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Digital Watermarking of Medical Images

— 의료영상의 디지털 워터마킹 —

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— **Abstract** —

This study proposes how to insert a strong watermark creating a big change in the areas of edge and texture. While conversion by existing Fourier transformation can acquire information for all ranges of frequency domain from the image, Wavelet transformation can manipulate edge and texture area selectively. Therefore, through wavelet transformation concerned area may be selected and watermarks in copyright formation are inserted. Our proposed algorithm was compared to Xia's watermarking technique using wavelet transformation. Its fidelity and robustness were tested with attack methods used in existing papers and it turns out that the proposed algorithm using HVS properties is more superior to Xia's techniques.

Ⅰ. Introduction

Medical images have been rapidly changed into digital images and improvement of internet technique and universalization of its use has also changed medical contents into digital forms of multi media. Digitalized medical information has been easily and rapidly distributed and utilized through external communication network like internet, resulting from the exchange of medical information with digital communication network of medical agencies and external medical agencies. However, the development of these techniques brought some side effects of illegal reproduction of patients' important disease information and artificial manipulation of disease information. Illegal reproduction and artificial manipulation of digital medical image is a very serious problem which may result in a lot of problems of artificial manipulation of disease information as well as unveiling patient's private information. For preventing these problems, some methods for protection of information and prevention of forgery and modulation of information have been developed through inserting medical information into original digital image for the protection of original data information. These methods can be divided into three categories :

Access-Control Header method is to easily eliminate concerned information with insertion of additional information into header of data, and encryption method encodes given data using public key encryption algorithm and is mathematically safe, but it has the disadvantage that once digital information was decoded, ownership of the information cannot be argued. These two methods are to inform or protect copyright by adding additional information rather than changing into digital information. The final digital watermarking method

is difficult to eliminate by inserting information of copyright into digital information itself and doesn't lower quality of original digital information using the cognitive model. Digital watermarking technique is recognized as a final stronghold of copyright protection solution needed absolutely for distribution of digital information through internet and is also acknowledged as necessary technique for the exchange of legally sound digital information with the establishment of standardized copyright information.

Types of hiding information related to copyright into image contain the two important structural features[1] : robustness and fidelity of watermark. In fact, since these two features conflict with each other, it is important to search for mutual trade-off for the protection of safe copyright. Existing watermarking techniques of sound and image focused on these points. This paper proposes the effective blind method in order to improve performance of robustness and fidelity and compares and analyzes to existing methods in terms of robustness and fidelity based on image processing experiments of watermarking images.

Ⅱ. Material and Method

Digital watermarking is the technique inserting specific data whose ownership is subject to be argued, including digital copyright information of text, image, audio and video, in order not to be discriminated with man's naked eyes or hearing. If ownership is in dispute or owner should not be in agreement on the process of distribution, an authoritative foundation to exercise such rights as ownership and copyright will take an action by retrieving and extracting it. Hidden data to confirm ownership into digital format is called watermark and their types may be image or signal sequence[2].

1. Digital Watermarking System

Generally watermarking system consists of embedder and detector as shown in Fig. 1[3]. Embedder has two inputs ; one is message to be encoded as watermark and the other is original work with watermark added.

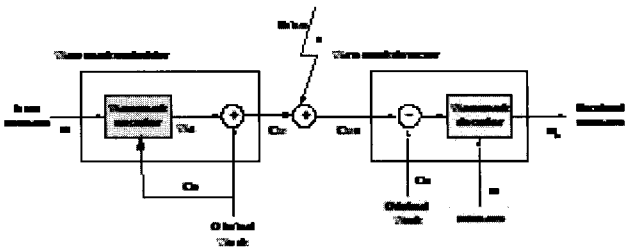


Fig. 1. Embedder/Detector

If original work can be functioned properly in embedder, it will achieve more effective system by examining the original work before inserting input message and then applying it to embedder. Feature of fidelity can be improved by inserting strong or weak watermark depending on properties of original work and it is difficult to eliminate watermark.

2. Requirements

Each watermarking technique has a specific requirement depending on its applications. The following explains properties of watermarking needed for protection of copyright and its related techniques[4].

1) Fidelity

Watermarking algorithm should be inserted in order not to affect quality of original works by watermark. Insertion process of watermark should not be completely recognized unless original data and inserted data can be discriminated by user.

2) Robustness

Fragile watermark that must verify authentication of original work needs no robustness since it may be damaged easily by a little manipulation or forgery. However, most of other applications may have watermark loss by malicious attack or compression to remove hidden watermark in original work. Watermark should be detected for such an intended or unintended attack.

