

A Novel Data Hiding Method based on Edge Detection and 2^k Correction with High Payload and High Visual Quality

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Abstract— In this paper a novel edge adaptive data hiding method is proposed. The proposed edge adaptive steganography method is improved version of the Bai et al.'s [31] (A high payload steganographic algorithm based on edge detection) method. The main aim of the proposed method is to achieve high payload with high visual quality. This method consists of preprocessing, edge detection, classification of the secret data, data embedding and data extraction phases. In the preprocessing phase 6 and 7 least significant bits (LSB) elimination are applied on the cover image to get a better edge detection in the next phase. As edge detection methods Sobel, Canny, Laplacian Of Gaussian (LOG), block-based edge detection and hybrid edge detectors are used. After the edge detection, secret data is divided into 2 classes and then these are embedded into edge pixels and texture pixels of the image. In order to increase the visual quality 2^k correction is applied on the stego images. Modulus operator is utilized in the data extraction phase. In the experimental results, payload and visual quality measurements demonstrated the success of the proposed method.

Index Terms— Least Significant Bit (LSB) substitution; 2^k correction; Edge Detection; Data hiding


I. INTRODUCTION

THE ERA we live in is called information era. The vast majority of information is stored as digital media. As a result the information security has become a very important research topic in order to provide security of digital media, thus information security has become a hot-topic research area [1]. In the information security, cryptography and data hiding are widely used. While cryptography provides the confidentiality of digital data, aim of the data hiding is to provide security of the communication. Recently, data hiding has gained popularity over cryptography and started to appear more often in the literature [2-4]. Data hiding methods generally use spatial domain and frequency domain for data embedding.

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Spatial domain based data hiding methods have shorter execution time, higher embedding Capacity and higher visual quality but these methods are not robust. In order to increase the robustness of the data hiding method, frequency domain is used [5-8]. In frequency domain, Discrete Wavelet Transform (DWT) [9], Integer Wavelet Transform (IWT) [10], Discrete Cosine Transform (DCT) [11,12], Discrete Fourier Transform (DFT) [13], etc. are used as transformation functions. Data hiding algorithms generally consist of host image, secret data, data hiding, stego image and data extraction. In addition to these basic components, cryptography, frequency transforms, heuristic optimization techniques, edge detectors, segmentation algorithms, secret sharing, visual cryptography, game rules, etc. are widely used in data hiding [14-20]. The most popular data hiding method is Least Significant Bit (LSB) substitution [21]. LSB is a practical method because LSB provides higher visual quality, higher payload Capacity and shorter execution times. Thus, LSB is the widely used method in the data hiding. Some of the previously presented data hiding methods are given as follows. Mahato et al. [22] presented a data hiding method based on the popular minesweeper game for secure communication. The authors generated a scenario for secure communication where the sender plays minesweeper game to embed the secret data and then he/she sends the game to the receiver. The secret message can be extracted from the received game-play. Liao et al. [23] suggested a data hiding method for medical images. To increase robustness against JPEG compression of this method DCT was used. Shiu et al. [24] proposed a reversible signal data hiding for physiological signals. They analyzed this method theoretically and they showed that this algorithms computational complexity is $O(n)$ and this method can be used for ECG and EMG signals. Yuan [25] suggested a secret sharing based image data hiding method with high visual quality. In this method, firstly secret sharing was used to generate minimal distorted secret shares and these secret shares were embedded into multi cover images by using LSB. Wu and Tsai [26] described a data hiding concept based on pixel value difference (PVD). In this method, cover image was divided into non-overlapping blocks and 2 connected pixels differences was modified for data hiding. Subhedar and Mankar [27] proposed a robust QR factorization based data hiding. To evaluate of this method, they used robustness and visual quality performance metrics. Maheswari and Hemanth [28] proposed a Fresnelet Trasform (FT) and QR code based

data hiding method. They utilized LSB as data hiding function. FT and QR coding provided robustness. Chen et al. [29] suggested a hybrid edge detector based data hiding method. Hybrid edge detector utilized Gaussian filter and sobel matrix. Capacity and visual quality was used to evaluate performance of this method. Tseng and Leng [30] proposed an extended edge based data hiding method to achieve minimal distortion. This method was a block based method and they calculate Mean Square Error (MSE) for each 4 x 4 blocks. Bai et al. [31] suggested an edge detection based image data hiding algorithm with high payload Capacity. This method consisted of 5LSBs elimination, edge detection by using Canny [32], Sobel [33] and Fuzzy Logic Edge Detector (FLED) [34], secret message classification in two sub-class, data hiding and data extraction phases. Capacity and visual quality were used to evaluate performance of this method. Sun [35] presented a edge based image data hiding method. In this method, Canny Edge Detector (CED) was used for edge detection, Huffman was used for secret data compression and 2k correction was used for data hiding and data extraction.

