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*Article Paper*

# Steganography in Motion Vectors of a Compressed Video

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**Abstract:** Steganography is the art of secret communication between two parties that not only conceals the contents of a message, but also its existence. Most videos are stored in the compressed MPEG form. The MPEG algorithm has two main advantages, the first is using the macro block-based motion compensation for the reduction of the temporal redundancy and the second is the transform domain based compression for the reduction of spatial redundancy. In this paper, we apply a steganography algorithm that uses the motion vectors as a carrier to embed the secret information. In our algorithm data was embedded in the blocks of P frames with magnitude of motion vectors greater than certain threshold. From the results we conclude that the higher the threshold the lower degradation is obtained, also we found that the embedding capacity is inversely proportional to the threshold. By increasing threshold the number of selected frames for the embedding process increase but this depends on the dataset itself. To get the suitable threshold in our algorithm we study the relation between the threshold values for the magnitude of motion vector and the PSNR, the suitable threshold depends on the dataset used.

**Keywords:** Video Steganography; Moving Picture Experts Group (MPEG); Types of frames

## 1. Introduction

Steganography refers to the science of invisible communication. The term steganography comes from the Greek words stegos (cover) and graphy (write). As result a steganography literally means covered writing. The purpose of cryptography and steganography is to provide secret communication. However, steganography is different from cryptography. Cryptography hides the contents of a secret message from a malicious people, whereas steganography conceals the existence of the message so it can not be seen [1,2].

The cover media can be any multimedia data like text, image, audio or video. Video files are a sequence of still images (frames). Embedding data in videos is similar to images. However, there are many differences between embedding data in images and videos, the first important difference is the size of the host media. Since videos contain more numbers of pixels, a video has higher capacity than a still image and more data can be embedded in the video. Also, there are some characteristics in videos which cannot be found in images as the redundancy due to their temporal features.

There are two main classes of video steganography according to the used video in data embedding:

1. Using an uncompressed video and which is compressed after data hiding. This may cause distortion in the embedding data, so the used algorithm here must resist any changes due to used video compression technique.

2. Using the compressed video which is more used due to the existence of video in compression format to embed the data [3].

Video compression can be achieved by exploiting the similarities or redundancies. The redundancy in a video signal is divided into two types. The first is the spatial redundancy that exists in each frame. The second is the temporal redundancy which is the correlation between the frames.

In MPEG coding, the video sequence is divided into groups of pictures (GOP). Each group may include three types of pictures or frames such as Intra coded Frame (I-frame), Predictive Frame (P-frame) and Bidirectional predictive frame (B-frame), as shown in Figure 1.

- **Intra coded Frame (I-frame)** is entirely coded in one frame by intraframe technique such as DCT. This type of frame doesn't need previous information.
- ***Predictive Frame (P-frame)*** is coded using one-directional motion-compensated prediction from a previous frame, which can be either I-frame or P-frame. Also, P-frame is referred to as inter-frame.
- ***Bidirectional predictive frame (B-frame)*** is coded using bi-directional motion compensated prediction from a previous frame or future frame. The reference can be either I-frame or P-frame. B-frame is also referred to as inter-frame.

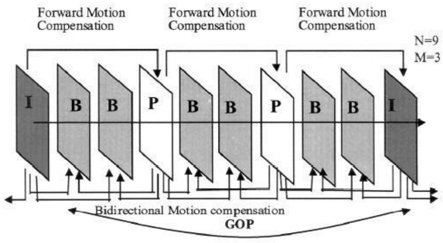


**Figure 1.** A group of frames.

Within a GOP, I frame is the first frame and I frames and P frames are reference frames. The distance between two anchor frames is denoted by M. Usually, M is chosen from 1 to 3. If M is selected to be 1, this means no B-picture will be used [4,5,6,9].

## 2. Related Work

The authors in [3], proposed a new compressed video steganographic scheme . In this algorithm, data hiding operations are executed entirely in the compressed domain. The macro blocks of I frame with maximum scene change and block of P and B frames with maximum magnitude of motion vectors are used to embed data. A novel steganographic approach called Tri-way Pixel-Value Differencing (TPVD) is used for embedding in order to increase the capacity of the hidden secret information and to provide an imperceptible stego-image for human vision.

