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An Approach of Data Hiding in Video Steganography using Object Detection

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Abstract*: *In today's digital world, the growth of internet and communication technology has significantly increased the transmission of data in large amount. As a result, the secure transmission of data has become a pre-requisite. Generally, for video steganography whole frame/frames are utilized to conceal secret data which usually causes visual distortion. To overcome this problem, the paper presents a new video steganography approach based on moving object detection and tracking where the secret data is embedded in LSB (a least significant bit) of moving objects. Background subtraction using GMM (Gaussian mixture model) is used for detection in objects that possess motion. Albeit the embedding in moving objects is cumbersome, however, pixels selection of moving objects in videos provides more security than embedding in each frame considering as an individual image. Also, moving objects causes less distortion after embedding making it hard for the intruder to detect, ensuring the imperceptibility of the stego-video. Eventually, the proposed technique is compared with LSB embedding exclusively in frames of the video, and the results illustrated that the proposed scheme performed better than the simple LSB embedding technique.

Index Terms: Background Subtraction, LSB, Object Detection, Video Steganography.

I. INTRODUCTION

Nowadays communication of data is the most important task that is carried out in all walks of life. Therefore, the safety and secrecy of data is an important concern in the present scenario. This needs to form policies to avert, discern, document and counter threats to the information present on the internet. Information security policies and processes commonly involve both physical and digital protection for the data from unauthorized use, access, reproduction or demolition [1]. These measures can include network intrusion detection systems, encryption key management, and many other techniques. One of the most frequently used information security technique is cryptography which is the process to modify the message in an encrypted form also known as ciphers form using some encryption key known to sender and receiver only. The other commonly used technique for secure communication is steganography, which is the art of hiding message so that the secret message is not visible to the third party and not identified easily. It conceals valuable information in the general data, and the resultant (stego object) must resemble the original form. The flowing time has integrated cryptography and steganography to conceal the data for transmission. In steganography, data can be embedded in any multimedia form such as audio, text, images, and videos. The prime purpose of steganography is to resist any suspicion by the third party, and if any suspicion is raised, then the algorithm is of no use. Steganography takes into account the human visual system (HVS) which cannot recognize slight distortion in the cover object. The general concept of steganography is illustrated in Fig. 1.

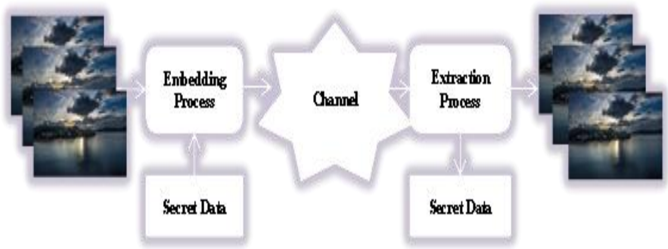

Fig. 1 Steganography general block diagram

Today, digital videos have become one of the most frequently utilized cover medium for steganography because of the advantages it offers. It can hide massive amount of data due to multiple frames of video and videos provide more security because it causes minor modifications after embedding secret data in the video streams hence it is hard to detect the embedded data by simple steganalysis algorithms. There are three primary requirements for a successful steganography technique: capacity, imperceptibility, and robustness [2]. Moreover, the values of these requirements have an influence on each other as capacity increase means more data is hidden inside a cover object results in degradation of the visual quality. However, a successful technique must provide a trade-off between these requirements and for this; videos are the perfect choice as a cover object to provide a good trade-off between these three requirements. Typical steganography methods can be classified into the spatial domain and transformation domain methods. Spatial domain has an advantage of storing large capacity [3] and on the other hand transformation, ones are often equipped with a robust function from being attacked. The spatial domain includes the Least Significant Bit (LSB), pixel value differencing, pixel indicator, etc. and transform domain includes Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT). The embedding using these techniques can be done in a complete frame or by using only some specific region called ROI (region of interest).

