Early Detection of Fire in Videos using Computer Vision and Deep Learning

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Abstract: *Early detection of fire is a must to prevent the dangerous accidents it could cause. Traditional fire detection systems use hardware like sensors to detect the presence of fire. A more automated approach is provided with the use of Deep learning and Machine learning. This study talks about using Convolutional Neural Networks with a large dataset. This dataset helps in reducing the false positives, false negatives and provides a more accurate classification. Fog, weather, climate, sunrise, sunset, wildfire, and non-fire images are collected and combined. This is done so that fog is not confused with smoke and all orangish-red colored objects are not misinterpreted as fire. Image augmentation is performed to increase the size of the dataset and to make it more versatile. Videos from CCTV footage are split into frames and processed for fire. These frames are fed into the trained CNN model which achieved an accuracy of 0.94. If any of the frames show a slight presence of fire, then the alert of fire is raised. This real-time immediate detection of fire will prevent the fire's spread and help in extinguishing it as soon as possible. The user interface developed has options for processing both videos and images. Once this is done, attributes of sound waves such as airflow, decibels, frequency, and distances are used to predict if fire can be extinguished or not. Machine learning models are trained using a labeled dataset with all these features. The Decision Tree classifier showed the highest accuracy of 0.97 for the above. By using these techniques, fire detection and prediction of its extinction is made easier and more efficient.*

Keywords: Convolutional Neural Networks, Computer Vision, Early Fire Detection, Image Processing, Improved dataset.

Introduction

Traditional methods of fire detection are using devices like sensors, smoke detectors. These devices have a lot of disadvantages. Hence, a new method to detect fire without as many disadvantages is essential. Moreover, detecting fire especially when fire is still small, is the need of the hour. The Machine Learning Model in this study takes videos as input and alerts if it has detected fire. So Live streaming of videos from any CCTV footage will help in the early detection of fire, which has the capability of spreading far and wide in seconds. The model has been trained with about 4320 images, so it detects all kinds of fire like forest fires and household fires, with very less probability of false positives. Traditionally, fire is extinguished using water, or air. Both of these extinguishing methods require fire fighters to be in direct contact with the flames and put in manual efforts, which is usually life threatening. Recently, there are studies on whether sound waves can be used to extinguish fire. Though it hasn't been used yet, experiments have been conducted to check what kind of sound waves can be used to extinguish different kinds of flames - flames caused by gasoline, kerosene etc. The results of one such experiment is used to train multiple machine learning models. The models predict if the given fire can be extinguished with a certain sound wave, when we have certain features of the sound wave and the fire.

Literature Review

Fire accidents take many lives every year. Innocent bystanders and fire fighters often fall victim to the accidents. The existing fire detection systems have to be improved to save lives. Using machine learning to detect fire, and predict its extinguishing status is much easier, and can help save innumerous lives. It is also faster, and cost effective, since we can use surveillance cameras, which are present everywhere. The fire detection model proposed by Rama Krishna V.V et al. (2022) makes use of both general benchmark data sets, especially the ones from MNIST websites, as well as a specialized FIRE-DATASET aimed at aided fire detection systems. These datasets were carefully split into training and testing sets where 50% of the data was used to train the model and the remaining percentage was used to test the model's performance. This model employs a Convolutional Neural Network (CNN) based architecture known as Squeeze-Net for its efficiency and precision. The experimental results showed that Squeeze-Net model achieved remarkable accuracy of around 94% which is a 5% rise from earlier models including Alex Net. Again, the method reduced the false alarm rate from 9.07% to 8.06% proving the model's utility in discretizing between fire and non-fire conditions.

Another paper by Wangda Zhao et al. (2020) presents a comparative study on fire detection algorithms, with intervention level 1-6 being based on manual feature extraction and intervention level 7-12 based on automatic feature learning, hence the use of Faster-RCNN, R-FCN, SSD and YOLO v3 architectures to focus on fires. Two datasets have been created to carry out the experiments. The first one is Testset1, which is a controlled fire video dataset made up of 31 videos of which 14 are of fire and 17 are non-fire. The second one is Testset2, which consists of an extensive collection of 14,590 images (3,890 smoke, 5,322 flames) obtained from different activities and is much harder than the previous set. The results support the claim that convolutional neural networks (CNN) based algorithms are significantly better than traditional ones. In particular, in terms of average precision (AP), the best-performing model is YOLO v3, achieving 87.8% AP while processing at a speed of 28 frames per second.

