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In-Theatre Real Time Piracy Detection and Discouraging System

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Abstract. Today, movie piracy is greatly affecting the economic growth of the film industry. Hence, combatting piracy is critical in averting losses for the film producers. This paper aimed to develop an anti-piracy model composed of a real time pirated video degradation system and a piracy activity estimation system, which in turn are based on Thermogram analysis and an ARDUINO programmed IR LEDs array. In the pirate estimating system, the Cubic SVM model is trained to classify the thermal images acquired from the theatre environment into normal and abnormal classes. An accuracy of about 99.9% is achieved in real time while testing for piracy actions. The proposed piracy discouraging system is programmed to real time degrade the quality of pirated video and to invisibly watermark the pirated video with the theatre name, date, and time information. The distortion created by our prototype system is evaluated by recording the video displayed on screen using different mobile cameras and the corresponding pirated video quality is compared objectively and subjectively. Based on the subject's quality rating, it was found that the system has created enough degradation in the visual quality of pirated video to discourage piracy.

Keywords. Alex Net, Camcorder, Movie Piracy, SVM

1. Introduction

Cinema is the major source of entertainment for people all over the world. Movie piracy is the act of unauthorized acquisition of copyrighted content without the authorization of film makers. This is a new epidemic that is economically impacting the film industry on a global level. According to a survey [1-5], pirated movies gain around 230 billion views every year. It was also reported that Indian media lost about US$2.8 billion to piracy. As per the study conducted by the US-India Business Council (USIBC), the Indian film industry experiences a loss of 11% in employment due to piracy. It also influences content creation by discouraging filmmakers, directors, and producers from making sequels and remakes. Consequently, national government and entertainment firms have come up with effective strategies and tools to combat piracy. The Indian government implemented the Cinematograph Act in the year 2019 that declares piracy as a crime and penalizes pirates with three years of imprisonment and with a fine of 10 lakh rupees.

Movies can be pirated before they are released, which is known as pre-release piracy [6-10]. On the other hand, if a movie is pirated after the release, it is known as post-release piracy. In the pre-release piracy, a movie is recorded by guests or theatre operators during private screenings for VIPs and critics.

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During post-release piracy, both audiences and theatre operators can pirate the film and make the bootleg available for illegal distribution. Some of the ways in which pirated movies can be derived include cams having low quality, DVD & VOD ripping, digital distribution copy, WEB-DL and Telecine. All these pirate strategies have a detrimental influence on box office revenue. To curb piracy, many anti-piracy systems have been proposed in the literature with a variety of approaches. In a few of the approaches, watermarking techniques [11-15] are used to build the systems. But watermarking techniques involve complex procedures and might damage the movie's content.

Thakur et al. [16] presented a model for estimating the pirate position in theatres by analyzing the tilt angle of an input image to a reference image using projective transform and zero padding approaches. Reference images are those acquired without any tilt angle and saved as a basis or reference, whereas input images are those captured at different tilt angles. Akshatha et al. [17] presented a two-level authentication based anti-piracy screening system. Initially, the information on the smart card possessed by the theatre owner is compared with the predefined reference data stored in the comparator. The optocoupler receives the comparator's digital output as input, separates the comparator from the driver, preventing the back emf from entering the comparator. The comparator's signal is sent to the driver, which is made up of pairs of Darlington transistors, where it is amplified and inverted. The relays are driven by this driver to activate the microcontroller. This completes the first stage of authentication. Once the microcontroller is turned on, the keypad is activated for password input. If valid, the microcontroller output is sent to the driver via a buffer that offers impedance matching. The driver then amplifies the signal and enables the relay for controlling the IR LEDs since the microcontroller output is low. The signals generated by the IR LEDs located behind and around the theatre screen are directed towards the audience. Consequently, this invisible radiation interrupts the camera's acquisition operations, prohibiting piracy.

Chen et al. [18] proposed a method for tracking movie piracy leveraging temporal psychovisual modulation (TPVM). Once the movie begins to play, the projector emits frames of fixed patterns for pirated video degradation. TPVM stacks invisible fixed patterns on the theatre screen using the disparity between digital camera image formation and human-eye perception. The human eye interprets images as continuous light field integration, whereas digital cameras capture images as discrete samples with a "blackout" phase in every sample cycle. According to this difference, the movie is split as series of display frames displayed at a higher rate without being noticed by the audience. However, video frames captured with a camcorder will have undesirable artifacts and can be utilized to track a pirate.