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ROI could be any object in the frame or video whether static or moving and detection of the objects can be done by using different object detection techniques. This paper focuses on moving objects detection as ROI for embedding using LSB technique. Object detection is the procedure of detecting occurrences of the real-world objects such as bicycles, vehicles, faces, and buildings in frames or images. Object detection algorithms usually involve features extraction and machine learning techniques to identify occurrences of an object of the particular type. These are often used in applications such as surveillance, security, image retrieval, and many other areas. In videos object detection involves confirming the existence of an object in frame/image sequences and pinpointing it precisely for recognition. Object tracking is a method to observe an object's changes, spatial and temporal, throughout a video sequence, counting its presence, shape, size, position and other attributes Yilmaz et al. [4]. It can be done by resolving the temporal correlation problem, i.e., the matching problem of the target area in successive frames of a video captured at closely spaced time intervals. Both the processes are firmly correlated because the process of tracking generally starts with the detection of objects, and object detection frequently in subsequent frame sequences is often required to assist and confirm tracking. In this research study, an algorithm is presented using the Least Significant Bit (LSB) method to hide data in the video with object detection. The primary aim of this paper is to achieve the two primary goals of steganography: 1) The steganography algorithm must be secure enough to resist attacks and 2) The visual quality of the stego-object must be good. The remaining paper is organized as follows: Section 2 presented the related work and in Section 3 introduction to object detection techniques are presented with the visual result of the used technique. In Section 4, the proposed approach flowchart is delineated, and Section 5 concludes the paper.

II. RELATED WORK

Over the last decade, numerous video steganography algorithms have been proposed using different spatial and transform domain techniques. Video steganography using object detection is a new area that calls for more research. This section describes the related work of video steganography using LSB and object detection. Liu et al. [5] proposed a steganography algorithm by using variable length code (VLC) for embedding in MPEG-2 videos. The embedding was done using LSB method utilizing A/S trees of VLC domain which are predefined in a standard table of VLC. The mapping was done using the table and embedding was done automatically by generating a pseudo-random number sequence. The experimental results suggested that the average PSNR of the proposed technique was 41 dB. Additionally, Moon and Raut [6] presented a video steganography scheme to improve the payload by employing a 4LSBs method for hiding data. The proposed scheme security was upgraded by using computer forensics as an authentication tool, and the security analysis was done using the histogram. The algorithm provided three layers of security using encryption and computer forensics with steganography. The obtained results signified that the proposed scheme has 4 times more capacity than 1LSB. Further, Dasgupta et al. [7] presented a novel steganography algorithm for efficient and effective data hiding in videos using 3-3-2 LSB as a base technique and were enhanced with Genetic Algorithm for optimal imperceptibility of hidden information. An anti-steganalysis method was also used to test the innocence of the stego frame as compared to the original frame. The results show that the PSNR and IF (Image Fidelity) is better after optimization as compared to the base technique. Ramalingam and Isa [8] proposed a simple and secure video steganography algorithm for AVI videos based on Haar Integer Wavelet Transformation. The secret text was embedded in the LSB of RGB components which were normalized to avoid overflow/underflow. The proposed approach used 1 level Haar IWT (Integer Wavelet Transform) for embedding in the red, green and blue (RGB) components of the frames of the video. The results demonstrated that there was no change in the size of the video file after embedding and statistical values like mean and median did not change the histogram. Sudeepa et al. [9] used randomization and parallelization to present an efficient video steganography scheme using LSB insertion. The encryption of secret text was done using the symmetric key, and the frames were chosen randomly with Feed Back Shift Register (FSR) for embedding the secret data. Four threads were utilized for the parallelization process, and the processes of embedding and encryption were done in parallel to improve the throughput. Additionally, Singh and Singh [10] presented a new approach of hiding information by employing pixel-based motion detection in the frames of the video. Background Subtraction was utilized to detect the background and foreground pixels in video frames. The secret data was embedded in foreground pixels using the LSB technique. The proposed approach preserved video quality and supported ample data storage. The temporal differencing method was used for pixels selection to hide lossless data in the raw video frames. The scheme was not able to recover the original cover video while extraction of the secret data. Mstafa and Elleithy [11] presented a new video steganography scheme by utilizing multiple-object tracking where the motion areas were extricated by using Kalman Filter. The secret message was encoded using Hamming Code (15,11) and was embedded in the 1 and 2 LSBs of the RGB(Red, Green, Blue) components. After that, Mstafa and Elleithy [12] suggested another algorithm relied on Kanade Lucas Tomasi (KLT) tracking algorithm with Voila Jones for face detection and error correcting code was used for the secret data pre-processing. The secret data was initially encoded by using Hamming Code and after that encryption of the secret data was done to ensure double security. The embedding was done using 1, 2, 3, and 4 LSBs of the facial pixels. Video steganography using object detection techniques is an emerging area as embedding in moving objects provides better visual quality and security. Some of the object detection techniques are also being discussed with their advantages and disadvantages in order to select a suitable technique for video steganography.