In this method, we proposed a novel edge adaptive data hiding method. This method consists of mLBSs elimination, edge detection, secret data classify, data hiding and data extraction phases. In this method, LSB is used for data hiding and data extraction. Briefly, the proposed method is an improved version of Bai et al.'s [31] method. The main aim of the proposed method is to provide higher payload with higher visual quality than Bai et al.'s [31] method. Technical contributions of the proposed method are given below.

mLSBs elimination is used for achieving high payload Capacity. Bai et al.'s [31] used 5LSBs elimination in order to increase Capacity. In this method, we used mLBSs elimination ($m \in \{6,7\}$) to find more edge pixel. A block based edge detector is presented in this paper. In this edge detector, OTSU [36] method and 2 x 2 non-overlapping blocks are used. This method detects edge pixel in the binary form.

A hybrid edge detector is proposed in this paper to achieve high payload Capacity. This detector uses Canny, Sobel, Laplacian of Gaussian and the proposed block based edge detectors. The main aim of the HED is to detect all of the edge pixels in an image. In this method, edge detectors are used for creating data hiding map. By using this map, secret data is divided into x and y classes. xLSBs and yLSBs data embedding method are used as data embedding function. To achieve high visual quality, 2^k correction is applied on the stego image. By using 2^k correction, higher visual quality is achieved than Bai et al.'s method.

II. PROPOSED EDGE DETECTOR

Canny, Sobel and LOG methods are used in this paper for known edge detection methods. In addition to these methods, a block based edge detection method which is a modified version of the FLED method and a hybrid edge detection method are used.

Block based Edge Detection (BED): This method is a modified version of the Fuzzy Logic Edge Detector (FLED) method. In this method, OTSU thresholding method, 2 x 2 size of non-overlapping blocks and a rule table are used. This

method detects edges of binary form of the images. The steps of the proposed edge extraction algorithm are as follows.

- **Step 1:** Convert binary image to original image by using OTSU threshold method.
- **Step 2:** Divide binary image into 2 x 2 size of non-overlapping blocks. A sample 2 x 2 size of block is shown in Fig. 1.

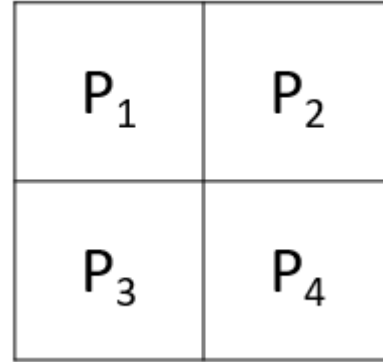


Fig. 1. 2 x 2 sized block.

- **Step 3:** Detect edges by using Eq. 1.

$$Edge = \begin{cases} 0, & \sum_{i=1}^4 p_i = 4 \text{ or } \sum_{i=1}^4 p_i = 0 \\ 1, & \text{Otherwise} \end{cases} \quad (1)$$

Hybrid Edge Detection (HED): Many edge detection methods are proposed in the literature. These methods yield different edge properties of images and edge detectors used in the literature have weak and superior features against each other. This has led to the development of an edge detection method that can obtain all edge data in the image. In this article, a hybrid edge detector which uses the widely used edge detection methods is proposed and this edge detector can obtain more edge information from the image. The main purpose of this method is to increase the Capacity of the edge based data hiding method by obtaining more edge information. BED, Canny, Sobel and LOG edge removal operators are used in this method. The steps of the HED is given in Eq. 2-6.

$$C = Edge(I, 'Canny') \quad (2)$$

$$S = Edge(I, 'Sobel') \quad (3)$$

$$L = Edge(I, 'LOG') \quad (4)$$

$$B = Edge(I, 'BED') \quad (5)$$

$$H = C \oplus S \oplus L \oplus B \quad (6)$$

Where C is edge image using canny edge detector, S is edge image using sobel edge detector, L is edge image using LoG edge detector, B is edge image using binary edge detector, \oplus is OR operator and H is edge image using hybrid edge detector.