Gouri et al. [19] proposed a piracy control system based on IR transmitters and image processing techniques. The system is comprised of a camera location unit and a camera deactivating unit. A webcam interfaced with a computer continuously scans for the presence of a camera lens. If the camera lens is recognized, a signal is transmitted to the Raspberry Pi module. After determining the position and focal point of the camera, a flag is transmitted to microcontroller. Later, IR transmitters coupled to servomotors are activated to emit IR rays towards the camera focal point. These IR rays distort the quality of recorded video. Abhishek et al. [20] proposed an RFID based pirate detection system. Pirates are located using RFID tags. Everyone who buys a movie ticket receives an RFID tag. Before entering the movie theatre, the user must input the OTP using a keypad. The information provided by the user assists theatre officials in locating the pirate. Asborn et al. [21] presented a model where IR signals are used to prevent video recording in theatres. In this system, the projector and anti-piracy screening system operate in parallel. The microcontroller performs system authentication.

Kumar et al. [22] presented an Automated Anti-Piracy System to combat movie piracy. In this method, servomotors are connected to IR transmitters which rotate with the orientation of +450 and -450, covering the entire screen. The movement of IR transmitters produces a matrix of emitted rays which will be captured in the pirated video. The IR transmitter system and the projector are both powered by a single power supply to ensure that the projector does not switch on independently. A keypad-based password system is employed to establish this connection, and the power supply to the projector is denied until the user inputs the correct password. Chandana et al. [23] developed an automated IR screening system and steganographic based model to prevent movie piracy. This approach addressed both pre-release and post-release piracy. To overcome pre-release piracy, RFID tags were used to prevent unauthorized access of the movie. The RFID reader is paired to an RFID tag when the Microcontroller is switched on through the relay. Each RFID card contains a priorly defined unique code that is encrypted using the steganographic technique. Each movie is provided with one RFID tag and the respective card is possessed by the theatre owner and is checked for its validity. If the card is authentic, the LCD will display the message “movie is ready to play” along with the card number. If the card is not authentic, The LCD will display "Invalid access denied" and an alert message "movie is not played" along with the GPS location is sent to the theatre official. An IR LED system is used to address post-release piracy.

Venkata et al. [24] demonstrated an anti-piracy system based on infrared LEDs and image processing algorithms. If a recording device is located, the IR LED system is activated to emit IR rays. In addition to the IR LED system, there is a GSM-based alerting system. This alerting mechanism notifies the theatre manager that there is an active recording device. In addition, if the IR LED system fails to switch on even after the camcorder is detected, an emergency message is delivered. Khan et al. [25] proposed a model that uses an IR LED screen and watermarking techniques to combat piracy in theatres. In the movie file, a watermark with the logo provided by the producer and theatre information is inserted. Using Arnold's scrambling technique, this movie file is encrypted with a secret key to generate a video file along with noise. Also, when pirates attempt to record a movie with camcorders, the image quality is distorted by the IR LEDs placed in a pattern behind the screen. Dubey et al. [26] presented watermarking technique using discrete wavelet transform against camcorder piracy. The two key aspects of this approach are extraction of the watermark from the recorded video and estimating the pirate position in the theater. A watermark consisting of information regarding the timestamp and place of piracy is generated to form a payload. Illegal camcorder capture of a cinema is prevented by extracting the watermark from the pirated movie by adopting the blind extraction technique to locate the pirate’s position using the watermark message.

