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Analysis of Difference Expanding Method for Medical Image Watermarking

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Abstract. This paper proposes a reversible watermarking scheme for medical images. It has been developed through the analysis of difference expanding method proposed in [2] for medical images. It gives high distortion when embedding takes place in multiple layers. It directly affects the imperceptibility. In order to improve the imperceptibility, the color characteristics are introduced in the proposed scheme. The embedding process in the proposed scheme is carried out in two steps. First step selects the pixel according to the color characteristics of the medical images. Second step embeds the secret information into selected pixels by using the difference expanding method of the two pixels from different color planes. It is known as intra-plane difference expanding. It embeds more than one bit at each byte in one pixel of the image and give us imperceptible results. The digital fundus images are one particular class of medical images which has been chosen for analysis in this paper. These images were given in TIF format in RGB color space. This scheme was robust to statistical and visual attacks. The quantitative analysis shows that the proposed scheme improved the imperceptibility to 15% with respect to the scheme in [2] for fundus images. It is also found that 30000 bits is the optimum size of the watermark with good level of imperceptibility which is above 60 dB PSNR at an average.

Keywords: Fundus images, image watermarking, image authentication, integer transforms.

1. Introduction

The security of medical images is attained from strict ethics and legislative rules which can be classified in three fixed characteristics: confidentiality, reliability and availability [3] [4] [5] [6].

Confidentiality: It means that only the entitled users should have access to the images in the scheduled system.

Reliability: It is specified by two features. i) Integrity: Ensuring that the images have not been modified by unauthorized person. ii) Authentication: Ensuring the confirmation of the image belongings to the correct patient and correct source.

Availability: It is the capability of an image to be used by the permitted users in the normal scheduled conditions of access and exercise.

Providing security for medical imaging is very important, when the images are exchanged in inter and intra hospital networks. In such case, the first two characteristics have mainly to be considered. The watermarking scheme has been recognized as technique to control the image reliability by accentuating its integrity and authenticity [3] [5]. In medical images, modifications due to the insertion process are not accepted by physicians for diagnosis purpose [3].Hence, requirements in medical images are differed from multimedia applications [3] [7] [8] [9]. A watermarking scheme can be defined by three properties:

Payload: It refers to the number of bits per pixel (bpp) that can be used to embed the information.

Robustness: It refers to the survival ability of the embedded message to the insertion problems such as alteration in the pixels and information loss.

Invisibility: It refers that no external artifacts are generated due to the insertion process. The embedded information should be invisible under normal vision.

There are three possible solutions for medical image watermarking have been identified in the literature survey [3].The first solution is based on region of non-interest. Here the unwanted regions of images are chosen for embedding watermark [4] [8]. The second solution is based on reversibility. Here the watermarking scheme should able retrieve the original image from the watermarked image without any loss of information at the extraction process [9] - 16]. The third solution is based on non-reversible. Here, tolerable information loss is accepted as in lossy compression. Any watermarking scheme can be classified into either reversible or irreversible. It can use region of non-interest for embedding. However, the selection of region of images for embedding is application specific. Reversibility, imperceptibility and capacity are the three main factors of any watermarking schemes for medical images [2].The capacity refers the size of watermark and imperceptibility refers that embedded watermark completely invisible under normal vision. Here the capacity and imperceptibility are in trade-off relationship. The way in which the pixels are selected for embedding is directly affecting the imperceptibility. In [2], multiple layer data hiding scheme has been proposed to medical images. It embeds the secret data using the difference between the neighbor pixels and produces the reversible solutions. But, it failed to provide a reliable and confidential communication. Because, it generates high distortion when embedding takes place in multiple layer. Moreover, it could embed one bit of secret data into one pair of pixels. More than one bits of information can be embedded in multiple layers. It is found that few of pixels pairs are not expandable for longer time due to overflow or underflow problems while they are being modified for embedding. Hence, we carried out the analysis for designing new watermarking scheme for medical images by improving the imperceptibility. It is found in the analysis that proper selection of pixels can improve the imperceptibility than blind selection as in [2].In [2], the consecutive pixel pairs will be selected for embedding without following any fashion. To facilitate in selection of pixels, the color characteristics are found as good parameters [1]. With this, the main color and sub color of each pixel are identified. Only sub colors of each pixel can be used for embedding without touching main color. Thereby, we designed a new reversible watermarking scheme based on color characteristics of pixels for medical images. Digital fundus images are one particular class of medical images. The fundus is the interior surface of the eye, including the retina, optic disc and macula. The fundus can be viewed with an ophthalmoscope. The fundus images are taken using a special camera called fundus camera. A fundus camera is a specialized low power microscope with an attached camera designed to photograph the interior surface of the eye. The example of fundus images is shown in Fig1. Retinal fundus images are useful for the early detection of a number of ocular diseases. If it is not treated that will lead to blindness. Examinations on retinal fundus images are cost effective and are suitable for mass screening. For the quantitative analysis, we have taken these fundus images. Hence, this paper is dedicated to digital fundus images.

