposed algorithm is consists of following main steps:

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- Step 1: Dataset containing images along with reference emotions is fed into the System. The name of dataset is Face Emotion Recognition (FER) which is an open – source data set that was made publicly available on a Kaggle.
- Step 2: Now import the required libraries and build the model.
- Step 3: The convolutional neural network is used which extracts image features f pixel by pixel.
- Step 4: Matrix factorization is performed on the extracted pixels. The matrix is of m x n.
- Step 5: Max pooling is performed on this matrix where maximum value is selected and again fifixed into matrix.
- Step 6: Normalization is performed where the every negative value is converted to zero.
- Step 7: To convert values to zero rectified linear units are used where each value is ffiltered and negative value is set to zero.
- Step 8: The hidden layers take the input values from the visible layers and assign the weights after calculating maximum probability.

IV. CONCLUSION AND FUTURE WORK

The recent improved processing capabilities of smart devices have shown promising results in surveillance systems for identification of different abnormal events i.e., fire, accidents, and other emergencies. Fire is one of the dangerous events which can result in great losses if it is not controlled on time. This necessitates the importance of developing early fire detection systems. Therefore, in this research article, we propose cost-effective fire detection CNN architecture for surveillance videos. The model is inspired from GoogleNet architecture and is fine-tuned with special focus on computational complexity and detection accuracy. Through experiments, it is proved that the proposed architecture dominates the existing hand-crafted features based fire detection methods as well as the AlexNet architecture based fire detection method.

Although, this work improved the flame detection accuracy, yet the number of false alarms is still high and further research is required in this direction. In addition, the current flame detection frameworks can be intelligently tuned for detection of both smoke and fire. This will enable the video surveillance systems to handle more complex situations in real-world.

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