III. OBJECT DETECTION TECHNIQUES

Object detection is the task of locating/finding an object in a given video sequence or an image.

The human eye can quickly detect the objects present in a video or an image with different viewpoints and even if the frame is scaled, rotated or translated. However, it is a strenuous task for machines to detect objects present in a video. It needs more efforts to train a machine for the objects detection as compared to the human visual system. Although with the technological advancement there exist computer vision tools which made object detection comparatively easy but it still needs lots of data for training of the machine. Object detection is a method that differentiates the foreground moving objects from the stationary background. The first step of the object detection techniques is to discern a foreground object which can be utilized for further operations. Several methods have been used in literature to detect an object such as Voila jones method and the KLT algorithm. Some of these methods are discussed in this section.

A. *Viola Jones*

In 2001, Paul Viola and Michael Jones presented an object detection technique called Viola-Jones which is used for face detection [13]. This was the first efficient algorithm for face detection which made computer vision popular for real-world problems. The basic idea behind this technique is that it contains a sliding window across the frame and at every location, it tries to evaluate a face model. It used different simple binary classifiers for training and employs Haar features for detection. The features are simple rectangular features which are extracted by using the sum of pixels difference of areas inside the rectangle.

B. *KLT (Kanade Lucas Tomasi)*

The KLT algorithm employs by discovering good feature points known as Harris corners in the facial region starting from the initial frame and are traced through all the video frames. Between two consecutive frames, a point will have a corresponding feature point and the displacement between pair points can be calculated using motion vectors [12]. KLT is a feature point algorithm that deploys SSD (sum of squared intensity differences) of the frame which needs to be tracked as the basis for measurement to execute the feature points of measurement. Tracking of the object in a video sequence can be done using KLT whereas Voila Jones can be used for detecting features.

C. *Kalman Filter*

Kalman filter is an optimal estimation used to evaluate the state of a linear system which is presumed to be dispersed by a Gaussian [14]. The object is tracked by predicting the position of the object using the previous position information and confirming the object's position at the position predicted. The observed function and the motion model should be learned by a sample of frame sequences prior to object tracking.
These above-discussed object detection techniques have some advantages and disadvantages mentioned in Table 1.

IV. PROPOSED APPROACH

This section presents a new video steganography scheme using background subtraction and blob analysis. Videos include static and motion objects, where embedding in static objects is similar to the embedding in an image which may be attacked by image steganalysis technique. Also, the embedding in the non-motion area sometimes produces visual distortion in a video which can be visible even to the human eye. Embedding in motion objects/ moving objects improves the embedding strength and increases the security of the stego-video without any noticeable distortion to ensure imperceptibility. The proposed approach utilized moving objects for embedding the secret data inside a video. The moving objects are selected as a venue for hiding secret data for making it challenging to steganalyze and resist from attackers and intruders. The basic flow of the proposed approach is shown in Fig. 2. The moving object area is chosen for embedding, and the non-motion area is discarded after object detection. The details of object detection, embedding and extraction process are illustrated in this section.