In inference strategies, SSD and YOLO v3 trained best seem that they are superior than Faster-RCNN and R-FCN trained methods.

The research by Wang Yuanbin et al. (2020) is primarily concerned with mapping the flame images by examining individual pixels to obtain a color space-based segmentation on the Y, Cb and Cr images. In the process a convolutional neural network (CNN) model whose inspiration was drawn from alexnet was constructed. This convolutional layers setting comprised three convolutional layers and adopted multiple pooling techniques that included the standard maximum and average pooling and the new adaptive method of pooling which was designed to enhance extraction of features without the loss of too much of the local information. The data used was a 500 picture dataset - flame and non flame was used and the model was trained with different combinations of initial learning rates and batch sizes to obtain the best performance of 88.75% testing accuracy, thus confirming the viability of the proposed adaptive pooling method in promoting the segmentation process of the model.

In this paper, false positives are aimed to be reduced since equal number of datasets are used for each of the classes. Plus, the video processing done is also a bit faster. Integration of the acoustic fire extinguisher models will also give an idea of whether the fire can be put off or not. Using a limited dataset for CNN models will result in a lot of false detection. For example, as mentioned, if features take into account the reddish orange color of the flame, then sunrise/sunset/autumn pictures maybe misinterpreted as images with fire. These mistakes are avoided in this paper.

Methodology

The processes are described in detail along with the methodologies and data below.

Data Collection

Various Datasets in Kaggle were combined for the fire detection module. A new dataset was made by including the images that could cause a false positive. These images included images of Fire, Wildfire, Weather, Forest Fire, Autumn, Sunrise/sunset and other non-fire images. A total of about 4320 images were collected. The labeled dataset for the acoustic fire extinguisher module was also downloaded from muratkoklu.com (Koklu M. et al.). The properties of sound like size, airflow, decibel, frequency, etc. are provided as columns in the dataset. This dataset consisted of about 17442 rows and 7 columns.

Data Preprocessing and Dataset Creation

Fire detection: A new table was made consisting of the path and the label of the images (fire/non-fire). Height and width of the images were calculated and added to a new column in the dataset. Since the images were of non-uniform size, all the images were made into uniform dimensions - 256 x 256. The images were then put in an Image Data Generator Function to be rotated, resized, zoomed randomly. The images were also split into training set (80%) and testing set (20%). The input video was split into frames and stored in local folder. These frames were further resized to create a uniform dataset. Detailed architecture is provided in figures 1 and 2.

Acoustic Fire extinguisher: The dataset did not have any null values. So, no further preprocessing was needed. The dataset was split into training and testing dataset.