3) Security

Security of watermark can be explained with the same concept as security in encryption. Given that insertion and detection algorithm of watermark are known, they are necessary factors when watermark itself is important.

3. Watermarking Techniques

1) Watermarking in Spatial Area

It can be divided into spatial domain method of data and frequency domain method depending on how to insert watermark or its application techniques.

In the spatial domain method, watermark insertion method uses minute changes of pixel value as watermark. This method has disadvantages that it is fragile to image processing like loss compression or filtering although it is easy to insert watermark. And since it is difficult to look for non-cognitive area in spatial areas, watermark insertion method in frequency area close to recognition system has been frequently used.

2) Watermarking in Frequency Area

Frequency domain method is to transform multimedia data into frequency signal and to insert watermark. In general, data transform methods include discrete cosine transform(DCT), discrete fourier transform and discrete wavelet transform(DWT).

Since these methods make watermark coefficients distributed in the whole areas of original data and once inserted watermark is difficult to be cancelled, it is frequently used in recent watermarking techniques and is strongly resistant against noise and compression image.

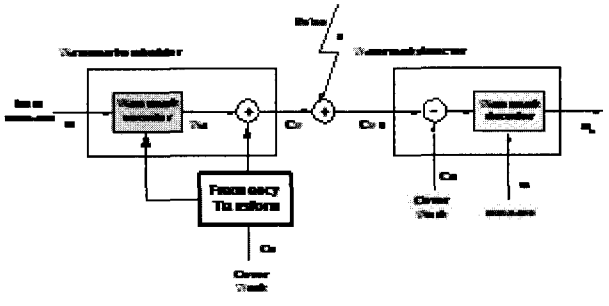


Fig. 2. Watermarking in Frequency Area

Watermarking proposed by Cox inserts signal sequence generated by signal generator in DCT area into AC area with the biggest coefficient except for DC. As the area where watermark is inserted is the part that JPEG compression coding is transmitted first, it has a high robustness against JPEG attack. But inserting watermark into big coefficient area except for DC is to insert watermark into almost low frequency areas and so its fidelity has considerably low value.

In comparison with watermark insertion of low frequency band by Cox, watermark insertion of middle frequency band may be considered[5]. However, it has been known by experiment that it is not robust compared to Cox's values.

Watermarking techniques as described above are based on inserting watermark with selection of wide frequency band through Fourier analysis. Technique proposed by Xia uses wavelet theory[6,7] and inserts watermark into all areas except for LL2 band. Watermark in the band except for LL band is mainly distributed to edge and texture part due to properties of wavelet transform. As it improves fidelity and can have better fidelity than conventional techniques even with use of a stronger watermark, it can obtain a higher robustness. Results of Xia's system are compared with techniques proposed in Chapter 4.

Ⅲ. Proposed Algorithm

1. Human Visual System

Weber's law explains that in order to discriminate brightness of an area from that of its surroundings, it can be recognized by a bigger change at a bright place. For example, noise at small signal is felt larger than that at big signal. In other words, since JND (joint noticeable difference) recognizing changes of minute luminance

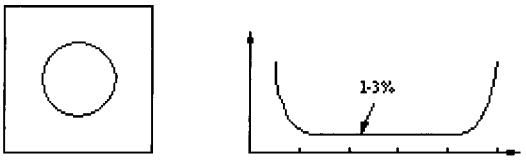


Fig. 3. JND by Changes of Luminance

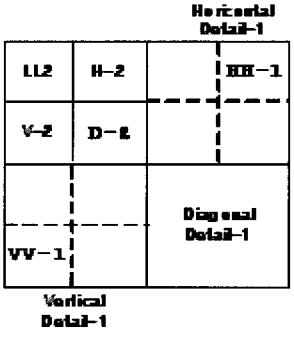


Fig. 4. Insertion Position of Watermark

level at a specific luminance of an image is close to constant value, human visual system cannot recognize difference even in the change of large values as luminance level is higher.

$$\Delta c = \Delta I / I = \Delta(\log I)' = \text{constant} \quad \cdots\cdots (1)$$

Considering background and an area as image and watermark, it can be known that part having a big change in image brightness is selected for inserting a strong watermark. Since edge and texture area have a big change in image brightness, more specific edge and texture are selected by means of wavelet theory.

2. Insertion of Watermark

1) Insertion Position

While HVS (Human Visual System) is not sensitive to small changes in edge or texture of image, it can detect small change in slow part[8]. Therefore, H1 and V1 parts obtained by general wavelet theory are dissolved once again and more specific edge (HH-1, W-1) are searched and watermark is inserted there.

