VIDEO STEGANOGRAPHY FOR SECURE COMMUNICATION BASED ON ADJOIN PREDICTION AND VECTOR QUANTIZATION

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ABSTRACT
The swift progress of data transfer through internet has made data to reach the destination at a faster manner. At the same time, the data being transferred through internet can be reorganized and misused through hacking. Many data hiding scheme using Particle Swarm Optimization (PSO) method and Structural Similarity (SSIM) indexes have been carried out but compromising image quality when applied to video frame and reversible method not effective in producing high performance code streams. In this work a reversible encoding method called, Adjoin Prediction and Vector Quantization (APVQ) are presented. Finally, to optimize the video quality and embedding capacity, the embedding capacity is adjusted according to the property of a frame in Grade Reversible Adjoin Prediction mechanism. Experimental analysis shows that our mechanism is able to reduce the runtime to extract the secret information by 31.43% and improves the true positive rate by 11.79% compared to the state-of-the-art works.
Keywords: Particle Swarm Optimization, Structural Similarity, Reversible Encoding, Adjoin Prediction, Index value, Region Match, Vector Quantization

1. Introduction

With immense development in digital arena, effective steganography mechanisms are highly required to ensure video quality with minimal runtime being transmitted over the internet for secure communication of data between the sender and the recipients. A data hiding scheme based on spatial domain called Particle Swarm Optimization was applied in [1] ensuring image quality in addition to the distortion tolerance.

Data hiding using discrete cosine transform [2] preserved the visual quality at a greater level by applying error propagation scheme. Another method to preserve the image quality was presented in [3] using reference image framework. The method not only ensured image quality but also subjective sharpness. Additionally the work using data hiding framework called Bit Plane Complexity Segmentation [4] ensured security and extracted data frames without compromising the quality of video. Likewise the work Flexible Macro block Ordering [5] reduced the distortion level and also improved the message extraction accuracy using quantization scale.

Mechanisms for information embedding information in hardcopy prints are significantly used in a varied manner in several applications. A method called clustered dot halftone prints was applied in [6] to preserve image quality. A binary image steganography scheme was applied in [7] to preserve effective the quality of image and embedding capacity through local texture patterns. However, false alarm rate increased with the increase in the number of images being submitted. In order to reduce the false alarm rate in [8], Generalized Likelihood Ratio Test (GLRT) was applied to various test images.

Another method based on Least Significant Bits (LSB) was presented in [9] to minimize the false alarm rate with respect to natural clipped images. Decision theory and quantized samples were applied in [10] with the objective of reducing the false alarm rate with quantized observation.

Speed optimization, network quality has improved the transmission of data beyond the limit over the Internet. As the Internet is a public access network, certain data has to be preserved from malicious users which can be addressed through steganography. In [11], Blakley's secret sharing method and steganography was applied for secret sharing of data with the objective of improving the quality of data being sent and received at the other end. However, the runtime was compromised. In order to reduce the runtime, local model of medium content [12] was applied resulting in reducing the false alarm rate. However, the rate of imperceptibility remained unaddressed.

In [13], voice activity detection algorithm was presented in Voice over Internet Protocol (VoIP) to ensure higher rate of PSNR. However, the rate of security and hiding capacity of cover image was not solved. To address these issues, Pixel Value Differencing (PVD) [14] approach was presented based on four sub bands, LL, LH, HL and HH respectively. In [15], EMSBI structures the highly efficient embedded payload using a high capacity secret data hiding method. The initial process of embedding is carried out in Enhanced Most Significant Bit Irreversible (EMSBI) method using the binary values. In [16], the average prediction error rate factor was experimented for improvement of predicting errors while embedding. In [17], the polynomial hashing in AIRFT ensures lesser complexity of data hiding and achieves pseudo randomness of the output without any packet (i.e.,) information loss on the video frame. In [18], technique is applied for improve the security on video files in communication process. In this paper, a Secure Hash Polynomial Function to provide multi-layer security according to the modular additions and density functions is presented.