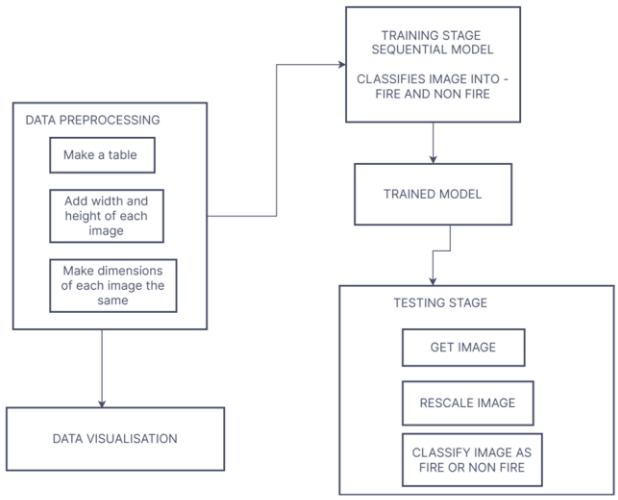

Figure 1: Architecture of Fire Detection

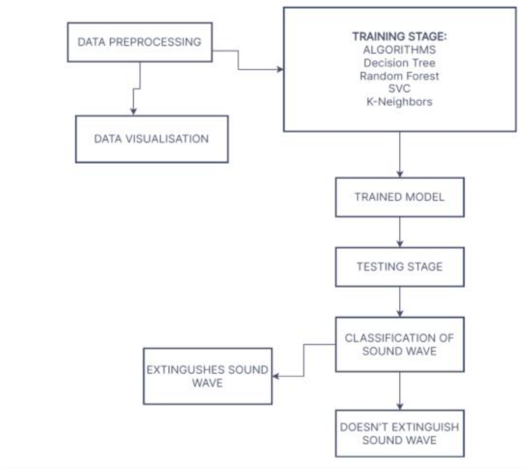

Figure 2: Architecture of Fire extinguisher

Method and Model Development

Fire Detection: A convolutional neural network is developed to classify the images into their correct labels. CNN model is one of the best to work with image data. The most important building block of a Convolutional Neural Network (CNN) is the convolutional layer. Max pooling is done to help with over-fitting. The output of the convolutional layer of CNN is flattened using flatten() to create a single dimensional vector. The dense layers use a linear operation on the output of this layer to classify the image. In this model, Convo2d and MaxPool were applied thrice to train the model. Initially, the input image size is 255x255x32 which becomes 31x31x128 after the 6 operations. The input is then flattened to get a single dimensional array of 123008 elements. The dense operation is finally applied thrice. Early Stopping and Reduced Learning callbacks are used when fitting the model. Adam Optimizer is used since it gives the best results while compiling the model. Any input video is first split into frames and these frames are fed to the developed model. If any of the frames have fire in them, the processing is stopped immediately and is alerted as fire. This is performed by this model. The model shouldn't get confused between smoke/fog and fire as it could lead to wastage of essential resources better utilized elsewhere. This is why a varied dataset is used. The features of the fire are to be extracted (like the color, texture, shape, motion, etc) in the future.

Acoustic fire Extinguisher: 4 ML Classification Models were used in this module. They were Decision Tree Classifier, K Nearest Neighbors, Random Forest Classifier and Support Vector Machine. For each of these models, grid search algorithm has been performed and the best parameters are taken into account.

During the testing phase, the first model was tested using various fire and non-fire videos and false positives were reduced as much as possible. The second model was built using various classification algorithms. The algorithm which gave the highest accuracy score was used ultimately. For both the modules described above, an UI is developed using Flask and Python where videos can be uploaded and inputs can be given for the fire extinguisher model.

Results and Discussion

As discussed above, the labeled datasets are shown below in figure 3. The path, label along with the image dimensions are made into a dataframe. Now this is the dataframe that is fed to the model for training. All the images were transformed to get images of uniform sizes to feed into the model.

	Path	Label
0	C:\Users\charanya\Downloads\1\55.jpg	Fire
1	C:\Users\charanya\Downloads\archive (6)\datase...	Non_Fire
2	C:\Users\charanya\Desktop\fire_dataset\fire_im...	Fire
3	C:\Users\charanya\Desktop\fire_dataset\fire_im...	Fire
4	C:\Users\charanya\Downloads\archive (6)\datase...	Non_Fire
5	C:\Users\charanya\Desktop\fire_dataset\fire_im...	Fire
6	C:\Users\charanya\Downloads\archive (6)\datase...	Non_Fire
7	C:\Users\charanya\Desktop\fire_dataset\fire_im...	Fire
8	C:\Users\charanya\Downloads\Fire_Dataset-2\Mul...	Non_Fire
9	C:\Users\charanya\Downloads\archive (6)\datase...	Non_Fire

	Path	Label	Height	Width
0	C:\Users\charanya\Downloads\1\55.jpg	Fire	299	447
1	C:\Users\charanya\Downloads\archive (6)\datase...	Non_Fire	480	892
2	C:\Users\charanya\Desktop\fire_dataset\fire_im...	Fire	676	1024
3	C:\Users\charanya\Desktop\fire_dataset\fire_im...	Fire	1267	1900
4	C:\Users\charanya\Downloads\archive (6)\datase...	Non_Fire	240	424

Figure 3: Data Frames made

After splitting the dataframe into train and test, the results are as shown in Fig 4.

```
Found 3507 validated image filenames belonging to 2 classes.
Found 876 validated image filenames belonging to 2 classes.
```

Figure 4: Train and Test

CNN Model is built using the CNN layers. Recall, Early stopping, Epoch, reduce_lr_on_plateau was also used. The accuracy was 94%. Detailed results are shown in Figure 5.

```
loss: 0.15
accuracy: 0.94
recall_1: 0.95
auc_1: 0.99
```

Figure 5: Results of the model

The web application has a separate page for each model, starting with the home page, which has the basic information needed by the user. Once the video is uploaded, the video is split into frames, and each frame has been checked for fire sequentially. When any one frame contains fire, it stops checking and the output is displayed along with the video. In the second case the first frame generated itself has fire and hence, the output is fire. In the first case, the video only has sunset, which is not been regarded as fire even though it has an orangish-red shade, then the full video is first split. These frames are then resized and fed for prediction. Since there is no frame with fire in it, we get non-fire as output. The outputs are depicted in Figure 6.