In addition, since D-2 band obtained as a result of 2-level DWT is the second low frequency band

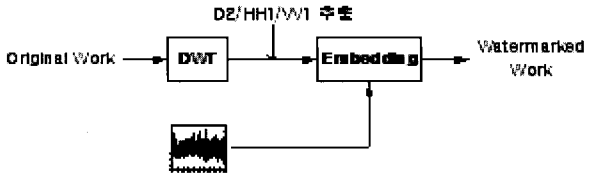


Fig. 5. Insertion Process of Watermark

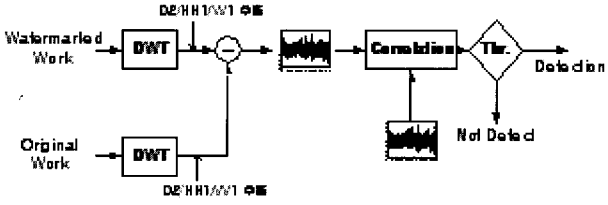


Fig. 6. Detection Process of Watermark

of the image, more watermarks are inserted here. And moreover, as lowering fidelity performance occurred in inserting it into LL2 band is prevented, a strong robustness against noise attack and JPEG compression is obtained same as in Cox's results[9].

2) Insertion Methods

Insertion methods of watermark are proposed by Cox and the same equations are used as in most of papers on watermarking.

$$Cw = Co(1 + a.Wa) \quad \cdots\cdots (2)$$

Since watermark is not removed easily against random image transform when inserted in the order of coefficient values having large quantity of information, watermark is inserted in the order of the biggest coefficient[10].

3. Extraction of Watermark

Watermark attacked in image with watermark inserted using original image is extracted with the following expression and presence or absence of watermark is discriminated by the degree of correlation.

Extraction Expression of Watermark :

$$Wa = (Cw/Co-1)/a \quad \cdots\cdots (3)$$

Presence or Absence of Watermark :

$$mn - Corr(Wa, Wa) \quad \cdots\cdots (4)$$

Ⅳ. Experiments

1. Experimental Environment

Input image is chosen as 256-gray level of uncompressed brain MRI image in size of 256×256 pixel and the Haar wavelet was used as wavelet filter. Gaussian random signal is used for watermark, in which multiple watermarking is possible and is difficult to be removed as described in Cox's paper.

Proposed algorithm used random signal sequence with $N = 2000$ and $\alpha = 0.4$ in the ratio of 1 : 2 for edge and texture area. In the experiment by Xia, $N = 1000$ watermark was inserted in the strength of $\alpha = 0.1$ into all bands except for LL2.

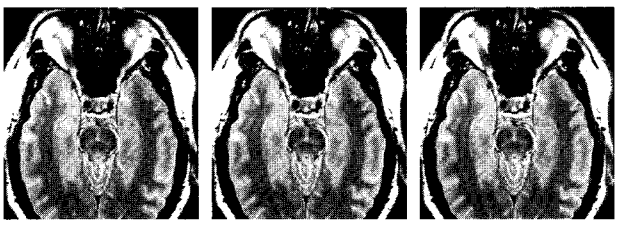
2. Fidelity Experiment

Measurement of similarity between original work and image with inserted watermark is presented below. It considers watermark as a noise and measures how much it is similar to original work. It can be judged in general that value with more than 35 dB is similar to original image.

$$PSNR = 10 \cdot \log_{10} 255/MSE \text{ [dB]} \quad \cdots\cdots (5)$$

As shown in the figure below, it is found that technique proposed through PSNR(Peak Signal to Noise Ratio) is closer to original image although it is difficult to distinguish its visual difference from original work.

Xia : PSNR = 27.95 dB, Proposed : PSNR = 37.30 dB



(a) Original image (b) Xia image (c) Proposed image

Fig. 7. Original Image and Watermark Inserted Image by Xia and the Proposed

3. Robustness Experiment

3.1 Addition of Noise

Three noises are used in this experiment. Gaussian white noise and speckle noise are added to dispersion of 0.1 and Salt & Pepper noise to original image with the density of 0.05. Effects of watermark insertion in low frequency band as in Cox's were obtained by inserting considerable amount of quantities of watermark into D-2 area.

2) Filtering

Gaussian Low/Laplacian High-pass and Unsharp filters were used for filtering attacks. In particular, fidelity from Unsharp filtering used frequently for improving image was improved more than that of existing papers. It is because Unsharp filter filtering edge and texture area passes most inserted watermarks in the proposed paper. But, all watermarks were removed at Laplacian HPF filtering edge of image because Laplacian filter adjusts pixel value randomly to highlight edge.

