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# A reversible data hiding method by histogram shifting in high quality medical images

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ABSTRACT

Enormous demands for recognizing complicated anatomical structures in medical images have been demanded on high quality of medical image such as each pixel expressed by 16-bit depth. Now, most of data hiding algorithms are still applied in 8-bit depth medical images. We proposed a histogram shifting method for image reversible data hiding testing on high bit depth medical images. Among image local block pixels, we exploit the high correlation for smooth surface of anatomical structure in medical images. Thus, we apply a different value for each block of pixels to produce a difference histogram to embed secret bits. During data embedding stage, the image blocks are divided into two categories due to two corresponding embedding strategies. Via an inverse histogram shifting mechanism, the original image will be accurately recovered after the hidden data extraction. Due to requirements of medical images for data hiding, we proposed six criteria: (1) well-suited for high quality medical images, (2) without salt-and-pepper, (3) applicable to medical image with smooth surface, (4) well-suited sparse histogram of intensity levels, (5) free location map, (6) ability of adjusting data embedding capacity, PSNR and Inter-Slice PSNR. We proposed a data hiding methods satisfying above 6 criteria.



## 1. Introduction

Recently, most hospitals have already established the electronic medical information to make healthcare better, safer, and more efficient. Over the Internet, digitized medical information is very convenient to transmit among patients, medical professionals, health care providers, and institutes of medicine. However, many risks are more and more increasing such as illegal accessing and unauthorized tampering. Therefore, data hiding plays an important role in information security such as authentication, fingerprinting, copy control, security, and covert communication. Depending on the relationship between the embedded message and the cover image, data hiding techniques are divided into two categories: steganographic applications and digital watermarking. Applications of steganographic are no relationship to the cover image used for communication. The cover image means nothing to the sender except masking the secret message. Digital watermarking has a close relationship to the cover image such as adding the cover image caption, author signature, and authentication code in it.

According to permanent distortion of the cover image, digital watermarking is divided into irreversible data hiding and reversible data hiding (Ni et al., 2006, 2008). Because of permanent distortion of the cover image, the original images cannot restore from stego-images. Thus, irreversible data hiding techniques are hard to satisfy many circumstances such as in the field of law enforcement, medical imaging systems, military imaging systems, remote sensing, and high precision systems in scientific research.

Nowadays, reversible data hiding, which is also called lossless data hiding, has drawn much attention among researchers (Huang and Fang, 2011; Ni et al., 2006; Wu et al., 2011). Reversible data hiding has complete blind restoration of the original data from stego-images after the hidden data retrieved. In general, reversible data hiding techniques can be classified into three groups by Feng et al. (2006): data compression (Chiou et al., 2011), pixel-value difference expansion (DE) (Lu et al., 2006; Ni et al., 2006; Wang et al., 2008) scheme and histogram-based scheme (Huang and Fang, 2011).

DE is one kind of integer wavelet transform proposed by Tian (2003). In order to realize a high-capacity and low-distortion reversible watermarking, Tian examined the redundancy in digital images by expanding the difference between the two neighboring pixel pairs to achieve a high-capacity and low-distortion reversible watermarking. By the generalized DE method, Alattar (2004) applied Tian's scheme to hide several bits in the DE of vectors

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of adjacent pixels. Later on, Kim et al. (2008) improved DE method to reduce the size of the location map. Further, Lin et al. (2008) proposed a DE scheme to remove the location map completely. In order to improve overflow map, Hu et al. (2009) proposed a new DE algorithm.

Histogram shifting is another technique applied in reversible watermarking schemes. De Vleeschouwer et al. (2003) attempted to achieve reversibility by Circular interpretation of bijective transformations. Ni et al. (2006) utilized a zero and a peak point of image histogram to embed messages. Luo et al. (2011) exploits the high correlation among image block pixels to produce a difference histogram and embedded secret data by a multi-level histogram shifting mechanism.

De Vleeschouwer et al. (2003) proposed a robust lossless data hiding technique against a high-quality JPEG compression based on the modulo-256 addition. Unfortunately, applying the modulo-256 addition method will produce salt-and-pepper noise. Therefore, many papers (Ni et al., 2008) proposed a robust (or semi-fragile) lossless data hiding technique to overcome this drawback.

With the development of electronic medical information and the network technique, data hiding plays an important role for medical images. Until now, many algorithms (Huang and Fang, 2011; Huang et al., 2012; Lou et al., 2009) have been proposed. Most of them were applied in 8-bit depth medical image expressing intensity 0–255. Now, high quality medical devices are applied for improving the detection rate of diseases and treating at the early stage. A vast amount of demands for recognizing complicated anatomical structures in images have been required on high quality of medical image with 16-bit depth. Because of 16-bit depth with intensity 65,536 discrete levels and the smooth surface of anatomical structures required, it is becoming more and more difficult to find duplicate intensities embedding secret bits in embedding algorithms.