The authors in [8], proposed a steganographic algorithm in MPEG compressed video stream. In each GOP, to facilitate data extraction the control information was embedded in I frame. The transmitted data were embedded in P and B frames, in which the motion vectors of macro-blocks that have larger moving speed are used for embedding to resist video processing.

In [10], a novel video steganography scheme based on motion vectors and linear block codes was proposed. In this paper, secret messages embed in the motion vectors of cover media. To reduce the modification rate of the motion vectors linear block codes has been used.

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## 3. Steganographic algorithm

### *3.1 Data embedding*

There are many techniques used for video compression, and the most famous technique is Moving Picture Experts Group (MPEG), which is an International Organization for Standardization International Electrotechnical Commission (ISO/IEC) standard for compressing digital video [7].

In MPEG video sequences, most frames are encoded using motion compensation prediction. In P frames each macro-block has one motion vector, while in B frames each macro-block has two motion vectors, the data can be embedded in motion vectors.

We applied the steganography algorithm in [8], which uses I frames, P frames and B frames in the embedding process, but in our algorithm we use only P frames.

In our algorithm, the data were not embedded in each motion vector of P frames, but the motion vectors which have larger magnitude than the selected threshold. The larger magnitude refers to the faster moving speed of the macro-blocks. This means that the distortion introduced by data embedding is minimum comparing to embedding data in all motion vectors that contain values for macro-blocks of slight movement or even still. The details of data embedding algorithm are shown in Figure 2 as follows:

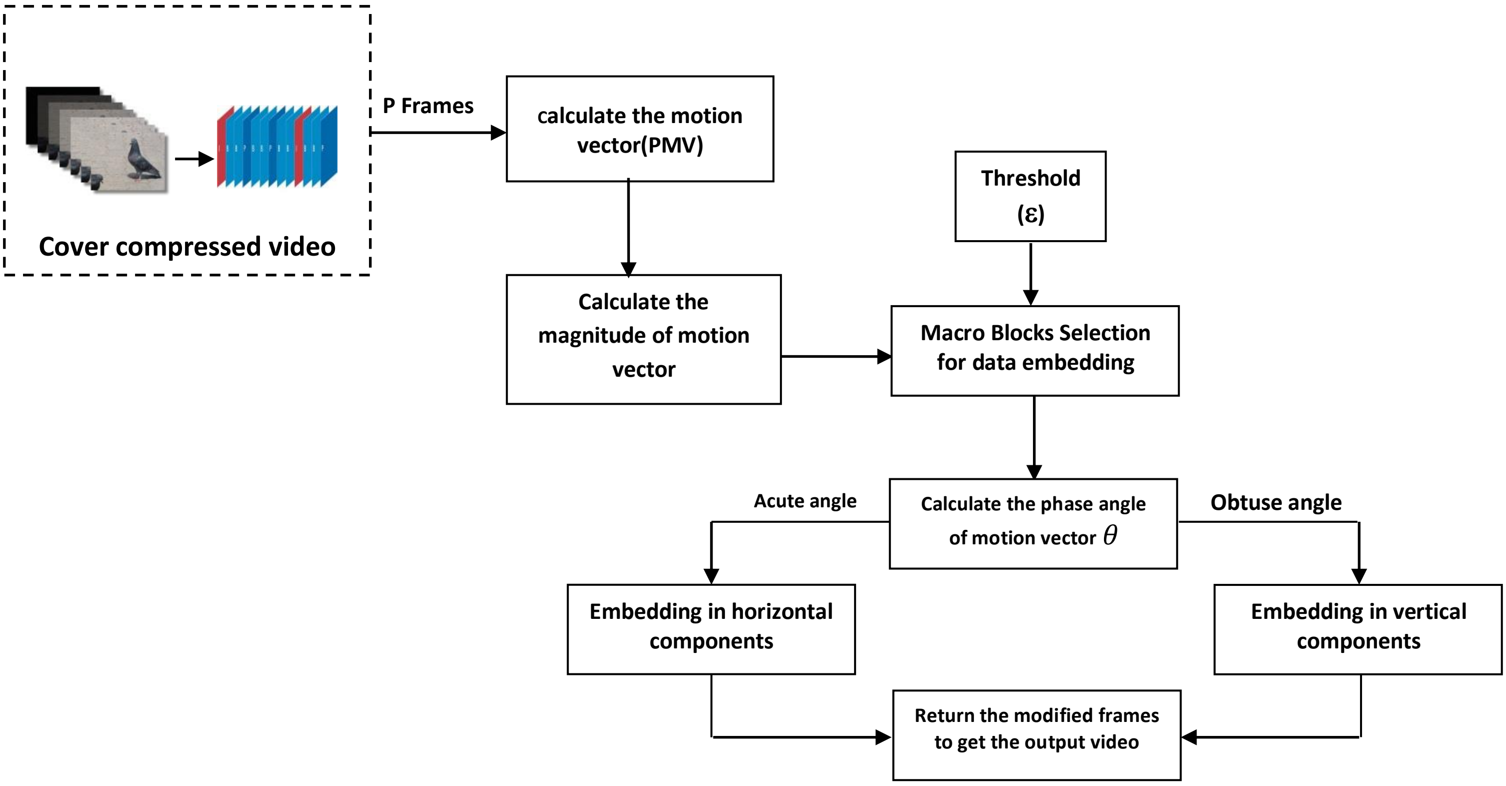


**Figure 2.** Block diagram of the proposed algorithm.

1) For a P frame, get the motion vector *PMV[i]*, $0<i<N_{MB}$ from the compressed video stream.
Where $N_{MB}$: is the number of macro-blocks in this frame.
2) Calculate the magnitude of motion vector

$$|PMV[i]| = \sqrt{H^2[i] + V^2[i]} \quad (1)$$

, Where
*H[i]*: is the horizontal component of motion vector in the $i^{th}$ macro-block.
*V[i]*: is the vertical component.

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3) Given the threshold of the magnitude of motion vector is ε, we can select the embeddable macro-blocks.

$$MB[i] = \begin{cases} 1 & |PMV[i]| > \varepsilon \\ 0 & |PMV[i]| \le \varepsilon \end{cases}$$ , where

$MB[i]$ =1: denotes the macro-block that satisfies the condition, and can be used for embedding.
$MB[i]$ =0: denotes no data embedding in this macro-block.

4) Calculate the phase angle of motion vector

$$\theta[i] = arctan\left(\frac{V[i]}{H[i]}\right) \quad (2)$$

5) Embedding data in the selected macro-blocks, based on the value of the phase angle of the motion vector (θ).

a) If θ is acute angle, less distortion will be introduced by modifying horizontal component of motion vector, so the data were embedded into horizontal component.

b) If θ is obtuse angle, less distortion will be introduced by modifying vertical component of motion vector, so the data will be embedded into vertical component.

6) The same calculations were repeated for all the P frames in a GOP, and the number of eligible motion vectors were achieved. For each eligible motion vector, one bit can be embedded.

*3.2 Data extraction*

To extract the hidden data, we follow the same steps in insertion operation. we get the motion vector $PMV[i]$, $0<i<N_{MB}$, Where $N_{MB}$: is the number of macro-blocks in this frame, calculate the magnitude of motion vector using equation (1), Depending on the threshold of the magnitude of motion vector, we can select the embeddable macro-blocks, calculate the phase angle (θ) of motion vector using equation (2). If θ is acute angle, data was embedded into horizontal component, then data extracted. Also, if θ is obtuse angle, data was embedded into vertical component, then data extracted. For all used P frames, the above calculations were repeated until all embedded data were extracted.

## 4. Experimental Results

In our algorithm, we used two datasets in the experiments and their characteristics are provided in Table 1.