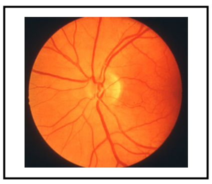

Fig.1: Digital Fundus Image

The paper has been organized as follows. Section I gives the introduction. Section II presents the proposed scheme. Section III shows the experimental results conducted on digital fundus images. The conclusion is given in Section IV.

2. The Proposed Scheme

The pixels of fundus image in the proposed scheme are given in 24-bits or 3 bytes of RGB color. Each byte contains two nibble. The left nibble contains the highest value in the byte while the right nibble contains the lowest value in the byte. Therefore, any changes in the right nibble will cause a minimal change in a byte value. Since, the right nibble value is given in the interval [0, 15], it gives 16 different levels. These levels are used for creating the priority of the colors. Thereby, we get 16 main color indexes *(MCindex)*. The main color index of the pixels is given by

$$\text{MCindex} = \text{floor}(\text{ColorValue}/16) + 1 \quad (1)$$

Where ColorValue = {Red, Green, Blue}. The main color index values are used to create the priority values in order to embed the data in the proper pixels. The priority value Pr (MCindex) is calculated as follows:

$$\text{Pr}(\text{MCindex}) = MC - 17 \quad (2)$$

The main color of the pixel is given by highest priority. Then, the rest colors of the pixels (sub colors) are chosen for embedding by using Eqn.3, the main color of the pixel is untouched.

$$MC = \min\{\text{Pr}(\text{MCindex}_i)\} \quad (3)$$

The sub colors of the pixels are taken to integer transform for embedding. The integer transforms works as follows. For an 8-bit grayscale-valued pair (x, y), x, yεZ, 0≤Z≤255, the integer average M and difference D are defined as follows:

$$M = \text{floor}((x+y)/2)$$

$$D = x - y \quad (4)$$

The inverse transform is defined as:

$$x' = M + \text{floor}((D+1)/2)$$

$$y' = M - \text{floor}(D/2) \quad (5)$$

The difference is expanded by using Eqn.6 for embedding.

$$D' = 2*D + b \quad (6)$$

Where D′ is modified difference after embedding the embedded bit (b). The modified difference (D′) is calculated by satisfying the following condition in order to prevent the over flow or under flow during embedding process.

$$|D'| \le 2*(255 - M) \quad \text{If } 128 \le M \le 255$$

$$|D'| \le 2*(M + 1) \quad \text{If } 0 \le M \le 127 \quad (7)$$

If D' satisfies the Eq. (7), the D is expandable, otherwise D is unexpandable. An expandable difference can be used to hide secret information. If all the expandable differences are selected for data embedding, the capacity rate will reach its maximum limit [2]. The hiding capacity of an image is defined as:

$$C = Ne/N \quad (8)$$

Where, N and Ne denote the number of difference and the number of expandable differences, respectively. Therefore, the hiding capacity of the image is proportional to the number of expandable difference. Thus, the proposed scheme embeds the secret data into the fundus image. The extraction process is reversible and which extracts the secret data and original image without any loss of information. Here some of the differences may not be expandable for longer time, while it is being used in multiple layers [2].

3. Results and Analysis

The proposed watermarking scheme has been simulated in MATLAB 6.5 using around 150 digital color fundus images. These images were taken from DRIVE and STARE public databases [3] [4]. The images in the databases were in different formats. We brought it to the fixed size of 512×512×3, 8 bits per pixel in color channel and represented in TIF format.