III. THE PROPOSED EDGE ADAPTIVE DATA HIDING METHOD

Capacity and visual quality are the most important evaluation criteria in edge detection based data hiding methods [29-32]. In this study, a novel edge detection based data hiding method is proposed to improve Bai et al.'s [31] method. In this article, edge detection is used as data hiding map. To increase capacity, mLBSs elimination and a new hybrid edge detector

are used together and the proposed hybrid edge extractor uses Sobel, Canny, LOG and the block-based edge extraction algorithm. To provide high visual quality, 2^k correction [35] method is used. The proposed method generally consists of preprocessing, edge detection, secret data classification, data hiding and data extraction phases. Flowchart of the proposed method is shown in Fig. 2.

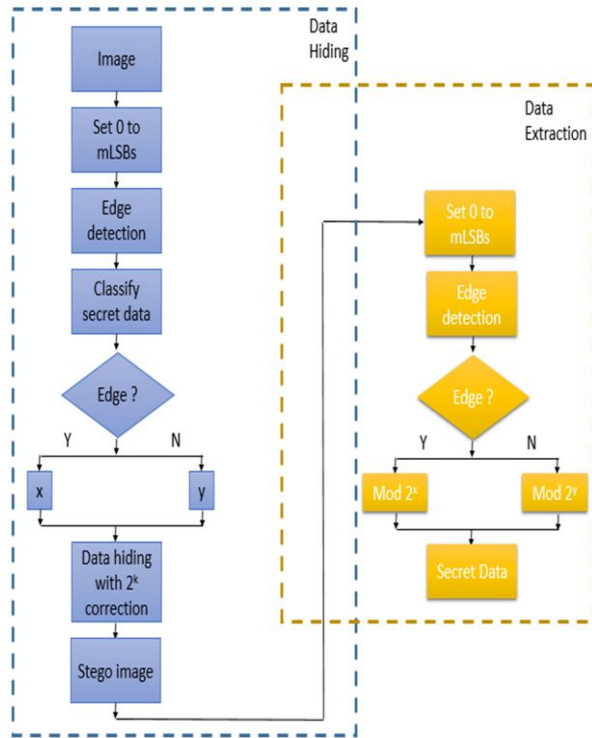


Fig. 2. Flow diagram of the proposed method.

Pre-processing, secret data classification and data embedding steps of the proposed edge based data hiding method are given below.

- **Step 1:** Load image
- **Step 2:** Set 0 to mLSBs by using Eq. 7. This step describes pre-processing phase of the proposed method
$$I = \left\lfloor \frac{I}{2^m} \right\rfloor \times 2^m, 5 < m < 8 \quad (7)$$
- **Step 3:** Apply edge detectors onto image. Edge image is used for secret data classification and data embedding.
- **Step 4:** Classify secret data using edge image. If pixel is edge, xLSBs secret data is embedded into the cover image. Otherwise, yLSBs secret data is embedded into the cover image. Eq. 8. mathematically describes the

presented data embedding function. Where OP is original pixel, SP is stego pixel and SD is secret data.

$$SP = \begin{cases} \left\lfloor \frac{OP}{2^x} \right\rfloor \times 2^x + SD, & \text{if } OP = \text{edge} \\ \left\lfloor \frac{OP}{2^y} \right\rfloor \times 2^y + SD, & \text{if } OP \neq \text{edge} \end{cases} \quad (8)$$

- **Step 5:** Apply 2^k correction to increase visual quality on the stego image. Mathematical description of the 2^k correction is shown in Eq. 9 [35].

$$NSP = \begin{cases} SP - 2^k, & \text{if } SP - OP > 2^{k-1} \text{ and } SP - 2^k \geq 0 \\ SP + 2^k, & \text{if } SP - OP < -2^{k-1} \text{ and } SP + 2^k \leq 255 \\ SP, & \text{Otherwise} \end{cases} \quad (9)$$

Where NSP is new stego pixel and data hiding function is kLSBs. If you use xLSBs data hiding function, k is x. If you use yLSBs data hiding function, k is y. The data extraction steps of the proposed edge adaptive data hiding methods are given below.

- **Step 1:** Load stego image.
- **Step 2:** Set 0 to mLSBs by using Eq. 7.
- **Step 3:** Apply edge detector to stego image. We use edge image as data extraction map.
- **Step 4:** If pixel value is edge, use Eq. 10. to data extraction. Where ED is extracted data.
$$ED = NSP \pmod{2^x} \quad (10)$$
- **Step 5:** If pixel value is not edge, use Eq. 11. to data extraction.
$$ED = NSP \pmod{2^y} \quad (11)$$

IV. EXPERIMENTAL RESULTS

In this section, payload (also called Capacity) and visual quality (also called imperceptibility) are utilized to evaluate performance of the recommended method. Tseng and Leng's [30], Chen et al.'s [29] and Bai et al.'s [31] methods are used to obtain comparisons.