Based on the aforementioned methods and techniques, in this paper, a reversible encoding method called, Adjoin Prediction and Vector Quantization (APVQ) is presented to improve the performance level on video code streams without compromising the video quality. This paper is organized as follows. Section 2 introduces a reversible encoding method using Adjoin Prediction and Vector Quantization using neat flow diagram and algorithmic description. Section 3 provides the experimental results and comparisons with existing work are reported in Section 4. Lastly, Section 5 concludes the paper.

2. Design of Video Steganography based on Adjoin Prediction and Vector Quantization

The art of Video Steganography hides the secret message and make it complicated for attackers to identify the prevalence of secret messages. Our research mainly focuses on images, audio, and video as cover media. Our research work is carried out in Video Steganography, where data hiding is performed on video files and the data to be hidden is of the form audio, image or text.

Figure 1 shows the block diagram of a simple reversible scheme where a video in which data is embedded is referred as a cover video and the video which is used for carrying secret data is termed as stego video. Video Steganography comprises of the reversible and irreversible scheme. In the proposed Reversible Video Steganography method based on Adjoin Prediction and Vector Quantization (APVQ) is presented where the secret data (i.e. image, audio or text) is embedded into a video and then recovers the video devoid of losing any information when the secret data is extracted on the receiving end.

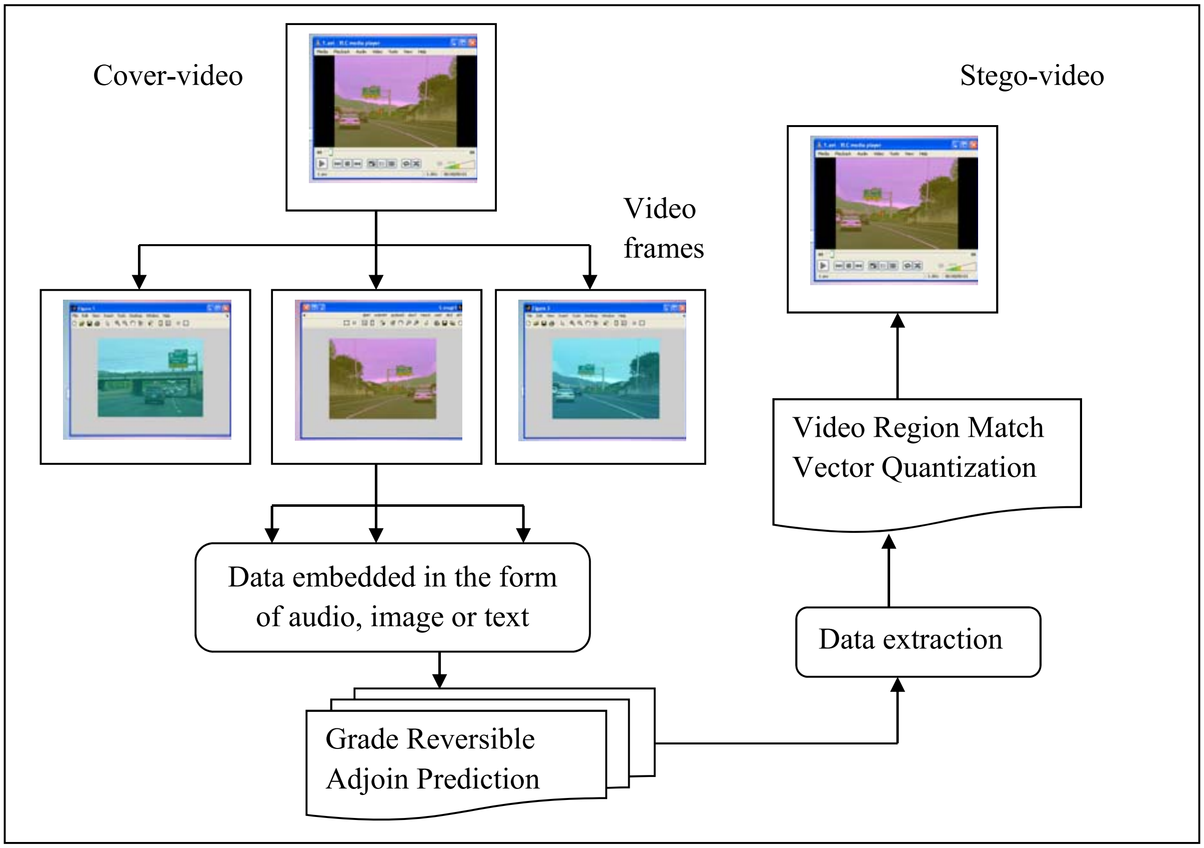


Fig. 1 Block diagram of Reversible Video Steganography

Figure 1 shows the block diagram of Reversible Video Steganography. The Reversible Video Steganography followed using Adjoin Prediction and Vector Quantization (APVQ) consists of an input video file. The input video file and the data to be hidden are obtained from the Internet Archive that includes texts, audio, moving images, and software as well as archived web pages.