Table 1 Advantages and disadvantages of different object detection techniques

Technique	Advantages	Disadvantages
Viola Jones	Simple and easy to implement	The computation time of detection is high, need many training examples and also causes multiple face detection problems. Further, it was not able to detect faces after rotation and scaling processes.
KLT	Reduces computation time because object need not be detected in each frame they are present	Gives an error when motion is significant, so to fix it key points are to be matched.
Kalman Filter	It tolerates small occlusions. Whenever an object is occluded, it will skip the measurement correction and keep on predicting, till getting object again into localization.	Accurate results are obtained only when the object moves at a constant velocity or constant acceleration

A. *Object Detection using Background Subtraction*

The existing object detection techniques such as Viola-Jones, Kalman filter and KLT have many disadvantages discussed in the previous section. To overcome the drawbacks of the above techniques, background subtraction and blob analysis technique are used for the proposed approach. Background subtraction accounts for one of the most prominent methods for object detection. It divides the frame into two complementary pixels set: one is the foreground details which are the objects of interest, and another one is a complementary background set.

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These two pixels set constitute the entire frame or image. This process works by removing the background pixels by subtraction and thresholding so that the actual region of interest is left to be worked upon [15]. There exist many background subtraction techniques in the literature with different segmentation techniques and models [16][17] such as mean method, graph cut method, Gaussian mixture model, etc. [18].

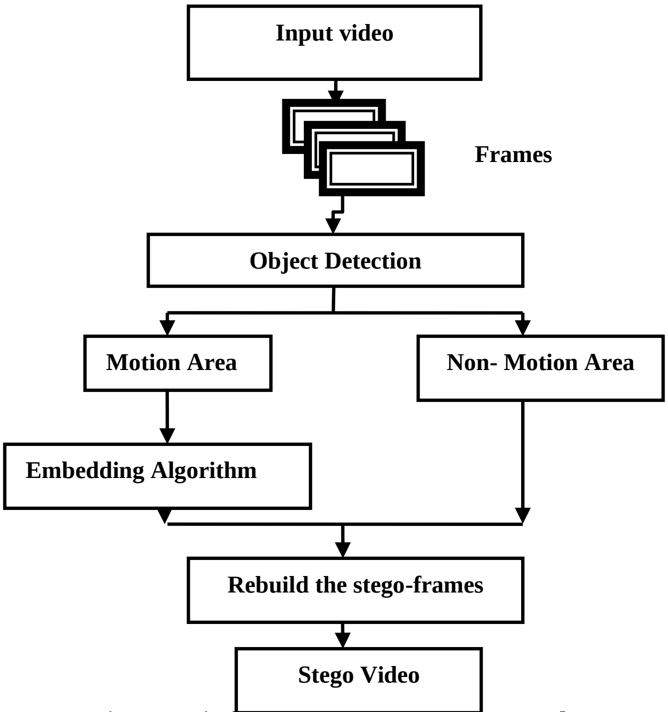

Fig. 2 Basic flow of the proposed approach

The proposed method used a Gaussian mixture model (GMM) for background subtraction [19][20]. A few frames are initially used to initialize the Gaussian mixture model (GMM).In this method, the observer frame is compared with the frame that does not have the object of interest. The regions of the frame plane with the notable difference between the estimated and observed frames denote the location of the object of interest based on the thresholding on a number of pixels [18]. These identified foreground pixels are then considered as a single blob object as these pixels have relatively constant intensity. These blobs are then surrounded with rectangular boxes around them. Blob analysis is a method mainly used to categorize specific regions in a frame that differ in various properties such as illumination color in contrast to the surrounding region. Blob is a region of space in which the densely present foreground pixels are connected in which have some properties such as illumination is constant or approximately constant [21]. In the proposed method GMM is employed to distinguish between the background and the foreground pixels to discern the foreground pixels from the background. After discerning noise need to be removed from the foreground pixels and the result of background detection with noise removal is used to generate a mapping of pixels of foreground objects and procure the video frame objects. The proposed approach used this technique for moving objects detection because it is robust and less complex in terms of time. The results of the considered object detection technique are shown in Fig. 3 with the original cover video frame, clean foreground and the result of the object detected surrounded by a rectangular box.

