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Image steganography based on Canny edge detection, dilation operator and hybrid coding

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ABSTRACT

In this paper, a novel steganography algorithm based on local reference edge detection technique and exclusive disjunction (XOR) property is proposed. Human eyes are less sensitive towards intensity changes in the sharp edge region compared to the uniform region of the image. Because of this, the secret message bits have been embedded in the sharp regions by local reference pixels which are detected by Canny edge method and optimized by dilation morphological operator. The predefined sets of pixels are easily identified with less computational complexity in the stego image. The embedding algorithm improved in terms of security and capacity using bit plane dependent XOR coding technique that makes least possible alterations in LSB bits of edge pixels. The existing edge-based steganography techniques provide better imperceptibility but relatively limits the embedding capacity. The proposed method efficiently improves the embedding capacity with an acceptable range of imperceptibility and robustness. The simulation results evaluated using full reference image quality assessment method, it exhibits better embedding capacity (bpp) compared to existing steganography techniques retaining the values of PSNR and structural similarity (SSIM).

1. Introduction

The exchange of information has increased rapidly in comparison with any other time in history. Because of the digitization of information, privacy and security have emerged as a serious issue. Encryption is presented as a solution in the early stages. Information can be easily shared through encryption on public networks, but additional bits are required. It is not very suitable for the low bandwidth insecure channel [1].

The alternate approach is steganography which overcomes all these shortcomings. It is capable of hiding a digital message in different media platform without revealing any noticeable presence [2]. Where cryptography protects the contents of a message, steganography can be called the defender of both the message and the communicating parties. This technique is based on the visual limitation of the human eye in which it tries to create some space in the image while maintaining the standards of human visual systems. It is quite popular in audio, image and video processing [3]. The image used for embedding secret message is called cover image, and the changed image which contains the hidden message is called stego image [4]. Like other data hiding techniques, the quality of steganography depends on three parameters namely capacity, imperceptibility, and robustness. These parameters depend on each other. So, it is not possible to get the optimum value of all the parameters simultaneously [5]. It is essential for an efficient steganography technique to achieve good embedding capacity while keeping the other parameters at the acceptable value.

It is divided into two parts that are the spatial domain and transform domain steganography both domains having its benefits and drawbacks [6]. The spatial domain provides good embedding capacity but shows weak performance against geometric attacks. LSB (least significant bit) and PVD (pixel value difference) are the traditional methods used in spatial domain steganography [7]. In ‘k-bits’ LSB substitution method, k-message bits are embedded into k LSB bits of the cover image pixels. Although the method is efficient, it creates a noticeable distortion that is detected by sample pair analysis [8]. Several adaptive techniques have been proposed to reduce such type of distortion where the choice of k- bits depends on the pixel intensity. This method increases the intensity of each pixel in irregular manner, but it can easily be detected by the histogram shift method. Techniques like LSB+ [9] and LSB++ [10] preserve the image histogram by adding some extra bits. Adjunctive redundant number system creates enough space for data embedding into the cover image by breaking into 13-bit planes (additional 5-bit planes) [11]. This method is also used very efficiently in colour image but has a weak performance against LSB

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Table 1
Method of embedding and extraction process.

	Group A	Group B
Numbers of bits used for embedding.	Bit array from 1st and 2nd LSB planes of edge pixels.	Bit array from 3rd and 4th LSB planes of edge pixels.
Embedding processes	$k_1 = p_1 \oplus p_2$ $k_2 = p_3 \oplus p_4$ $k_3 = p_1 \oplus p_3$ $k_4 = 1 \oplus p_5$	$k_1 = p_1 \oplus p_2$ $k_2 = p_2 \oplus p_3$
Extraction process	$m_1 = q_1 \oplus q_2$ $m_2 = q_3 \oplus q_4$ $m_3 = q_1 \oplus q_3$ $m_4 = 1 \oplus q_5$	$m_1 = q_1 \oplus q_2$ $m_2 = q_2 \oplus q_3$

steganalysis. Transform domain steganography provides better robustness but has less embedding capacity. It takes more computation time than a spatial domain. In this method, message bits are embedded into transform coefficient of the cover image. The discrete cosine transform (DCT), discrete wavelet transform (DWT) and integer wavelet transform (IWT) are quite popular in transform domain steganography [12]. Proposed paper is based on edge block detection and improved embedding technique, which is applied to greyscale as well as colour image. The remaining part of the paper is organized as follows: In Section 2 has a brief description of the strength and weakneses of existing methods. Sections 3–4, represent details of purpose method. Section 5 is all about its conclusion.

