Digital Watermarking for ROI Medical Images by Using Compressed Signature Image

Akiyoshi Wakatani

Faculty of Science and Engineering, Konan University

E-mail: wakatani@konan-u.ac.jp

Abstract

In medical images, ROI (Region Of Interest) is an area which contains important information and must be stored without any distortion. We propose a digital watermarking method which avoids the distortion of the image data in ROI by embedding signature information into other area than the ROI. Signature image compressed by a progressive coding algorithm is used as the signature information. The most significant information of the signature information is embedded in the nearest area to the ROI.

The proposed method can detect the signature image with moderate quality from a clipped image including the ROI. Furthermore, by dividing the contour of the ROI into several regions and embedding the signature information in the regions respectively, the signature image with moderate quality can be acquired from a clipped image including only part of the ROI.

1. Introduction

Medical images are stored for the following three purposes: [1].

- Diagnosis
- Database
- Long-term storage

Since an obtained image must be kept perfectly without any loss of information before the image is diagnosed by a doctor, the image should be compressed by *lossless* algorithm or should be stored without using compression. Note that an image data compressed by lossless algorithm can be restored completely at the cost of low compression rate, while *lossy* algorithm loses information of the image in some degree in order to achieve high compression rate. When the image is diagnosed by a doctor at distant site, it cannot be exposed to public by using secured channel to transmit it [2, 3, 4]. However, since any person with privilege can access to images which are contained in database and can modify them maliciously, the integrity of the images must be protected by using watermarking, which is called *integrity watermark* [5]. Meanwhile, web-based image database system contains valuable medical image resources for not only research purpose but also commercial purpose [6]. Therefore the copyright and intellectual property of the database should be also protected by a watermark, which is called *copyright watermark* [5].

Moreover, for long-term storage, the protection of the integrity and copyright of image is also critical issue [7]. First, when a person ("archiver") stored a image in the long-term storage system long ago and a different person ("viewer") refers to the image, the viewer can confirm the integrity of the image only through a watermark embedded in the image. Second, when a patient does not want his/her medical images open to the public, the copyright of the image is thought to belong to the patient. Therefore the patient can protect the copyright of the image by using watermarking.

It is usual that a medical image is diagnosed before storing the image in the long-term storage, so the significant part of the image is already determined. The significant part is called *ROI (Region Of Interest)*, which must be preserved without lack of any information even for the long-term storage. In general the ROI part is stored as it is or compressed by lossless algorithm and the other part is compressed by lossy or nearlossless algorithm, which can achieve higher compression rate than lossless compression algorithm. Thus the image with ROI part can be stored with less data after the image is diagnosed.

Distant learning [8] is one of applications using database of medical images, which may refer to the image of newly discovered medical case, and they may be images with ROI part for long-term storage. Therefore it is desirable that the copyright and integrity of the medical image with ROI part are protected by digital watermarking. However it is impossible to embed signature information into the ROI part since the ROI must be kept without any distortion.
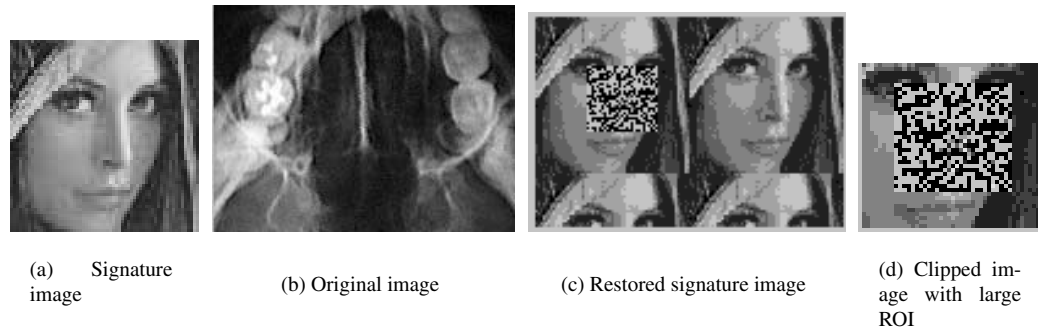
COMPUTER SOCIETY

(a) Signature image
(b) Original image
(c) Restored signature image
(d) Clipped image with large ROI

Figure 1. Digital watermarking using Wavelet compression (prior art)

In order to protect the copyright and integrity of medical images, we propose a digital watermarking scheme which embeds signature information (signature image, here) around ROI part in a way that the most significant part of the signature is embedded into pixels nearest to the ROI part. Thus the clipped image including the ROI can reproduce the signature image with moderate quality.

2. Digital watermarking using wavelet transformation

This section shows the prior art of digital watermarking using wavelet transformation by Ohnishi [9, 10], where the signature image is embedded into the original image.

The algorithm is that an original image is transformed by using Haar basis and the bit of the signature image is embedded into the lower bit of high frequency part of the transformed image. Note that Haar is the simplest wavelet basis and wavelet with Haar basis transforms 2×2 pixels into 2×2 wavelet coefficients. For example, when each pixel of the signature image is represented by 3 bit value, an original image is divided by 2×2 pixel block, which is transformed by wavelet. Each 1 bit of the 3 bit value of the signature is embedded into the high frequency part (LH, HL, HH) of the transformed images respectively. Then the embedded image is transformed by inverse wavelet to generate an image with signature after some post-processing. Namely, in order to embed the signature image of the size of 128×128, the original image is larger than 256×256. Note that the embedded area of image causes some distortion, thus an area which must be kept completely should be specified as ROI and the signature should not be embedded to the area.