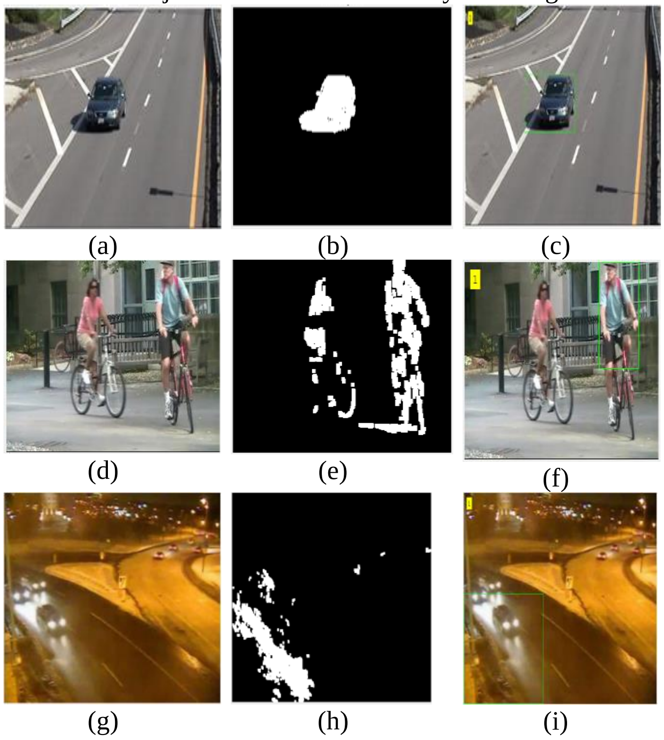

Fig. 3 Result of background subtraction and blob analysis: (a), (d), (g) represents original video frame, (b), (e), (h) illustrates clean foreground and (c), (f), (i) personify object detected surrounded with a rectangular box

B. *Embedding Process*

The cover data in each video frame is the motion objects obtained through background subtraction. The motion objects change with every frame, in size and number of objects. In each video frame, background subtraction is applied to obtain a foreground mask and using blob analysis four corners of every moving object is calculated and used for embedding. The embedding process is done in RGB (Red, Green, and Blue) components of the moving object pixels by deploying the LSB technique. LSB is the simple approach to embed data in a cover video by making changes in the least significant bits of the pixel [22]. The proposed scheme deployed 3-2-3 LSB representing 3 bits of red, 2 bits of green and 3 bits of blue color components for embedding. The secret data is converted into binary bits, and one byte of secret data is embedded in each pixel of RGB components using LSBs at a time. The first three bits of secret data is concealed in three LSB bits of the red pixel, next two bits of secret data is concealed in two LSB bits of the green pixel, and last three bits of secret data is concealed in three LSB bits of the blue pixel. This particular arrangement is considered by taking into account the human visual system, and in RGB components the human eye is more sensitive to green color. Therefore, without immolating the visual quality of the stego-video, a good hiding capacity can be achieved. The steps for embedding process are as follows:

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Algorithm I

1. Input cover video (V)
2. Convert video into frames $(f_1, f_2, f_3 \ldots f_n = F_n \leftarrow V)$
3. Apply background subtraction to the frames for motion objects (Mo) extraction; $Mo_1, Mo_2 \ldots Mo_n \leftarrow F_n$
4. Differentiate motion objects area $(Mo_1, Mo_2 \ldots Mo_n)$ and non-motion area $(Nm_1, Nm_2 \ldots Nm_n)$
5. Convert the secret data (S) into binary form for embedding
6. Embedding, $LSB(RGB(Mo_1, Mo_2 \ldots Mo_n)) \leftarrow S$
7. Combine embedded motion area (EM) and non-motion area to build stego-frames (SF_n), i.e., $Sf_1, Sf_2, \ldots Sf_n \leftarrow (EMo_1, EMo_2 \ldots EMo_n) + (Nm_1, Nm_2 \ldots Nm_n)$
8. SV(Stego-video) $\leftarrow Sf_1 + Sf_2 + \ldots Sf_n$

After embedding the secret data in motion objects using background subtraction and blob analysis, the regenerated stego-video is transmitted through a communication channel. The process of extraction is elucidated in the next sub-section.