Kumar and Gururaj [27] proposed a technology that employs infrared LEDs and the concept of video steganography to prevent illicit video recording of movies in theatres. The IR transmitters are positioned in and around the perimeter of the theatre screen, and since, IR wavelength is longer than visible light, human eyes can view the movie without any disturbance. The system provides access verification by providing an exclusive secret key to the authorized person for playing the movie. Devraj et al. [28] proposed a two-level approach for preventing piracy in movie theatres. In the first method, authorization of ownership is monitored, to play the movie in theatre when password is entered. If it is unauthorized access, the movie will not be played. MATLAB software was used for programming. In the second method, IR LEDs are used to degrade the quality of recorded video. Patil et al. [29,30] presented a real-time solution for preventing movie piracy by locating the pirates in theatres. A local dataset acquired with day light vision cameras was created and is used to train the classifiers [31-33] available in MATLAB for classification, which is not effective in dark environments inside theatres. Along with detecting pirates, the proposed work intends to discourage piracy by degrading the visual quality of pirated video. A matrix of infrared LEDs is placed behind the screen to emit IR rays as the movie begins to play.

While few of the existing approaches are simply turning ON the IR LED matrix behind the screens for pirated video degradation with or without secret key, there is no specific method proposed to display a meaningful scrolling content made up of IR LEDS display such as theatre name, place, date, and show timings, which really helps in identifying the place and time of piracy once the pirated videos are caught for the purpose of legal actions. Further, it is very important to catch the pirate during the act itself. This paper aims to address these concerns of movie piracy in theatres and proposes an anti-piracy system which is based on a machine learning approach and an IR LED screen system which displays the theater and show timings. While machine learning approach is employed to estimate the presence of piracy actions in theatres, IR LED and Arduino-based systems are developed to distort the quality of recorded pirated movies and to embed a watermark which is visible to only recording devices., but not to humans.

Section 2 overviews the proposed anti-piracy approach. Section 3 presents the results and Section 4 concludes the paper.

2. Proposed Piracy Detection and Discouraging System

In this section, an antipiracy system to curb piracy is presented. It involves two approaches. The first subsystem is designed to estimate piracy actions in theatres using machine learning techniques. The system classifies every real time image acquired by a thermal camera into normal (Class1)/abnormal (class 2) scene and sends alert messages to the owner accordingly. The second subsystem is designed to quality degrade the pirated video with a scrolling IR LED display system. Figure 1 shows the proposed Machine Learning approach for piracy detection in theaters using thermograms.

Before the training phase, a thermal camera is positioned in the theatre to acquire dataset images under different conditions. The dataset images are then categorized into 'normal' and 'abnormal' classes. Normal class includes images without the presence of recording devices, whereas abnormal class includes images with recording devices. The dataset acquired contains 8400 images in total, with 4200 images belonging to each class (20 % testing+80 % training). During the training phase, the images are pre-processed by resizing them to the dimension of 227×227, later given as Alex Net inputs for the sake of feature extraction. Alex Net extracts 1000 features from each of the resized images, which are then used to train several machine learning models in the MATLAB Classifier for their performance. Later, the model which yielded the highest accuracy is selected for classifying the images in real-time. Cubic SVM was selected as a real-time classifier since it produced the highest accuracy for the given dataset. Later, when the movie is playing in the theatre, real-time thermal images are captured at regular intervals, pre-processed, and sent to Alex Net for feature extraction. The extracted features are then fed to the Cubic SVM model for classification as a normal or abnormal class. If the predicted class is abnormal, the theatre owner is notified with a message indicating the presence of an active recording device.

Support Vector Machine (SVM) determines the N-dimensional space hyperplane that classifies the data points distinctly. The number of features defines the dimension of the hyperplane. When the number of features increases, finding the hyperplane for separating the data points becomes more challenging. This results in data that is not linearly separable. Hence, to obtain the soft margin for non-linearly separable datapoints, a kernel optimization technique is employed. SVM is a kernel optimization technique used to obtain the soft margin between the datapoints that are non-linearly separable. SVM, being a binary classifier, can also perform multiclass classification by dividing the problem into several binary classifications. It employs a one-versus-one approach for multi class classification. In the proposed work, the Cubic kernel is used to produce the hyperplane that separates the non-linear datapoints as follows:

Let the training dataset contain set of points that are to be classified where every point is denoted as x

$$x \in R^D \tag{1}$$

where the mapping of each of the input feature vector x to a transformed basis vector $\varphi(x)$

$$\varphi(x) \in R^M \tag{2}$$

A decision boundary, also referred as a hyperplane, is a surface that separates vector space into two classes. The equation for hyperplane is given by

$$H: W^T \varphi(x) + b = 0 \tag{3}$$

where b represents bias and w denotes weight vector

The distance from hyperplane to point vector is given by

$$d_H(\emptyset(x_0)) = \frac{|w^T \emptyset(x_0)+b|}{||w||_2} \tag{4}$$

To make predictions, the hyperplane equation for first-class with positive datapoints is given as

$$WT\ \varphi(x) + b > 0 \tag{5}$$

The hyperplane equation for second-class with negative datapoints is given as

$$W^T \varphi(x) + b < 0 \tag{6}$$

The label for positive group is +1 and for negative group is -1

If the datapoint is classified correctly, the actual label and predicted label's product is greater than zero, otherwise it is less than zero.

$$y_n[w^T \emptyset(x) + b] = \begin{cases} \geq 0, & correct \\ < 0, & incorrect \end{cases} \tag{7}$$

The optimal hyperplane categorizes the total datapoints accurately if it is perfectly separable. On substitution of values in the equation for weight equation we get,

$$w^* = arg \max_w [\min_n d_H(\emptyset(x_n))] \tag{8}$$

There can be more than one hyperplane to separate the two classes, but SVM chooses the hyperplane with the maximum margin from the closest point.

Substituting for $d_H(\emptyset(x_n))$ in equation (8) we get

$$w^* = arg \max_w \left[\min_n \frac{|w^T \emptyset(x_n)+b|}{||w||_2}\right] \tag{9}$$

The final form of weight equation is

$$w^* = arg \max_w \frac{1}{||w||_2} \left[\min_n y_n[w^T \emptyset(x_n) + b]\right] \tag{10}$$

Where $\min_n y_n[w^T \emptyset(x_n) + b]$ represents the distance of closest point from the decision boundary.

The primal form of SVM for linearly separable data is given as

$$\min_{w} \frac{1}{2} ||w||_2 \tag{11}$$

$$s.t\ y_n[w^T \emptyset(x_n) + b] \geq 1\ \forall n \tag{12}$$

When the data is nonlinearly separable the new primal form of SVM is

$$\min_{w,b,\{\xi_n\}} \frac{1}{2} ||w||_2 + C \sum_n \xi_n \tag{13}$$

$$s.t\ y_n[w^T \emptyset(x_n) + b] \geq 1 - \xi_n\ \forall n \tag{14}$$

Where $\xi_n \geq 0\ \forall n$

To obtain the desired soft margin kernel optimization approach is used to project nonlinear data onto a higher dimension space.

The kernel function is generally represented as,

$$kf(x_i, x_j) = (x_i . x_j + 1)^m \tag{15}$$

where the polynomial's degree is denoted by m.

As a result, the Cubic kernel expression is given as,

$$kf(x_i, x_j) = (x_i . x_j + 1)^3 \tag{16}$$

The second subsystem involves an IR LED system controlled by the Arduino in which two P 10 boards made of IR LEDS are positioned at the back of the theatre screen to quality degrade the recorded video. When the movie is projected, the system is turned ON to emit IR rays in a specific pattern highlighting the theatre name, place, date, and time. Since recording devices are sensitive to IR rays, the pirated video is distorted. As the human eye is insensitive to IR rays, the audience can watch the movie without any disturbance.

3. Results

The performance of the proposed piracy discouraging system is evaluated by creating a theatre setup with IR LEDs array placed behind the screen. These IR LEDs are driven using an Arduino Uno to display the scrolling theatre information along with geographical location, date, and time of show. This information when though is displayed along with the movie, cannot be perceived by human eye as human eye is not sensitive to IR rays. However, the recording devices such as mobile cameras are sensitive to this IR display and the net effect is creation of overlaid information in the pirated video, which is a kind of real time embedding of scrolling visible watermark in the actual video. The sample piracy discouraging results obtained (Mobile Model: MI Note 8 Pro) are shown in Figure 2.