The data embedding is performed using Grade Reversible Adjoin Prediction aiming at improving the performance level on video code streams without compromising the video quality. In contrast, data extraction is performed to obtain the stego video using Video Region Match Vector Quantization. The objective behind the application of Video Region Match Vector Quantization is to attain better visual quality of information with minimal runtime. The elaborate description of APVQ method is presented in the forthcoming sections.

2.1 Design of Grade Reversible Adjoin Prediction mechanism

In this section a reversible encoding mechanism called, Grade Reversible Adjoin Prediction (GRAP) is presented to enhance the performance level on video code streams. To embed secret data (i.e. image, audio or text) into the cover video frame GRAP mechanism decides the capacity of the secret data per pixel in a video frame. Figure 2 shows the flow diagram of embedding process performed using Grade Reversible Adjoin Prediction mechanism

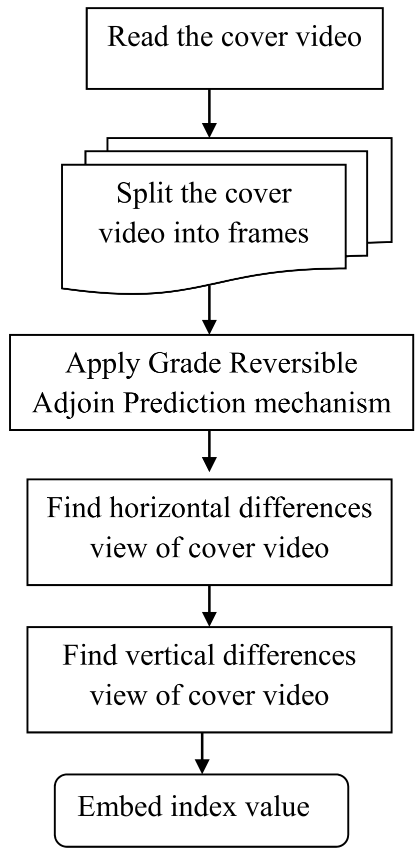


Fig. 2 embedding process for secret data

As shown in the figure 2, the embedding process starts with the input as cover video file. The cover video file is split into several video frames. In each frame, horizontal differences and vertical differences view of cover video file is obtained. In the encoding side, secret data is embedded accordingly with GRAP mechanism. Figure 3 given below shows the block diagram of mechanism.

	$Pixel_a$	$Pixel_b$
$Pixel_c$	$Pixel_d$	$Pixel_e$
$Pixel_f$	$Pixel_g$	i

Fig. 3 Grade Reversible Adjoin Prediction with 7-neighboring pixel

The figure 3 given above shows the Grade Reversible Adjoin Prediction with 7-neighboring pixels. Let us consider a cover video to which the secret data has to be embedded with a size of '$512 * 512\, pixels$' and the pixel value lies between '$0\, and\, 511$' and is mathematically formulated as given below.

$$Pixel(i,j) \in \{0 \leq i,j \leq 511\} \quad (1)$$

From (1) the pixel size of the cover video file lies between 0 and 511. The GRAP mechanism uses five attributes 'att_i' to define pixel regions 'PR_i', namely strong horizontal 'SH', strong vertical 'SV', balanced 'B', weak horizontal

'WH' and weak vertical 'WV'. Then the horizontal and vertical differences view of the cover video file is mathematically formulated as given below

.