Capacity: One of the commonly used measurement criteria of the steganography. To evaluate edge adaptive data hiding methods is Capacity. In this method, mLSBs elimination and a hybrid edge detector are used for increasing the payload. In addition to, Canny, Sobel, LOG and BED edge detectors are applied on the test images to obtain experiments. The mathematical description of the Capacity of the proposed method is given in Eq. 12.

$$PC = \frac{(NE \times x) + (W \times H - NE) \times y}{W \times H} \quad (12)$$

Where PC is payload and bit per-pixel (bpp) is used to expression it, NE is number of edge pixels, W is width of image and H is height of image. Fig. 3 shows number of edge pixels by Canny, Sobel, LOG, BED and HED edge detectors.
















Edge Detector	mLSBs Elimination					
Canny	No	 1779	 1833	 2019	 1772	 2153
	Yes m=6	 2114	 2374	 2523	 2499	 2568
Sobel	No	 669	 827	 673	 927	 862
	Yes m=7	 1290	 1433	 1189	 1169	 1382
LOG	No	 1143	 1243	 1637	 1438	 1439
	Yes m=6	 1468	 1404	 2042	 1874	 1637
BED	No	 1061	 2147	 2133	 2583	 2636
	Yes m=6	 1561	 2415	 2809	 1799	 3001
HED	No	 3032	 3735	 4414	 4299	 4723
	Yes	 4349	 5305	 5897	 5161	 5782

Fig. 3. The number of edge pixels by used edge detectors with test images ‘Lena’, ‘Peppers’, ‘Goldhill’, ‘Boat’ and ‘Barbara’.

Fig. 3 shows that the mLSBs elimination method generally increases the Capacity. Additionally, Eq. 12 clearly showed that FLED Capacity of the Bai et al.'s [31]

method was incorrectly calculated and true payloads of the FLED and HED are shown in Table 1.

TABLE I
COMPARATIVELY RESULTS OF THE PROPOSED METHOD AND BAI ET AL.'S [31] METHOD FOR 128 X 128 SIZE OF IMAGES.





Image	FLED (Bai et al.'s [31] method)	HED (The proposed method)
 Lena	x=2, y=1 Payload=1.2072 bpp	x=2, y=1 Payload=1.2654 bpp
	x=3, y=2 Payload=2.2072 bpp	x=3, y=2 Payload=2.2654 bpp
	x=4, y=3 Payload=3.2072 bpp	x=4, y=3 Payload=3.2654 bpp
 Peppers	x=2, y=1 Payload=1.2089 bpp	x=2, y=1 Payload=1.3238 bpp
	x=3, y=2 Payload=2.2089 bpp	x=3, y=2 Payload=2.3238 bpp
	x=4, y=3 Payload=3.2089 bpp	x=4, y=3 Payload=3.3238 bpp
 Goldhill	x=2, y=1 Payload=1.2133 bpp	x=2, y=1 Payload=1.3599 bpp
	x=3, y=2 Payload=2.2133 bpp	x=3, y=2 Payload=2.3599 bpp
	x=4, y=3 Payload=3.2133 bpp	x=4, y=3 Payload=3.3599 bpp
 Boat	x=2, y=1 Payload=1.2197 bpp	x=2, y=1 Payload=1.3150 bpp
	x=3, y=2 Payload=2.2197 bpp	x=3, y=2 Payload=2.3150 bpp
	x=4, y=3 Payload=3.2197 bpp	x=4, y=3 Payload=3.3150 bpp

Table 1 clearly demonstrates that the proposed HED provides superior payload than FLED of Bai et al.'s [31] method. *Visual Quality*: Peak Signal Noise-to-Raito (PSNR) was used to measure visual quality in this model. The mathematical definition of PSNR is Eq. 13.

$$PSNR = 10 \times \log_{10} \left(\frac{255^2 \times W \times H}{\sum_{i=1}^W \sum_{j=1}^H (OI_{i,j} - SI_{i,j})^2} \right) \quad (13)$$

Where OI is original image, SI is stego image. In this work, 2^k correction is applied on the stego images to increase visual quality. Lena, Peppers, Goldhill, Sailboat, Barbara and Tiffany test images used to obtain the experimental results. These images are 128 x 128 sized and gray-level. The secret data is also randomly generated. The obtained results of the proposed method are shown in Table 2.