2. Review of literature

Along with a good embedding capacity, imperceptibility is an important issue for image steganography. It decreases with increase of message embedding bits in the cover image. So, the steganographer targets the scattered region of the cover image where the human visual system is less sensitive towards change. The sharp edge regions of the image are an ideal for message embedding. Wu and Tsai [13] proposed a steganography method called pixel-value differencing. The technique embeds the message bits according to the difference between consecutive pixels horizontally or vertically. The way to detect edge pixels of the cover image does not take into consideration all neighbourhood pixels. The directional approach is easily identified by chi-square analysis method [14]. Despite these shortcomings, this method has been constantly revised and many improvements have been proposed. A new PVD method is proposed by Luo et al. [15] that is based on the Mielikainen algorithm and adaptive embedding. Edge pixels have been optimized based on the secret message length. In the partition of a pixel pair, the image is divided into non-overlapping blocks; then it is rotated by pseudo-random angles. This gives better PSNR and robustness compared to the previous method. Although due to lack of relationship between vertical and horizontal edge pixels, stego image ($\geq$ 0.05 bpp) is detected by difference histogram method.

Researchers are still interested in proper embedding location in the cover image used for imperceptible stego image. Edge and its neighbourhood pixels are the best locations for it. There are so many well define edge detection technique, but it is difficult to get same edge pattern before and after embedding process [16]. So true message extraction is not possible. Canny edge detection performs much better than other edge detection techniques its Gaussian filter variance and the threshold value are used as reference parameters [17]. These parameters are used for extracting the edge pixels in stego image. Although this method does not provide enough embedding space in the cover image. Zero crossing, sboel and other first-order edge detection techniques do not perform better than Canny. Chang and Le [18] propose a hybrid technique that is based on fuzzy logic and Canny edge detection; that has been used for a colour image and performs well in terms of embedding capacity. However, this method does not provide any detection technique for same edge pixel in stego image.

Table 2
Embedding conditions for Group A.