$$Diff_H = \left(Pixel_f - Pixel_g\right) + \left(Pixel_c - Pixel_d\right) + \left(Pixel_a - Pixel_b\right) \quad (2)$$

$$Diff_V = \left(Pixel_f - Pixel_c\right) + \left(Pixel_d - Pixel_a\right) + \left(Pixel_e - Pixel_b\right) \quad (3)$$

Input: Cover video frames '$CVF_i = CVF_1, CVF_2, \dots, CVF_n$', pixel size, attributes '$att_i = att_1, att_2, \dots att_5$', Pixel Regions '$PR_i = PR_1, PR_2, \dots, PR_5$', secret data '$SD$'

Output: Stego video CVF_i'

Step 1: **Begin**
Step 2: **For** each cover video frame CVF_i
Step 3: Measure horizontal view of cover video frame using ()
Step 4: Measure vertical view of cover video frame using ()
Step 5**:** $\boldsymbol{if}\ (Diff_V - Diff_H)\ lies\ between\ (8\ and\ 12)$
Step 5: $i' = Pixel_g$,
Step 6: 'PR_i'= SH
Step 7: **end if**
Step 8: $\boldsymbol{if}\ (Diff_V - Diff_H)\ lies\ between\ (4\ and\ 8)$
Step 9: $i' = Pixel_d$,
Step 10: 'PR_i'= SV
Step 11 : **end if**
Step 12: $\boldsymbol{if}\ (Diff_V - Diff_H)\ lies\ between\ (4\ and - 4)$,
Step 13: $i' = i$,
Step 14: 'PR_i'= B
Step 15: **end if**
Step 16: $\boldsymbol{if}\ (Diff_V - Diff_H)\ lies\ between\ (-4\ and - 8)$,
Step 17: $i' = (Pixel_f + Pixel_g)/2$
Step 18: 'PR_i'= WH
Step 19: **end if**
Step 20: $\boldsymbol{if}\ (Diff_V - Diff_H)\ lies\ between\ (-8\ and - 12)$,
Step 21: $i' = (Pixel_c + Pixel_g)/2$
Step 22: 'PR_i'= WV
Step 23: **end if**
Step 24: Obtain i and i' value
Step 25: Embed the index value using LSB in the successive pixel value
Step 26: Integrate the pixels generated from step 24 and step 25 to form new stego video CVF_i'
Step 27: **End for**
Step 28 : **End**

Fig. 4 Embedding using Grade Reversible Adjoin Prediction

Figure 4 given above shows the steps involved during embedding using the Grade Reversible Adjoin Prediction. For each cover video frame, before performing the data hiding process, Grade Reversible Adjoin Prediction efficiently predicts the adjoin neighboring pixels through which the data hiding process can be performed. In order to predict the adjoining neighboring pixels, grade reversible method is applied where the horizontal view of cover video frame and vertical view of cover video frame is obtained for embed the secret data in best area of the pixel location.

Based on these two values, the new 'i'' value and pixel region 'PR_i' values are obtained that forms the adjoining neighboring pixels where the actual data hiding (i.e. audio, image or text) is embedded. It also embeds an index value in each video frame to ensure that the secret data recovered back with higher quality rate on decoding side. The index value points to the adjoining secret key of a state secret frame to easily achieve the performance rate.

2.2 Design of Video Region Match Vector Quantization

Once the effective embedding is performed using Grade Reversible Adjoin Prediction where the adjoining secret key of a state secret frame easily achieve the performance rate, the corresponding extraction process is performed. In the proposed Adjoin Prediction and Vector Quantization (APVQ) method, in the decoding side, Video Region Match Vector Quantization is used. Figure 5 given below shows the extraction process performed using Video Region Match Vector Quantization.