3) JPEG Compression

Since JPEG compression is DCT based compression method[12], it shows a very superior robustness in watermarking proposed by Cox, but experimental results by Xia based on wavelet also showed good performance. Our proposed algorithm made more use of watermarks into D-2 band and proved more robust properties than Xia's.

Table 1. Extracting Watermark of Noise Addition

Correlation	Gaussian	Speckle	Salt & Pepper
Xia	0.0853	0.2571	0.5613
Proposed	0.3194	0.5954	0.2789

Table 2. Extracting Watermark of Filtering Attack

Correlation	LPF	HPF	Unsharp
Xia	0.5475	-0.2126	0.2979
Proposed	0.9042	-0.0913	0.7781

Table 3. Extracting Watermark of Compression Ratio of JPEG

Correlation	Quality Compression 30%	50%	70%
Xia	0.5075	0.3561	0.2759
Proposed	0.7818	0.6457	0.4719

Table 4. Extracting Watermark of Compression Ratio of JPEG2000

Correlation	Quality Compression 30%	50%	70%
Xia	0.3234	0.2051	0.1023
Proposed	0.9942	0.9961	0.9978

4) JPEG2000 Compression

JPEG2000 is the compression method implemented on the basis of wavelet theory. And then, it is expected that both results of Xia's experiment using wavelet theory and our proposed experiment would be good enough. But, result from Xia's showed lower value than expected and it was because of EBCOT coding method of JPEG2000. EBCOT examines correlations among coefficients and when it is high, its inferior coefficients are excluded and compressed. As watermark insertion area in the proposed paper has no preference to D-2, HH-1 and W-1, most areas of watermarks were used for compression.

V. Conclusion : Future Tasks

While Cox's paper and insertion method of watermark into middle frequency band have a strong robustness against attack related to low frequency, high frequency filtering or fidelity value showed low performance. Xia inserted watermarks into all bands using wavelet and so, it assumed to show strong watermark, but it revealed weaker robustness than existing methods in fidelity and EBCOT based JPEG 2000 method.

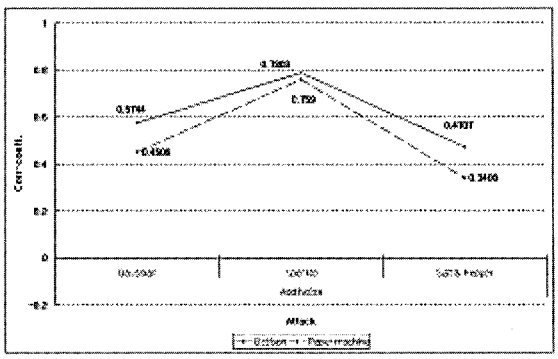


Fig. 11. Comparison between Xia and Proposed Algorithm

This study analyzed Cox method resistant against noise and JPEG attack and inserted different watermarks into D-2, HH-1 and W-1 areas using HVS. Consequently, more improved results of Unsharp filtering used in noise and JPEG attack and general image processing could be obtained. Also robustness without any loss in JPEG2000 compression could be obtained by inserting watermark into different areas. But, since original image is required in detecting watermark, technique to detect watermark without original image is necessary in relation to off-line watermarking technique. Algorithm which can extract insertion technique in the proposed watermarking without original image should be developed in future.

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• Abstract

의료영상의 디지털 워터마킹

이상복 · 이삼열 · 이준행

남부대학교 방사선학과

본 논문은 의료영상에 강력한 워터마크를 삽입하는 방법을 제안한다. 기존의 푸리에 형태의 변환은 영상의 전체적 주파수 성분에 대한 정보를 구할 수 있는 반면, 웨이블릿 변환법은 국부적으로 에지와 텍스처 영역을 찾을 수 있다. 그러므로 웨이블릿 변환을 통해 해당 영역을 선택하여 저작권 형태의 워터마크를 삽입한다. 이러한 제안 알고리즘을 단순히 웨이블릿 변환을 이용한 Xia의 워터마킹 기법과 비교하여 실험하였다. 기존 논문에서 사용된 공격법으로 충실도(Fidelity)와 견고성(Robustness)에 대해 실험하였고, 그 결과 HVS 특성을 이용한 제안 알고리즘이 Xia의 기법보다 우수함을 확인하였다.

중심어 : 의료영상, 워터마킹, 충실도, 견고성