**Table 1.** Datasets details.

| No | Data set | Resolution | No. of frames/sec | No. of frames |
|---|---|---|---|---|
| 1 | news | 288*352 | 30 | 300 |
| 2 | Foreman | 288*352 | 30 | 300 |

We use the macro-block size 8x8 pixels, the motion search window is set to 16x16 pixels, the length of a GOP is set to 15 and a text document "**A computer network is the infrastructure that allows two or more computers to communicate with each other**" was embedded into the video. We use the peak signal to noise ratio (PSNR) to measure the quality of the reconstructed (modified) video, also to measure the distortion results from the embedding data.

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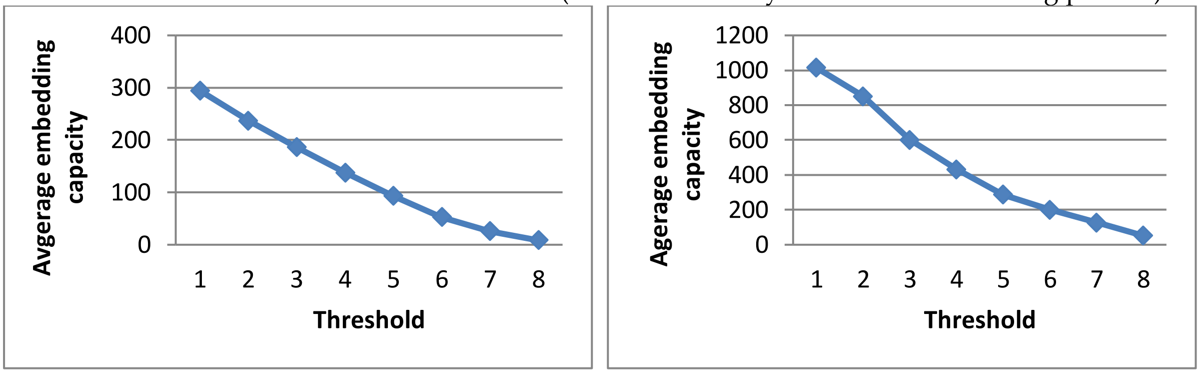
To get the suitable threshold in our algorithm we study the relation between the threshold values for the magnitude of motion vector and the PSNR. Also we study the relation between the threshold and the embedding capacity, the relation between the threshold values for the magnitude of motion vector and the number of the selected P frames (that were actually used in the embedding process).

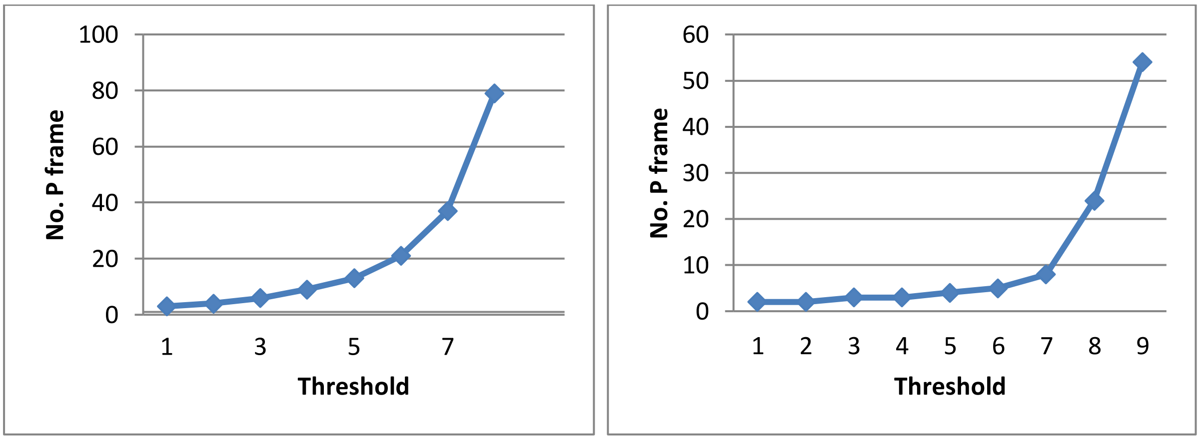



**(a)** **(b)**

**Figure 3. (a)** Illustrates the relation between the average embedding capacity and the threshold for the first dataset. **(b)** For the second dataset.