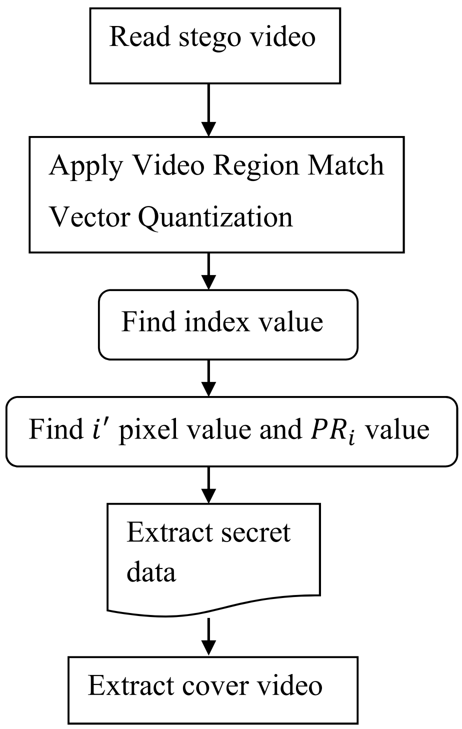


Fig. 5 Extraction process

Figure 5 given above shows the extraction process using Video Region Match Vector Quantization. During extraction process, stego video is given as input. The Video Region Match Vector Quantization decodes the adjoining frames based on the index values. The embedded index value is decoded using the adjoining secret key of a state secret frame in the video frame to obtain the secret information. The reversible method of Video Region Match Vector Quantization evolves with better visual quality of information with minimal runtime.

Input: stego video CVF_i',
Output: secret data 'SD'
Step 1: **Begin** Step 2: Split the stego video CVF_i' Step 3: **For** each stego video CVF_i' Step 4: **Repeat** Step 5: Using Grade Reversible Adjoin Prediction predict i and i' pixel value Step 6: Retrieve the least significant bits from the successive pixel value

Step 7: Obtain the index value
Step 7.1 Apply index value on the video
Step 8: Based on the i' pixel value and corresponding PR_i value retrieve the secret bits
Step 9: Extract the secret data SD
Step 10: **Until** (all stego video is processed)
Step 11: **End for**
Step 12: **End**

Fig. 6 Extraction using Video Region Match Vector Quantization

The Video Region Match Vector Quantization uses an adjoining prediction concept in order to effectively quantize a stego video to non-overlapping 4×4 pixels. As shown in the figure 6 that describes the extraction process to obtain the secret data using adjoining prediction for each stego video. The Video Region Match Vector Quantization uses least significant bit position to obtain the index value and therefore extracts the secret data.

3. Experimental settings

This section (section 3) describes the process of evaluating the APVQ method for enhancing the fastness of video steganography. The APVQ is evaluated in different aspects, performance level on video code streams, visual quality, runtime, true positive rate using video frames. The APVQ method is implemented using MATLAB to enhance the fastness in data hiding and retrieval process of video images.

For the illustration, the below CVF and SM files are listed. The data set used in APVQ method is obtained from Internet Archive 501(c)(3), a non-profit organization. The Internet Archive includes texts, audio, moving images, and software as well as archived web pages. The video used for embedding is shown below with detailed information.

Table 1 Cover video and secret data information

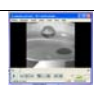
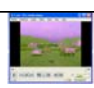
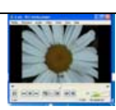
	Cover video Information			**Secret Data information**		
Name	**Video frames**	**Resolution**	**Size (KB)**	**Name of secret message**	**Secret data type**	**Size (KB)**
blossom.avi		216 * 192	349.5	Rose.jpg	Image	25.4 KB
sample.avi		256 * 240	113.6	Faresabbad.wav	Audio	64 KB
vehicle.avi		510 * 420	323.7	Lily.jpg	Image	31.3 KB
sample.avi		256 * 240	113.6	Part01.dat	Text	20.4 KB
Flower.avi		350 * 240	454.5	Tulip.jpg	Image	92.5 KB
athletic.avi		854 * 480	905.3	Akbar.wav	Audio	484 KB

Table 1 describes the Cover Video Frame (CVF) and Secret Data (SD) information used in APVQ method comprises of CVF name, CVF resolution, CVF size, SD name, SD size, SD format type and SD resolution used as sample images in APVQ method. The APVQ method is compared with data hiding in mpeg video files using PSO based Image Hiding (PSO-IH) [1] and DTC based Data Hiding (DCT-DH) [2].

4. Results and Discussion

The reversible encoding method called, Adjoin Prediction and Vector Quantization (APVQ) is compared against the existing data hiding in mpeg video files using PSO based Image Hiding (PSO-IH) [1] and DCT based Data Hiding (DCT-DH) [2]. The experimental results using MATLAB are compared and analyzed with the aid of graph form given below.