We develop a novel reversible data embedding scheme testing on 16-bit depth with dicom medical image. This scheme proposes 6 criteria well-suitable for requirements of medical images. The detail will be described in the following. This paper is organized as follows: Section 2 describes the criteria of reversible data hiding. In Section 3, we present our method. Section 4 presents the experimental results. And finally in Section 5 is conclusion and discussion.

## 2. The criteria of reversible data hiding

In general, the quality of a reversible data hiding is measured by payload capacity limit, visual quality, and complexity. However, high resolution medical images are different from low resolution medical images ex. 8-bit depth image. We divide the criteria of reversible data hiding into traditional criteria of reversible data hiding and the criteria of reversible data hiding in medical image described as follows.

### 2.1. Traditional criteria of reversible data hiding

The basic requirement of data hiding is low quality degradation on the image after data embedding.

In order to measure the quality of a reversible data embedding, Tian (2003) provided 3 criteria: (1) payload capacity limit, (2) visual quality, (3) complexity. We describe detail as follows:

(1) Payload capacity limit
The maximum amount of secret bits can be embedded to cover images with acceptable visual quality.

(2) Visual quality
The difference between the cover image and the stego-image is low degree of distortion. The PSNR is most commonly adapted to measure the quality of reconstruction of lossless data hiding.

(3) Complexity
The complexity is a method to measure efficiency of a data hiding algorithm. In general, complexity is analyzed by quantifying the amount of resources needed such as time and storage.

### 2.2. The criteria of reversible data hiding in medical image

Many medical images are a volume structure constructed by a series of images slices. Modern medical devices produce high quality medical images for detecting diseases. Therefore, more criteria are needed to measure high quality medical images for identifying complicated anatomical structures. We proposed 6 criteria to measure data hiding algorithms such as well-suited for high quality medical images, applicable to medical images with smooth surface, without salt-and-pepper, ability of adjusting data embedding capacity, PSNR and Inter-Slice PSNR, sparse histogram of intensity levels, and free location map. The detail demonstrated as follows:

(1) Well-suited for high quality medical images
In digitalized images, a certain number of bits is assigned to each pixel to represent its intensity. The number of bits, the bit depth, will determine the number of gray levels between the minimum and maximum intensities that the imaging devices are able to capture. High quality images have high resolution and high bit-depth up to 12 bits or more per pixel. If the bit depth is not sufficient, the images will be a loss of grayscale resolution (Gunturk et al., 2001; Bartrina-Rapesta et al., 2009). In high-resolution computed tomography (HRCT), CT images with a higher resolution and bit-depth can demonstrate subtle anatomical structures such as tissue characterization to detect diseases (Wang et al., 2010; Zhang et al., 2006). In other words, HRCT can get higher contrast CT data. Nowadays, enormous demands for recognizing complicated anatomical structures in medical images have been required on high quality of medical images (Bartrina-Rapesta et al., 2009) such as each pixels expressed by 16-bit depth as shown in Fig. 1. A 16-bit depth image can handle 65,536 discrete levels of information instead of the 256 levels achieved by 8-bit image. In Fig. 2, 8-bit images express intensity 255 as most of light anatomical structures in medical images. However, 16-bit depth image demonstrates the light part of anatomical structures as different intensity. In general, medical image have background of the images (or called None ROI) (Fallahpour et al., 2011) which does not contribute to the diagnosis. Because high bit-depth medical images are detail-rich images, ROI area utilizes more intensity to presented anatomical structures for disease diagnosis. Some schemes are hard to embed secrets to ROI area. For instance, the schemes search for continuous duplicate values to hide secrets. Thus, most of secret bits will be embedded in None ROI area. Unfortunately, there is a copy attack (Fallahpour et al., 2011) in these kinds of schemes. If a data hiding scheme is well-suited for high quality medical images, the embedded secret bits will distribute to whole images with copy attack avoidance.

(2) Without salt-and-pepper
Salt and pepper noise is one kind of noise typically seen on images presented by white and black pixels. In other words, the histogram for the salt-and-pepper has an extra peak at the white end of the spectrum since the noise components were pure black and white (Gonzalez and Woods, 2002) as shown in Fig. 3.
From the position of salt-and-pepper, the illegal attackers can easily get the information to revise the stego-image.

(3) Applicable to medical image with smooth surface