As expected from the above results we found that the embedding capacity is inversely proportional to the threshold. The smaller threshold, the more embedding capacity we can get. Also, the average embedding capacity values is different from one data set to another according to its nature, as shown in figure 3.

From the relation between threshold and the number of P frames which can be used. we found that for the first dataset the number of selected P frames increases with the increase of the threshold as shown in figure 4a. For the second dataset we note that the number of selected P frames increases with the increase of the threshold as shown in figure 4b but at threshold 1 and 2 the number of P frames were the same but the embedding data is different, also at threshold 3 and 4 the number of P frames were the same but the embedding data were different. This means that the number of selected frames depends on the length of secret message, threshold value, and the motion of objects in the dataset.




**(a)** **(b)**

**Figure 4. (a)** The relation between the number of P frames used in the embedding process and the threshold for the first dataset. **(b)** For the second dataset

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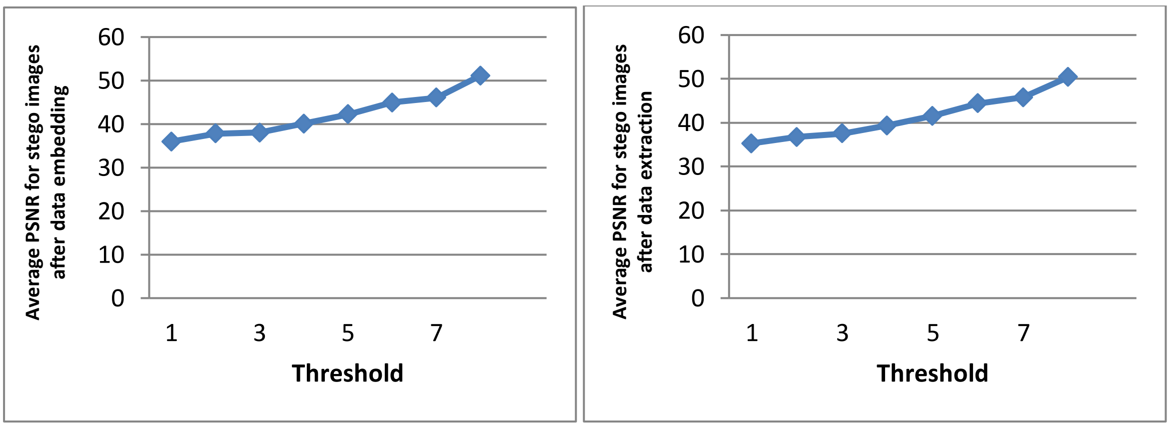
We change in the threshold values and at each value we take the PSNR for stego images after data embedding and calculate the average value for the PSNR and for stego images after data extraction then we calculate the average value for the PSNR. Table 2 illustrates the relation between the average PSNR (embedding, extraction) and threshold for the first dataset. Figure 5a illustrates the relation between the average PSNR of stego images, after data embedding, and threshold. Figure 5b illustrates the relation between the average PSNR of stego images, after data extraction, and threshold. Fig.6 shows an example for the selected frame used for embedding in dataset one.

**Table 2.** Average PSNR values of dataset one.

| Threshold | Average PSNR extraction | Average PSNR embedding |
|---|---|---|
| 1 | 35.29740669 | 35.9939714 |
| 2 | 36.74706863 | 37.80378282 |
| 3 | 37.56603598 | 38.07196063 |
| 4 | 39.37371733 | 40.08946585 |
| 5 | 41.56410503 | 42.21255557 |
| 6 | 44.42407663 | 44.99009689 |
| 7 | 45.76266463 | 46.09251989 |
| 7.3 | 50.41159534 | 51.13590496 |




**(a)** **(b)**

**Figure 5.** The relation between the average PSNR and threshold.


**(a)** **(b)** **(c)**

**Figure 6.** Illustrates the selected frame from the first dataset, **(a)** shows the original P frame, **(b)** shows the reconstructed image with hidden text, **(c)** shows the reconstructed image after hidden text extracted.