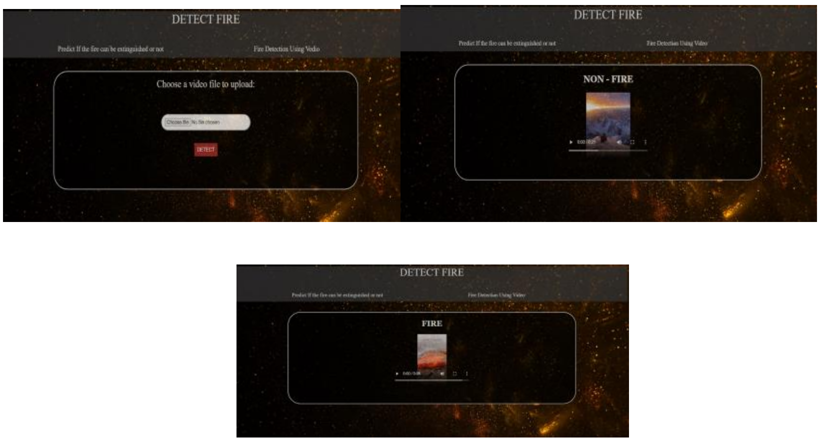

Figure 6: Homepage and Outputs

Along with the output, the video uploaded is also displayed for reference. Libraries in python like OpenCv are used for video processing. Moving to the Acoustic Fire extinguisher model, there's again another page dedicated for this in the UI. Once the fire has been detected using the videos, values can be entered into this page. Using the values entered, the predict function predicts if the fire can be extinguished or not. For the below given values, the fire can be extinguished so it gives the output as extinguished. The values entered and the corresponding output is displayed on the webpage in figure 7.

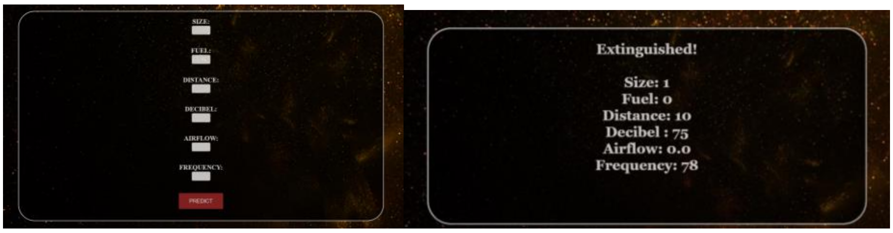

Figure 7: Outputs of fire extinguisher model

Moving on to the metrics of the classification model, out of Decision Tree Classifier (96.5%) , SVC (89.1%) , Random Forest Classifier (96.3%) and KNN Neighbors Classifier (91.7%), Decision Tree Classifier algorithm provided the highest accuracy. So the Decision Tree Classifier was chosen as the final model.

Table 1: Metrics of Classification Models

Model	**Accuracy**
Decision Tree Classifier	0.965
Support Vector Classifier	0.891
Random Forest Classifier	0.963
KNN	0.917

The performance metrics of all the models used are shown in Table 1. For all of these models, the parameters are fine-tuned. Above-mentioned functionalities—starting from image preprocessing to machine learning model prediction/forecasting—are combined in an interactive UI in a web-based interface using Flask, which provides an integrated platform for the management.

Conclusion and Recommendation

With this project, the attempt is to make a real-world application that can help predict if fire can be extinguished without putting people's lives in danger, and to detect fire faster and more efficiently. Both these models have immense importance with regard to the rising temperatures and global warming, to save an uncountable number of lives in the future. The models mentioned above can detect fire with a high accuracy, and the probability of false positives is greatly reduced by accounting and training the models for all outliers. The acoustic fire extinguisher model provides an easy platform to check if fire can be extinguished with a sound wave, if the attributes of the sound wave and fire are given as input. This project can be improved, by segmenting fire in the video if fire is detected in it. The acoustic model can also be improved by taking input from the user as a sound wave instead of the attributes of the sound wave.

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