3.1. Imperceptibility and Reversibility

Medical sciences are very strict with the quality of images. Therefore, it is often not allowed to alter in any way the bit field representing the image. Hence, the watermarking method is designed as reversible, in that the original pixel values can be exactly recovered after extracting the watermark. This limits significantly the capacity and imperceptibility [5].The secret information is a binary image of size 40×40 that represents identification mark. It has been used to authenticate the images. The image is then converted in to a binary sequence of length 1600.

To evaluate the proposed scheme quantitatively, we used peak signal to noise ratio(PSNR) in decibel (dB) between original image(I) and its watermarked version image(Iw) which have been found as best parameters in measuring the fidelity of the method [3][6].

$$PSNR\ (I, Iw) = 10\ Log_{10}\ [(2^p-1)^2/\ MSE] \quad (9)$$

For the comparative analysis, we have taken the difference expanding method given in [2]. In [2], the pixels are embedded sequentially. That means one by one. In the proposed scheme, only sub colors are chosen for embedding. From the experiment, it is found that the proposed scheme improves imperceptibility to 15% at an average with respect [2]. The sample images used in the test bed are shown in fig 2 and whose PSNR values in both previous algorithm [2] and proposed scheme are tabulated in Tab 1 and Tab 2. As already mentioned, the imperceptibility and size of watermark are in tradeoff. To identify the best size of the watermark, the experiment conducted on a set of 100 fundus images and the corresponding imperceptibility has been calculated using PSNR (Peak Signal to Noise Ratio) between original image *(I)* and watermarked image *(Iw)*.

By the number test, it is concluded that 30000 bits will be the best maximum size of the watermrk which will not introduce any visual artifacts. It is clearly shown in fig.3.When, the size of the watermark is crossing 30000bits, the visual artifacts are introduced. It is achevied with PSNR of 60dB at an average and it is best suited for authentication [3].

Tab.1: PSNR values of previous algorithm in [1]

Sample Images	PSNR at Red	PSNR at Green	PSNR at Blue
S1	77.3747	77.4448	67.745
S2	77.2783	77.4026	67.5435
S3	76.9506	79.0324	67.4775
S4	76.9506	77.0399	67.4775
S5	77.0014	77.1179	67.5147

Tab.2: PSNR values of proposed algorithm

Sample Images	PSNR at Red	PSNR at Green	PSNR at Blue
S1	100	70.9458	96.2956
S2	70.9206	100	99.3059
S3	100	64.8608	69.5585
S4	70.9206	100	100
S5	71.1206	100	100

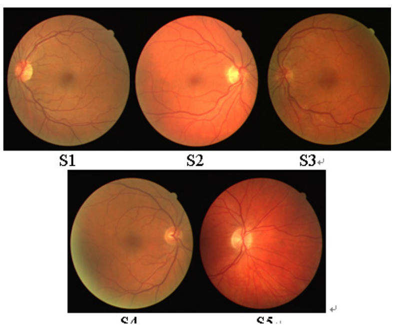

Fig.2: Sample Images used in the test bed

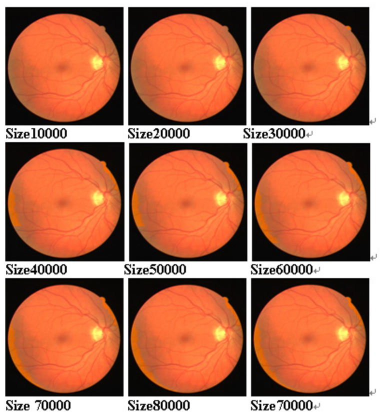

Fig.3: Imperceptibility Vs Size of Watermarking

4. Conclusions

In this paper, we proposed a reversible, multilayered watermarking scheme for fundus images using intra-plane difference to assure the confidentiality and reliability of the communication. The proposed scheme allows an individual to hide secret data inside the fundus image with hopes that the communication process will be so obscure. It will not give any rooms for suspicion about the contents of the file. It is found that the proposed scheme improved the imperceptibility to 15% and 30000 bits were found as optimal size of watermark with 60 dB of PSNR at an average. The proposed scheme in the paper can be extended to provide the multi level security by combining with cryptosystems for any classes of medical images.

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