4.1 Effect of runtime

Runtime measures the amount of time taken to extract the stego message with respect to the stego message size. Runtime is measured in terms of milliseconds and is mathematically formulated as given below.

$$R = Extraction\ Time\ (Stego\ message) * SMS \quad (4)$$

From (4), runtime 'R' is obtained based on the stego message size 'SMS'. Lower the runtime, more efficient the method is said to be.

Table 2 Tabulation for runtime

Stego message size (KB)	Runtime (ms)		
	APVQ	PSO-IH	DCT-DH
23.4	26.14	32.43	37.89
25.4	31.19	39.21	44.26
31.3	28.35	36.37	41.42
43.2	34.16	42.18	47.23
88.3	41.35	49.37	54.42
92.5	39.42	47.44	52.49

The table 2 represents the runtime obtained using MATLAB simulator based on input cover file which may contain image, audio and video then comparison is made with two other methods, namely PSO-IH [1] and DCT-DH [2].

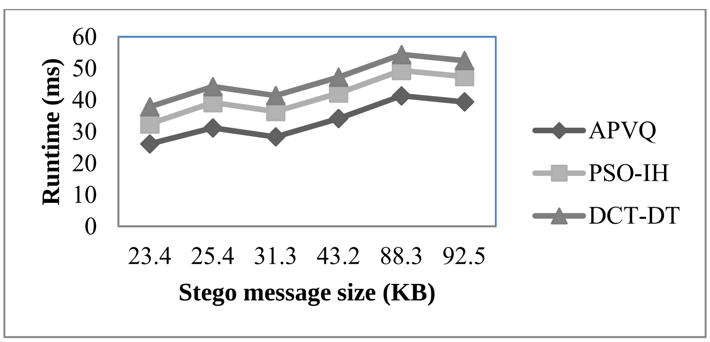


Fig. 7 Measure of runtime

Figure 7 show the variation of the runtime rate as a function of Internet Archive 501(c) (3), provided as input. Comparatively, the runtime observed is lower using APVQ method compared to that of PSO-IH [1] and DCT-DH [2] respectively. The authentic acceptance rate at the receiving end is increased in the proposed method by using Video Region Match Vector Quantization that efficiently decodes adjoining frames with index values with larger test samples.

Moreover by integrating both the new pixel value and pixel region value, the reversible method potentially attains better visual quality of information with minimal runtime using the vector quantization. The APVQ method in turn decodes adjoining frames with index values with larger test samples resulting in minimizing the runtime to extract the stego message with respect to the stego message size by 23.54% compared to PSO-IH and 39.33% compared to DCT-DH respectively.

4.2 Effect of performance level on video code streams

The performance level on video code streams is measured in terms of the bit error rate. The bit error rate refers to the number of bit (in terms of KB) errors divided by the total number of transferred bits (in terms of KB) at a specific time interval. In our proposed method, the performance level on video code streams is measured according to the bit error rate and is mathematically formulated as given below.

$$BER = \left({Bit\ Errors}/_{SMS} \right) * 100 \quad (5)$$

From (5), the bit error rate ‘’ is obtained which is measured in terms of percentage (%). Lower the bit error rate, the performance level on video code streams is said to be higher.

Table 3 Tabulation for bit error rate

Stego message size (KB)	Bit Error Rate (%)		
	APVQ	PSO-IH	DCT-DH
23.4	14.15	21.23	23.19
25.4	16.14	21.16	29.20
31.3	19.23	24.25	32.29
43.2	25.17	30.19	38.24
88.3	48.23	53.25	61.29
92.5	53.16	58.18	66.22

The bit error rate involved while transferring the stego message is presented in table 3 with respect to six cover video of different sizes measured in terms of KB. With respect to the increasing size of stego message, the bit error rate is also increased.