The distortion created in the recorded video by IR LED prototype screen is analyzed by calculating the PSNR value of each frame in the recorded video. The PSNR obtained for the images in Figure 2 is 35dB. The average PSNR values determined for pirated frames received from distinct mobile cameras (Galaxy A51, Realme 7, Galaxy M30, iPhone 11 Pro, 1 Plus 7 pro, Galaxy j7 prime, Asus Zen max pro m1) is 20 db. Since the proposed model is a prototype made with only small screen, the obtained PSNR value is around 20 dB, but it can be increased by expanding the IR LED array size.

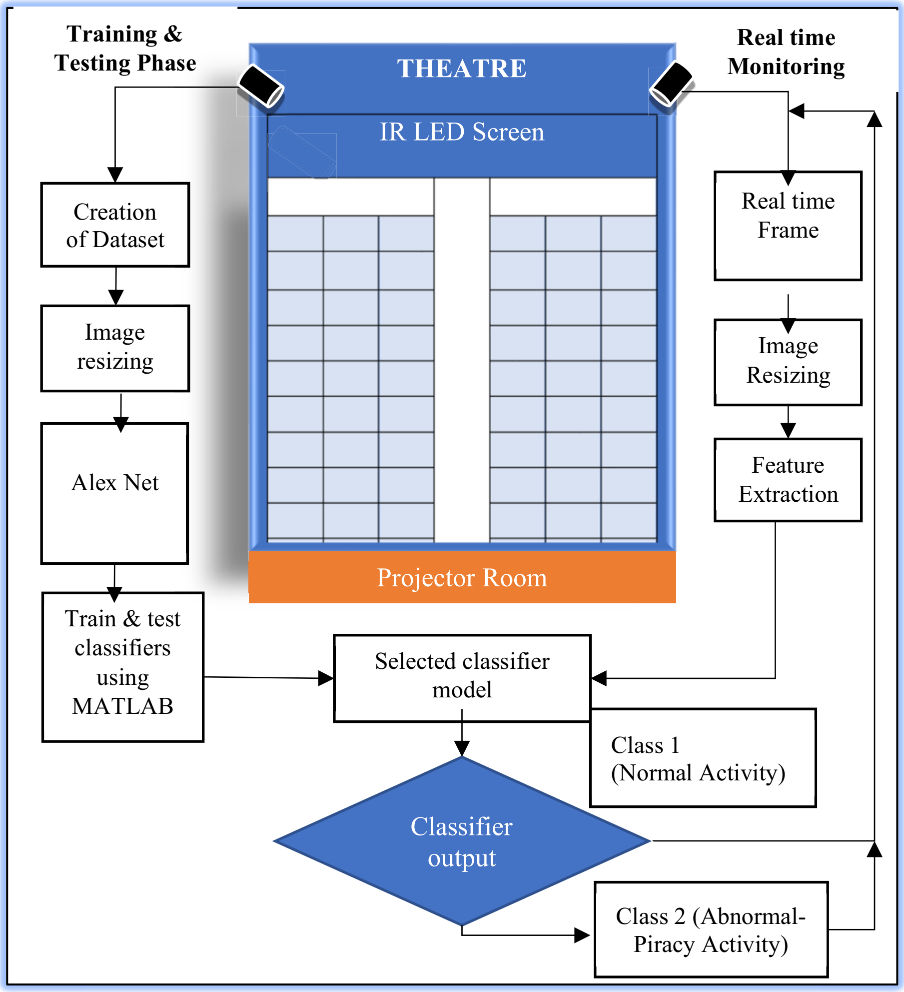
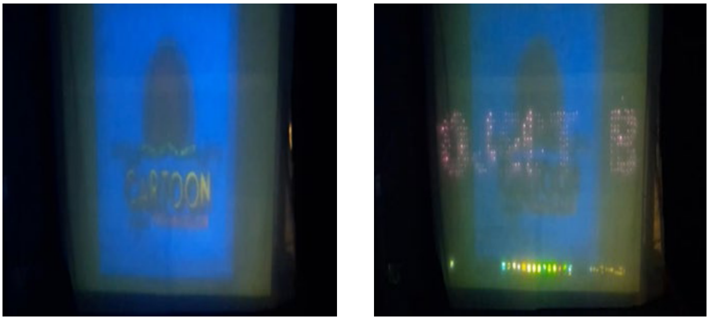


Figure 1. Proposed Machine Learning based Piracy Detection and Discouraging System