C. *Extraction Process*

At the receiver side, the process of extraction is reverse of the embedding process with stego-video as input, and the frames of the stego-video are extracted for the process. The object detection technique is applied to extricate the motion area of the frames for the secret data extraction. The binary form of secret data is extracted from the 3-2-3 LSBs of RGB components from the embedded motion objects. Algorithmic steps of the extraction process are as follows:

Algorithm II

1. Input stego-video (SV).
2. Extract stego-frames $(Sf_1, Sf_2, \ldots Sf_n \leftarrow SV)$.
3. Apply background subtraction and extract motion objects, $EMo_1, EMo_2 \ldots EMo_n \leftarrow Sf_1, Sf_2, \ldots Sf_n$.
4. Differentiate motion objects area $(EMo_1, EMo_2 \ldots EMo_n)$ and non-motion area $(Nm_1, Nm_2 \ldots Nm_n)$.
5. Extract secret data, $S \leftarrow LSB(RGB(EMo_1, EMo_2 \ldots EMo_n))$.
6. Rebuild cover frames, $F_n \leftarrow Mo_1, Mo_2 \ldots Mo_n + Nm_1, Nm_2 \ldots Nm_n$.
7. Regenerates cover video $V \leftarrow F_n$.

V. RESULTS AND DISCUSSION

This section dispenses experimental results with a discussion of the results obtained by using MATLAB version R2017a. The videos used for experiments are from public datasets Video Trace Library [23] and CDNET [24]. All the videos data set used for the experiments is in H.264/AVC video standard. The videos from Video Trace Library are in CIF format which is converted into H.264/AVC standard using FFmpeg tool [25] with default quantization parameter. The videos used for experiments are of different resolutions, three videos with 325x288 resolution and other videos are of 624x420 resolutions with a frame rate of 25 frames per second. The secret message is a text file which is embedded only in the moving objects of the frames in a cover video. One of the main concerns of steganography is the quality of the stego-video which is measured and evaluated in this section. The performance parameters used for analysis are PSNR, MSE, and SSIM which are discussed in this section with the obtained results. The visual quality of the stego video is calculated by employing the PSNR (peak signal-to-noise ratio) which is an objective metric. PSNR estimates the difference between the cover and the stego video which is calculated in decibels (dB) using the equation 1.

$$PSNR = 10 * \log_{10} \frac{(Max_{or})^2}{MSE} \quad (1)$$

Here, Max_{or} is the maximum pixel value of the original frame, and MSE (Mean Squared Error) can be measured by using the equation 2.

$$MSE = \frac{1}{r * c} \sum_{i=0}^{r-1} \sum_{j=0}^{c-1} (o_{i,j} - s_{i,j}) \quad (2)$$

Here, o and s represent the original and the stego frames, respectively and r, c indicates the resolution of the frames. Another metric SSIM (Structural Similarity) Index Metric is also used for quality analysis of the video which is calculated by using the equation 3 [26].

$$SSIM\ (or, st) = \frac{(2\mu_{or}\mu_{st} + C_1)(2\sigma_{or,st} + C_2)}{(\mu_{or}^2 + \mu_{st}^2 + C_1)(\sigma_{or}^2 + \sigma_{st}^2 + C_2)} \quad (3)$$

Here μ_{or}, μ_{st} are the mean intensities, σ_{or}, σ_{st} refers to the variance of the original and stego frames respectively and $\sigma_{or,st}$ represents the covariance of the videos; C_1 and C_2 are the constant values. The value of SSIM lies between 0 and 1, and the values near 1 represent better quality. The obtained results for different videos are presented in Table 2 with their respective PSNR and SSIM values. Also, Fig. 4 shows the value of PSNR for first 150 frames of all the videos.

Table 2 PSNR and SSIM values for different videos

Video	PSNR	SSIM
Video1	42.32	0.9842
Video2	35.57	0.9551
Video3	41.56	0.9986
Video4	40.39	0.9895
Video5	39.83	0.9873
Video6	41.37	0.9924
Video7	35.25	0.9794

The proposed scheme attained high PSNR value above 35db for all the videos stipulating high visual quality of the stego video. The obtained SSIM values are also close to 1 for all the videos. Overall the experimental results achieved high imperceptibility for the stego-videos using the proposed scheme.