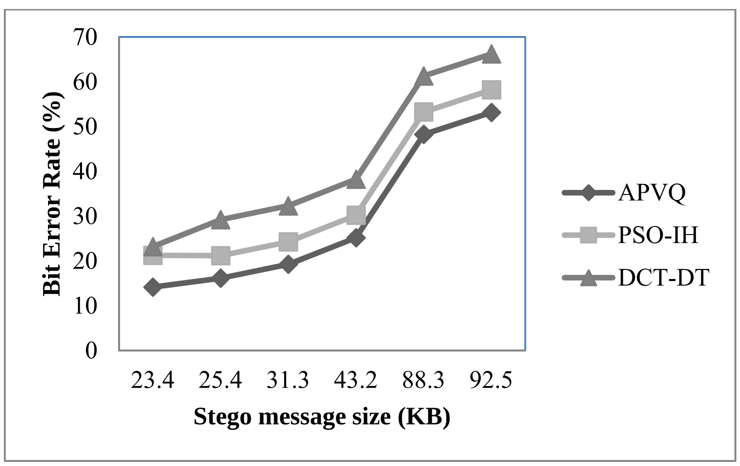


Fig. 8 Measure of bit error rate

The convergence plot for six cover video files with varying message size is depicted in figure 8. From the figure we can note that the proposed APVQ method achieved lower bit error rate compared to other methods. We also figure out that, in Figure 8, the proposed Adjoin Prediction and Vector Quantization method shows a decrease in curve in the beginning of the convergence graphs and rising graph when the stego message size was at 88.3 KB. The figure shows that the graph become tranquil and better bit error rate is observed with a drift increase when fifth and sixth cover video with 88.3 KB and 92.5 KB of stego messages were considered.

The bit error rate is reduced using the APVQ method because of the application of Grade Reversible Adjoin Prediction during the process of embedding that minimizes the rate of bit error to cause a significant gain. Furthermore, the adjoin predictions with different attributes and pixel regions ensure that the secret data recovered back with higher quality rate on decoding side. Therefore, the bit error rate is reduced by 24.50% compared to PSO-IH and 52.71% compared to DCT-DH respectively.

4.2 Effect of true positive rate

True positive rate measures the percentage of stego medium that is correctly classified as stego. The true positive rate is measured in terms of percentage and is mathematically formulated as given below.

$$TPR = \left(\frac{Correct\ Classification\ made\ as\ stego}{n}\right) * 100 \quad (6)$$

From (6), the true positive rate 'TPR' is obtained on the basis of the number of frames per second 'n'.

Table 4 Tabulation for true positive rate

No of frames/second (n)	True Positive Rate (%)		
	APVQ	PSO-IH	DCT-DH
20	71.35	61.89	46.93
40	75.18	70.16	66.13
60	78.35	73.33	69.30
80	80.12	75.10	71.07
100	82.35	75.33	71.30
120	84.18	79.16	74.13

The comparison of true positive rate is presented in table 4 with respect to the number of frames per second in the range of 20 – 120 using six different cover video files. With increase in the frames per second, the true positive rate also gets increased.

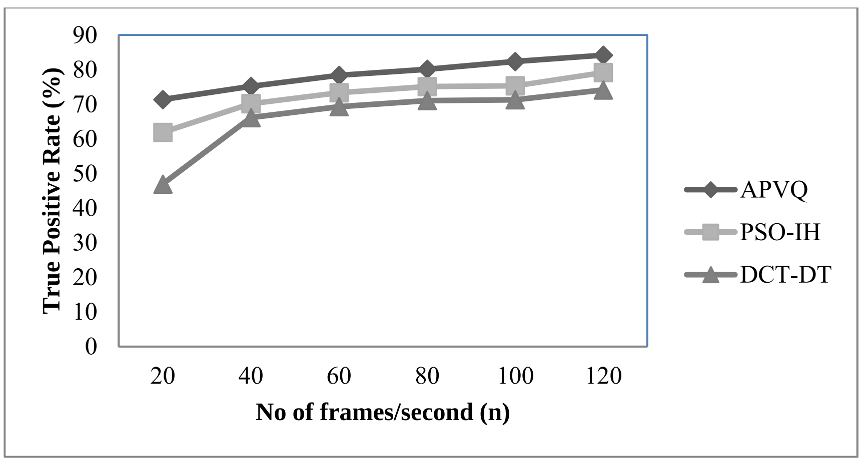


Fig. 9 Measure of true positive rate

The APVQ method is compared with the three existing methods in terms of true positive rate in this section. The convergence plot using embedding and extraction algorithm with differing samples is depicted in Figure 9. We can notice that the proposed APVQ method had better true positive rate compared to the state-of-the-art works respectively. From the figure we can notice that the APVQ method converge higher true positive rate than PSO-IH [1] and DCT-DT [2] respectively by yielding higher number of correct classification as stego which increases the performance measure.