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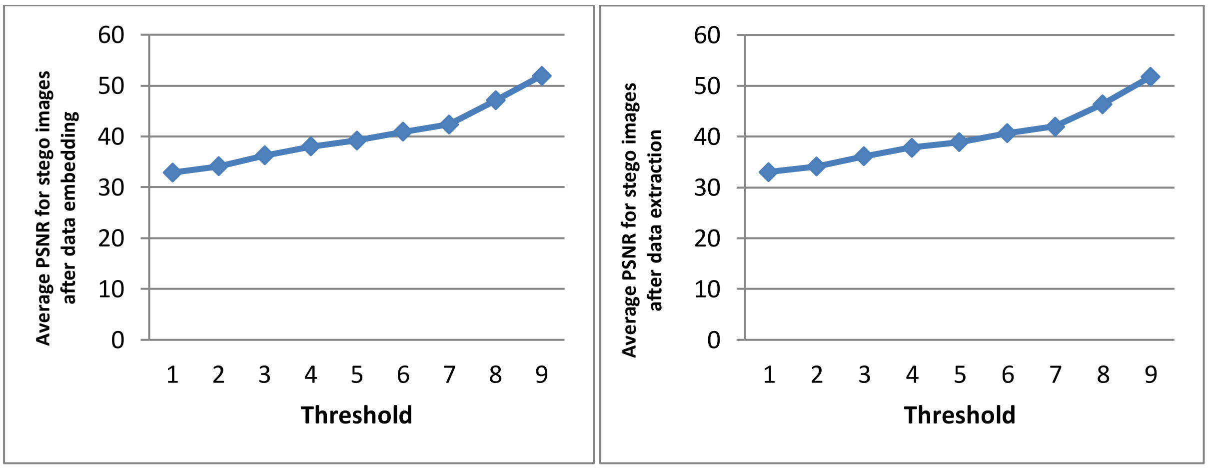
As shown from the above results we found that, by increasing threshold value, the quality of the stego image increases and low degradation is obtained. The same experiment was repeated for the second dataset. Table 3 shows the relation between the average PSNR and threshold for the second dataset. Figure 7a illustrates the relation between the average PSNR of stego images, and threshold, after data embedding. Figure 7b illustrates the relation between the average PSNR of stego images, after data extraction, and threshold.

Form the results of the second dataset we found that, by increasing threshold value, the average PSNR increase and low degradation obtained. Figure 8 shows an example for selected frame used for embedding in dataset.

**Table 3.** Average PSNR values of dataset two.

| Threshold | Average PSNR extraction | Average PSNR embedding |
|---|---|---|
| 1 | 33.06125024 | 32.89002955 |
| 2 | 34.16091603 | 34.1440565 |
| 3 | 36.13334173 | 36.27505235 |
| 4 | 37.88712453 | 37.99822837 |
| 5 | 38.91261521 | 39.22074083 |
| 6 | 40.68578492 | 40.90392221 |
| 7 | 41.99672931 | 42.35961037 |
| 8 | 46.43288963 | 47.0497922 |
| 9 | 51.77951922 | 51.9467662 |




**(a)** **(b)**

**Figure 7.** The relation between the average PSNR and threshold.

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**(a)** **(b)** **(c)**

**Figure 8.** Illustrates the selected frame from the second dataset, **(a)** shows the original P frame, **(b)** shows the reconstructed image with hidden text, **(c)** shows the reconstructed image after hidden text extracted.

## 5. Conclusion

From the applied algorithm, we conclude that the higher the threshold the lower degradation is obtained, also we found that the embedding capacity is inversely proportional to the threshold, by increasing threshold the number of selected frames for the embedding process increase but this depends on the dataset itself.

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