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The results of the scheme are also compared with simple 3-2-3 LSB technique, i.e., embedding is done in the actual frame without considering any moving object. The comparison of PSNR values obtained by using pure 3-2-3 LSB and the proposed scheme is shown in Fig. 5.

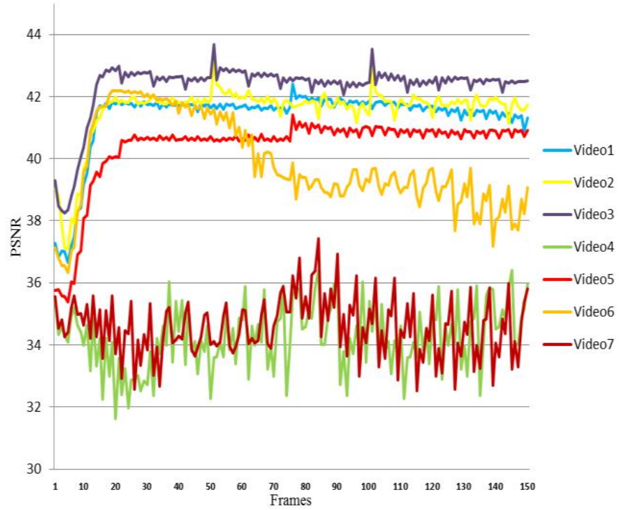

Fig. 4 PSNR values of the first 150 frames of all the videos

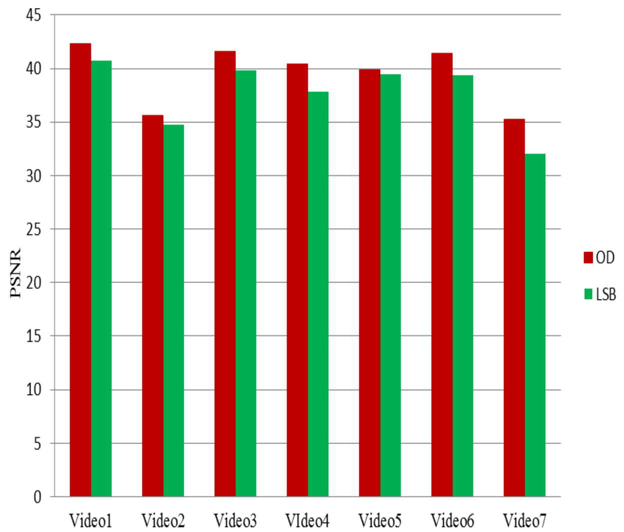

Fig. 5 Comparison of 3-2-3 LSB for the whole frame and the proposed scheme

The proposed video steganography scheme utilized motion objects for embedding in video frames to improve the visual quality of the stego video. The human eye is very poor in detecting slight changes in a video, especially in moving objects, focusing on this weak point of the human visual system the embedding venue is chosen. Despite embedding exclusively in the whole frame of the video, embedding in moving objects improve the quality of the stego-video as little distortion in moving objects is not visible by the human visual system. The overall obtained results for all the videos with high PSNR and SSIM value indicates the minimal distortion for the stego-video. Furthermore, the comparison results also clearly indicate high PSNR values of the proposed scheme targeting good visual quality. Also, the proposed algorithm is more secure as compared to the other video steganography algorithms that embed secret data in the complete frame because the embedding at some particular regions of the frame is difficult to detect and steganalyze.

VI. CONCLUSION

This paper presented an approach for embedding secret data in a video sequence using the LSB technique with object detection. The embedding venue was selected by utilizing background subtraction and blob analysis, object detection method using GMM. In this method, the background subtraction was done to obtain a foreground image which helped to detect objects in a video and using blob analysis method particular object region was categorized for embedding. In the proposed approach least significant bits of the moving object pixel were replaced with secret information without causing much distortion in the original video. The experimental results exhibit the better visual quality of the stego video with average PSNR above 41 dB for all the videos. Also, the proposed scheme outperforms the basic LSB technique used for embedding in the complete frame. The proposed method provides more security and imperceptibility as the data was embedded in the moving objects and the changes in the moving objects are difficult to notice rather than the static region in a video. For future work to improve the robustness, transform domain techniques can be applied for embedding.

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