(a) Original Frame (b) Pirated Frame

Figure 2. Comparison of original and pirated frames

13 parameters are calculated and displayed in Table 1, to evaluate the performance of cubic SVM. The following are the parameters evaluated for each class: False negative rate (FNR), True positive rate (TPR), False positive rate (FPR sensitivity (SE), True negative rate (TNR), specificity (SP), Misclassification (MC), Precision (P), Recall (R), Boundary F-1 Score (BF score), Pixel Score (Pxl). DICE similarity co-efficient (DSC), and Intersection over Union (IoU),

Table 1. Parameters of Cubic SVM

Class	TP	TN	FP	FN	TPR (%)	TNR (%)	FPR (%)	FNR (%)	P	R	SE	SP	MC	IoU	DSC	PxI	BF
1	3992	4000	0	8	99	100	0	1	1	1.0	1.0	1.0	8.0	1	1	1	1
2	4000	3992	8	0	100	99.8	0.2	0	1	1.0	1.0	1.0	8.0	1	1	1	1

The confusion matrix obtained after using Cubic SVM model on the acquired database is given in Fig. 3. The ROC curve of Cubic SVM is shown in Fig.4. It can be noted from Fig. 4 that the TPR of the machine learning model is comparatively high.

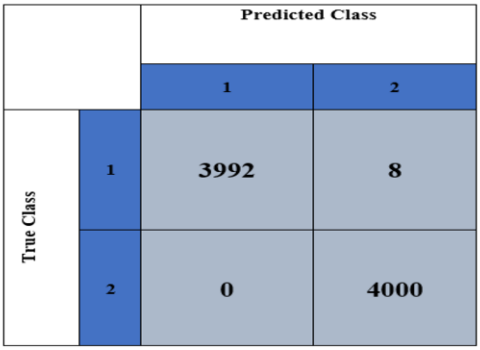


Figure 3. Confusion Matrix

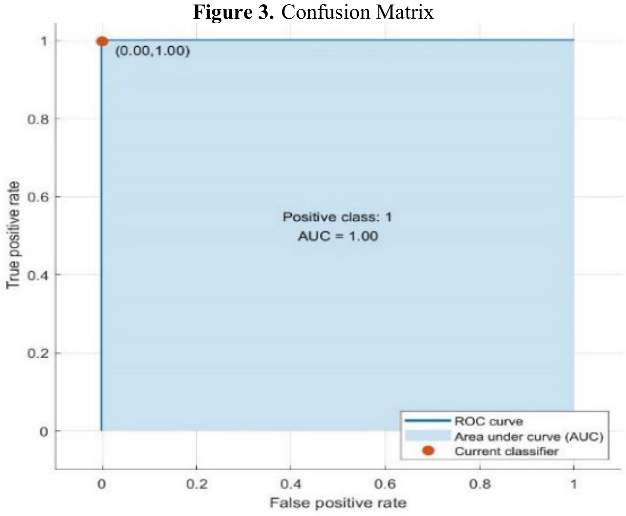


Figure 4. ROC

4. Conclusions

In recent years, movie piracy in theatres has become a major issue. To overcome this issue the proposed work focused on developing an anti-piracy system which can discourage the piracy by customized degrading the pirated video while recording Two cascaded P10 boards made up of IR LEDS array are placed behind the prototype theatre screen and are programmed using ARDUINO to display the scrolling text corresponding to theatre name, place, date, and time. This arrangement embeds a visible real time watermark into camcorders /cameras (only), creates degradation in pirated video, and aids in determining which theatre, date, and show time the piracy occurred. Unlike cameras, the audience can view the film without any disturbance since the human eye is not sensitive to IR radiation. The proposed system was tested with several recording devices (camera models) to observe the disturbance created in the illegal recording, and had obtained an average PSNR as 20 db. In future, degradation may be improved by employing high quality and a greater number of LEDs. Further, a thermal camera-based surveillance monitoring and automatic piracy activity alert system was developed using Alex Net for feature extraction and Cubic SVM for classification of surveillance frame acquired from thermal camera installed in the theatre. The system achieved an accuracy of 99.9% for identification of presence of active camcorders in thermal image frames.

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