The true positive rate is improved by applying an index value in both the embedding and extraction process. The figure shows that using APVQ the acquired method had improvement on true positive rate by 7.84%, 15.74% respectively which is consistent with the state-of-the-art methods PSO-IH [1] and DCT-DH [2]

4.4 Effect of video quality level on reversible method

The video quality level on reversible method for APVQ method is elaborated in table 5and comparison made with two other methods PSO-IH and DCT-DH respectively. We consider the method with six different cover video for experimental purpose using MATLAB.

Table 5 Tabulation for video quality level on reversible method

Methods	Video quality level (%)
APVQ	78.35
PSO-IH	61.48
DCT-DH	57.35

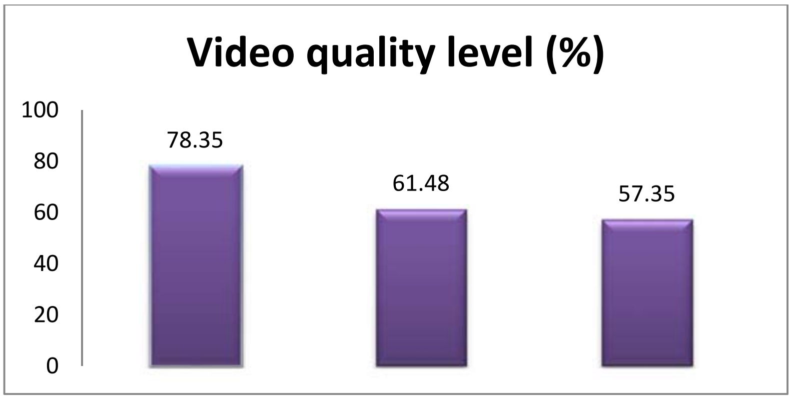


Fig. 10 Measure of video quality level

Convergence characteristics of video quality level on reversible method for six cover video files with different secret data (i.e. image, audio and text) were considered and applied in MATLAB and compared with three other methods and are shown in Figure 10. The targeting results of video quality level using APVQ method is compared with three state-of-the-art methods [1] [2] in figure 10 is presented for visual comparison based on the initialization of images being considered. The method APVQ differs from the PSO-IH [1] and DCT-DH [3] in that we have incorporated different types of secret data that efficiently improves the video quality level on reversible method. This improves the video quality level by 21.53% compared to PSO-IH.

With the application of Video Region Match Vector Quantization, the video quality level is improved. Further, with the aid of adjoining frames with index values, both the smaller and larger components are fine grained to fit the cover video file with higher video quality level by 6.71% compared to DCT-DH respectively.

5. Conclusion

A reversible encoding method called Adjoin Prediction and Vector Quantization (APVQ) has been designed to produce high performance code streams and to improve the performance level on video code streams without compromising the video quality. We adopt Grade Reversible Adjoin Prediction to efficiently embed the cover video file that maps the secret data (i.e. image, audio or text) from various users for performing reversible video steganography. With the mapped secret data, adjoining prediction is made in an efficient manner using the Grade Reversible Adjoin Prediction mechanism. Then, the horizontal and vertical differences view of the cover video is evaluated to obtain the pixel region and new pixel values and then embedded using an index value. Finally, extraction is performed on the other end using Video Region Match Vector Quantization that decodes adjoining frames with corresponding index values. Experimental evaluation is conducted with the Internet Archive 501(c) (3) dataset, a non-profit organization by applying embedding and extraction process. To measure the effectiveness of the proposed method parameter analysis are performed in terms of runtime, performance level on video code streams, true positive rate and video quality level on reversible method using different cover video files. Compared to the existing data hiding methods, the proposed APVQ method decreases the bit error rate by 38.61% and video quality level is improved to 28.24% compared to PSO-IH and DCT-DH.

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