TABLE II
THE OBTAINED PSNR (DB) AND CAPACITY (BPP) RESULTS OF THE PROPOSED EDGE ADAPTIVE METHOD USING VARIABLE EDGE DETECTORS AND X AND Y VALUES

Image	x=2, y=1	x=3, y=2	x=4, y=3	x=5, y=4
Canny				
Lena	PSNR=50.12, C=1.12	PSNR=45.03, C=2.12	PSNR=39.28, C=3.12	PSNR=33.16, C=4.12
Peppers	PSNR=50.07, C=1.14	PSNR=44.96, C=2.14	PSNR=39.15, C=3.14	PSNR=33.16, C=4.14
Goldhill	PSNR=49.95, C=1.15	PSNR=44.86, C=2.15	PSNR=39.17, C=3.15	PSNR=33.18, C=4.15
Sailboat	PSNR=49.97, C=1.15	PSNR=44.88, C=2.15	PSNR=39.14, C=3.15	PSNR=33.19, C=4.15
Barbara	PSNR=49.93, C=1.15	PSNR=44.81, C=2.15	PSNR=39.13, C=3.15	PSNR=33.18, C=4.15
Tiffany	PSNR=50.02, C=1.14	PSNR=44.97, C=2.14	PSNR=39.17, C=3.14	PSNR=33.24, C=4.14
Sobel				
Lena	PSNR=50.45, C=1.07	PSNR=45.58, C=2.07	PSNR=39.84, C=3.07	PSNR=33.80, C=4.07
Peppers	PSNR=50.47, C=1.08	PSNR=45.46, C=2.08	PSNR=39.68, C=3.08	PSNR=33.75, C=4.08
Goldhill	PSNR=50.54, C=1.07	PSNR=45.50, C=2.07	PSNR=39.84, C=3.07	PSNR=33.95, C=4.07
Sailboat	PSNR=50.56, C=1.07	PSNR=45.60, C=2.07	PSNR=39.95, C=3.07	PSNR=33.99, C=4.07
Barbara	PSNR=50.42, C=1.08	PSNR=45.44, C=2.08	PSNR=39.79, C=3.08	PSNR=33.85, C=4.08
Tiffany	PSNR=50.57, C=1.07	PSNR=45.64, C=2.07	PSNR=39.92, C=3.07	PSNR=33.97, C=4.07
LOG				
Lena	PSNR=50.44, C=1.08	PSNR=45.46, C=2.08	PSNR=39.69, C=3.08	PSNR=33.73, C=4.08
Peppers	PSNR=50.43, C=1.09	PSNR=45.41, C=2.09	PSNR=39.68, C=3.09	PSNR=33.75, C=4.09
Goldhill	PSNR=50.16, C=1.12	PSNR=45.11, C=2.12	PSNR=39.41, C=3.12	PSNR=33.43, C=4.12
Sailboat	PSNR=50.24, C=1.11	PSNR=45.21, C=2.11	PSNR=39.49, C=3.11	PSNR=33.53, C=4.11
Barbara	PSNR=50.32, C=1.09	PSNR=45.36, C=2.09	PSNR=39.64, C=3.09	PSNR=33.68, C=4.09
Tiffany	PSNR=50.29, C=1.10	PSNR=45.25, C=2.10	PSNR=39.48, C=3.10	PSNR=33.57, C=4.10
BED				
Lena	PSNR=50.37, C=1.09	PSNR=45.45, C=2.09	PSNR=39.64, C=3.09	PSNR=33.69, C=4.09
Peppers	PSNR=49.90, C=1.14	PSNR=44.92, C=2.14	PSNR=39.18, C=3.14	PSNR=33.15, C=4.14
Goldhill	PSNR=49.83, C=1.17	PSNR=44.72, C=2.17	PSNR=38.95, C=3.17	PSNR=32.99, C=4.17
Sailboat	PSNR=50.30, C=1.10	PSNR=45.25, C=2.10	PSNR=39.51, C=3.10	PSNR=33.54, C=4.10
Barbara	PSNR=49.81, C=1.18	PSNR=44.60, C=2.18	PSNR=38.87, C=3.18	PSNR=32.90, C=4.18
Tiffany	PSNR=50.81, C=1.03	PSNR=45.97, C=2.03	PSNR=40.33, C=3.03	PSNR=34.33, C=4.03
HED				
Lena	PSNR=49.29, C=1.26	PSNR=43.97, C=2.26	PSNR=38.27, C=3.26	PSNR=32.17, C=4.26
Peppers	PSNR=48.92, C=1.32	PSNR=43.69, C=2.32	PSNR=37.85, C=3.32	PSNR=31.86, C=4.32
Goldhill	PSNR=48.79, C=1.35	PSNR=43.49, C=2.35	PSNR=37.60, C=3.35	PSNR=31.65, C=4.35
Sailboat	PSNR=49.03, C=1.31	PSNR=43.67, C=2.31	PSNR=37.97, C=3.31	PSNR=31.96, C=4.31
Barbara	PSNR=48.83, C=1.35	PSNR=43.51, C=2.35	PSNR=37.61, C=3.35	PSNR=31.69, C=4.35
Tiffany	PSNR=49.22, C=1.28	PSNR=43.90, C=2.28	PSNR=38.07, C=3.28	PSNR=32.10, C=4.28