Condition				Action to be taken
$\boldsymbol{m}_1 = \boldsymbol{k}_1$	$\boldsymbol{m}_2 = \boldsymbol{k}_2$	$\boldsymbol{m}_3 = \boldsymbol{k}_3$	$\boldsymbol{m}_4 = \boldsymbol{k}_4$	No change required
$\boldsymbol{m}_1 = \boldsymbol{k}_1$	$\boldsymbol{m}_2 = \boldsymbol{k}_2$	$\boldsymbol{m}_3 = \boldsymbol{k}_3$	$\boldsymbol{m}_4 \neq \boldsymbol{k}_4$	Complement p_5
$\boldsymbol{m}_1 = \boldsymbol{k}_1$	$\boldsymbol{m}_2 = \boldsymbol{k}_2$	$\boldsymbol{m}_3 \neq \boldsymbol{k}_3$	$\boldsymbol{m}_4 = \boldsymbol{k}_4$	Complement p_1 and p_2
$\boldsymbol{m}_1 = \boldsymbol{k}_1$	$\boldsymbol{m}_2 = \boldsymbol{k}_2$	$\boldsymbol{m}_3 \neq \boldsymbol{k}_3$	$\boldsymbol{m}_4 \neq \boldsymbol{k}_4$	Complement $p_{1,p2}$ and p_5
$\boldsymbol{m}_1 = \boldsymbol{k}_1$	$\boldsymbol{m}_2 \neq \boldsymbol{k}_2$	$\boldsymbol{m}_3 = \boldsymbol{k}_3$	$\boldsymbol{m}_4 = \boldsymbol{k}_4$	Complement p_4
$\boldsymbol{m}_1 = \boldsymbol{k}_1$	$\boldsymbol{m}_2 \neq \boldsymbol{k}_2$	$\boldsymbol{m}_3 = \boldsymbol{k}_3$	$\boldsymbol{m}_4 \neq \boldsymbol{k}_4$	Complement p_4 and p_5
$\boldsymbol{m}_1 = \boldsymbol{k}_1$	$\boldsymbol{m}_2 \neq \boldsymbol{k}_2$	$\boldsymbol{m}_3 \neq \boldsymbol{k}_3$	$\boldsymbol{m}_4 = \boldsymbol{k}_4$	Complement p_3
$\boldsymbol{m}_1 = \boldsymbol{k}_1$	$\boldsymbol{m}_2 \neq \boldsymbol{k}_2$	$\boldsymbol{m}_3 \neq \boldsymbol{k}_3$	$\boldsymbol{m}_4 \neq \boldsymbol{k}_4$	Complement p_3 and p_5
$\boldsymbol{m}_1 \neq \boldsymbol{k}_1$	$\boldsymbol{m}_2 = \boldsymbol{k}_2$	$\boldsymbol{m}_3 = \boldsymbol{k}_3$	$\boldsymbol{m}_4 = \boldsymbol{k}_4$	Complement p_2
$\boldsymbol{m}_1 \neq \boldsymbol{k}_1$	$\boldsymbol{m}_2 = \boldsymbol{k}_2$	$\boldsymbol{m}_3 = \boldsymbol{k}_3$	$\boldsymbol{m}_4 \neq \boldsymbol{k}_4$	Complement p_2 and p_5
$\boldsymbol{m}_1 \neq \boldsymbol{k}_1$	$\boldsymbol{m}_2 = \boldsymbol{k}_2$	$\boldsymbol{m}_3 \neq \boldsymbol{k}_3$	$\boldsymbol{m}_4 = \boldsymbol{k}_4$	Complement p_1
$\boldsymbol{m}_1 \neq \boldsymbol{k}_1$	$\boldsymbol{m}_2 = \boldsymbol{k}_2$	$\boldsymbol{m}_3 \neq \boldsymbol{k}_3$	$\boldsymbol{m}_4 \neq \boldsymbol{k}_4$	Complement p_1 and p_5
$\boldsymbol{m}_1 \neq \boldsymbol{k}_1$	$\boldsymbol{m}_2 \neq \boldsymbol{k}_2$	$\boldsymbol{m}_3 = \boldsymbol{k}_3$	$\boldsymbol{m}_4 = \boldsymbol{k}_4$	Complement p_2 and p_4
$\boldsymbol{m}_1 \neq \boldsymbol{k}_1$	$\boldsymbol{m}_2 \neq \boldsymbol{k}_2$	$\boldsymbol{m}_3 = \boldsymbol{k}_3$	$\boldsymbol{m}_4 \neq \boldsymbol{k}_4$	Complement $p_{2,p4}$ and p_5
$\boldsymbol{m}_1 \neq \boldsymbol{k}_1$	$\boldsymbol{m}_2 \neq \boldsymbol{k}_2$	$\boldsymbol{m}_3 \neq \boldsymbol{k}_3$	$\boldsymbol{m}_4 = \boldsymbol{k}_4$	Complement p_2 and p_3
$\boldsymbol{m}_1 \neq \boldsymbol{k}_1$	$\boldsymbol{m}_2 \neq \boldsymbol{k}_2$	$\boldsymbol{m}_3 \neq \boldsymbol{k}_3$	$\boldsymbol{m}_4 \neq \boldsymbol{k}_4$	Complement $p_{1,p4}$ and p_5

Table 3
Embedding conditions for Group B.

Condition		Action to be taken
$\boldsymbol{m}_1 = \boldsymbol{k}_1$	$\boldsymbol{m}_2 = \boldsymbol{k}_2$	No change required
$\boldsymbol{m}_1 = \boldsymbol{k}_1$	$\boldsymbol{m}_2 \neq \boldsymbol{k}_2$	Complement p_3
$\boldsymbol{m}_1 \neq \boldsymbol{k}_1$	$\boldsymbol{m}_2 = \boldsymbol{k}_2$	Complement p_1
$\boldsymbol{m}_1 \neq \boldsymbol{k}_1$	$\boldsymbol{m}_2 \neq \boldsymbol{k}_2$	Complement p_2

Modi et al. [19] proposed a colour image steganography technique based on Canny edge detection and LSB matching. In this method, Canny edge detection is applied to only one channel of the colour image, which is used as a reference edge location for embedding purpose in other two channels. Extraction of same message bits is simple, and security is also improved. However, embedding capacity is relatively low because only two channels are used for embedding. This method is unable to achieve same edge pattern in all three channels of the colour image. The structural image quality is not up to the mark. Blind image analysis also got very high score means its statistical parameter not preserved.

Al-Dmour and Al-Ani [7] proposed a new edge detection method that is more suitable for steganography in which cover image is divided into 3×3 non-overlapping blocks for edge detection. Out of nine pixels, four corner pixels are used as a reference that is used for correct identification of edge blocks in stego image. The difference between the horizontal pair, vertical pair and diagonal pairs of the reference pixel determines that whether it is an edge block or not. Only five pixels are used for embedding. Embedding technique is also very efficient and fast. This approach is tested on both spatial and transform domain, but a spatial domain has a better result in terms of data embedding capacity [7]. This technique provides good PSNR value (48–51) with 0.7 bpp embedding