The comparison results of the proposed method with existing state-of-art edge-based data hiding methods in the

literature are shown in Table 3. In this comparison, 128 x 128 size of gray level Lena image is used.

TABLE III
COMPARISON WITH THREE PREVIOUSLY PRESENTED EDGE BASED DATA HIDING METHOD.

	Tseng and Leng's [30] method	Chen et al.'s [29] method	Bai et al.'s [31] method		The proposed method	
			Canny	Sobel	Canny	Sobel
Parameters	y=3	x=4, y=3, n=4	x=4, y=3	x=4, y=3	x=4, y=3	x=4, y=3
PSNR (dB)	38.18	37.50	38.34	38.34	39.2866	39.8499
Capacity(bpp)	2.41	2.10	3.11	3.05	3.1290	3.0787
Parameters	y=4	x=5, y=4, n=3	x=5, y=4	x=5, y=4	x=5, y=4	x=5, y=4
PSNR (dB)	33.58	32	30.10	30.69	33.1663	33.8079
Capacity(bpp)	3.16	2.73	4.11	4.05	4.1290	4.0787

The merits of the proposed method are given as below. In this article two novel basic edge extractors are presented.

1- By using 2^k correction higher visual qualities are obtained than the other state of art methods.

- 2- HED based steganography method has very high payload.
- 3- In this article, flaw of the other steganography is presented. Mathematical notations of the edge adaptive steganography methods are defined.
- 4- The proposed methodology is very basic and effective.
- 5- Researchers and developers can simply apply the proposed method to their problem.
- 6- The proposed method is a cognitive method because there is not any meta-heuristic optimization method to increase either payload or visual quality.

The disadvantage of the proposed edge-based steganography method: It is not robust method because it uses pixel domain to embed hidden data.

V. CONCLUSIONS

In this article, a novel edge adaptive data hiding method is presented with high payload and high visual quality. The proposed method consists of preprocessing, secret data classification, data hiding and data extraction phases. In this method, edge detectors are used as data hiding map. 6LSBs and 7LSBs elimination methods are utilized to increase the capacity in the preprocessing phase. Canny, Sobel, Log, BED and HED are used as the edge detection method. Two edge detectors are proposed to increase the payload in this method. The BED method extracts binary edges using the OTSU thresholding method, 2×2 blocks and a rule table. Mathematical definition of this rule table is shown in Eq. 1. The HED method use Canny, Sobel, LoG and BED methods together. Briefly, HED is combination of Canny, Sobel, LoG and BED detectors. The main goal of the HED method is to obtain all edge data in an image. Two separate secret data classes named x and y are created using edge information. The x and y classes are embedded into edge and non-edge pixels using the x LSBs and y LSBs methods respectively. More secret data are embedded into edge pixels than texture pixels because Human Visual System (HVS) is more sensitive to changes in the texture pixels than edge pixels. To increase visual quality, 2^k correction is applied on the stego images. Modulus operator is utilized to data extraction. Briefly, HED and m LSBs elimination are used to increase the payload of the edge adaptive method, and 2^k correction is used for increasing the visual quality.

Experimental and comparative results have shown that the proposed method superior than other edge-based data hiding methods. In the future works, novel edge-based steganography methods can be proposed using this method. Also, the proposed method can be used an image transformation for instance tunable q wavelet transform, discrete wavelet transform, discrete cosine transforms together. The other edge extractor can be used in this method.

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