Figure 1 shows the example of the digital watermarking. Figure 1-a is a signature image (part of "Girl"), which should be embedded into the high frequency part of the wavelet coefficients of an original image shown in Figure 1-b. It is noteworthy that the embedded area cannot be distinguished from ROI with no embedded signature information. From the embedded image which contains ROI area of the original image, the signature image can be detected as shown in Figure 1-c. It is noted again that the signature is not embedded into ROI area.

However, as shown in Figure 1-d, when the embedded image is clipped and the ROI area is relatively large compared with the clipped image, the signature may not be detected because the embedded information around ROI is too little to verify the signature.

3. Our proposed scheme

3.1. Basic scheme

Our scheme is a digital watermarking suitable for images in which ROI is compressed by lossless algorithm and the other is compressed by lossy algorithm. When the embedded image is clipped into the sub image which includes the ROI, the signature can be detected from the clipped image.

The basic scheme is described as follows:

1. Specify ROI area in the original image ("org").

2. Compress the signature image by a progressive coding to generate a bitstream ("bit") in the order of significance.

3. Embed the "bit" into pixels around the ROI in a spiral way to create the embedded image "dst" as shown Figure 2.

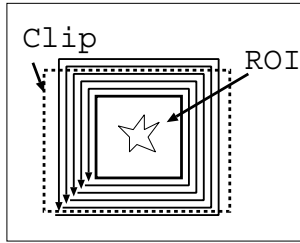4. Compress "dst" by any compression algorithm.

Figure 2. Bitstream embedded around ROI

3.1.1 Progressive coding

Since ROI is an important part in general, it is presumed that the image is clipped to include ROI. The signature image should be compressed by a *progressive coding* algorithm. Progressive coding is that a part of the compressed data can reproduce the whole image with moderate quality and the whole compressed data can reproduce the original image completely. Namely, the bitstream of the compressed data is generated in the order of significance, and thus the bitstream with any length can reproduce the signature image whose quality is correlated to the length of the consumed bitstream. For the sake of simplicity, we will describe our scheme using EZW (Embedded Zerotree Wavelet) [11] hereafter, which is one of the most popular progressive coding methods and consists of wavelet transformation and zerotree coding. It is noted again that *any* progressive coding algorithm can be applied to our scheme to compress signature image.

3.1.2 Attacks on watermark

The bitstream of compressed signature image is directly embedded into specified bitplane of the image. Usually medium level planes are used, say, 3 to 6 bitplane out of 8 bit. Bitplane to embed the bitstream is determined by a random sequence generated with a seed which is kept secretly. Only a person who knows the seed can determine the random sequence, and thus the image quality except ROI area is degraded drastically if the data of bitplanes which may contain the signature information is ignored. Therefore it is impossible that the signature information is invalidated without the degradation of the image quality.

Moreover, error correcting code, such as RS code, is effective for the attacks. Namely the compressed data of the signature image should be augmented with RS code if more reliability is required.

3.1.3 Image compression

An original image is usually compressed before storing or communicating as mentioned earlier. Although our digital

watermarking scheme can be combined with any compression algorithm, we utilize HS (Hierarchical Segmentation) compression algorithm for the original image here [12].

HS compression algorithm exploits the correlation of the lower bitplane with the higher bit plane. After segmentation of pixels of each bitplane, HS preserves only the difference of segmentation information of neighboring bitplanes to achieve high compression rate. It is also a seamless compression, that is, it accomplishes lossless compression by preserving information of all bitplanes, and lossy compression by that higher part of bitplanes.

Therefore, when the most significant part of the signature information is embedded into the nearest part to ROI in higher bitplanes, the signature can be detected even from the clipped and lossy-compressed image because lossy-compressed HS image consists of only higher bitplanes.

3.2. Our scheme

As mentioned below, in our scheme, the signature data is embedded into pixels on the k-th bitplane and l-th bitplane ($1 < k < l < n$) out of n bitplanes. If the area except ROI is compressed by lossy HS using up to l bitplanes, this compression algorithm is suitable for our digital watermarking scheme.

1. Encode

   (a) Generate an EZW bitstream ("bit") of the signature image. Add error code, such as RS code, for the robustness if needed.

   (b) Specify a ROI area in the original image.

   (c) Determine a random sequence ("ran") which specifies the bitplane to be embedded and keep the seed secretly.

   (d) Embed "bit" into the bitplane specified by "ran" around ROI.

   (e) Compress the embedded image by HS algorithm.

2. Decode

   (a) Expand the compressed image by HS algorithm as usual. Note that the drastic degradation of image quality results from the deletion of bitplanes which may contain the signature information.

3. Detection of signature

   (a) Determine ROI area .

   (b) Determine a random sequence ("ran") from the seed which is kept by the signer.

(c) Pick the bitstream ("bit") from the bitplane around ROI which is specified by "ran". For a clipped image, pick the bitstream as long as possible. If the bitstream is divided into some parts, concatenate the parts (the details are described in section 5).

(d) Expand "bit" by EZW algorithm to reproduce the signature image.

4. Example

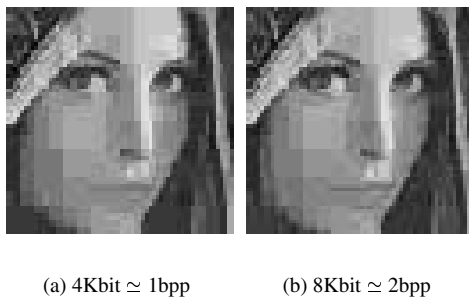(a) 4Kbit ≃ 1bpp   (b) 8Kbit ≃ 2bpp

Figure 3. Detection of signature

Figure 3 shows restored signature images which are embedded by our digital watermarking.

As mentioned earlier, ROI is specified as an area where the signature should not be embedded. Then an area which contains ROI is assumed to be clipped. The ROI is 64×64 and the clipped area is 95×88. Since the signature data is embedded equally over the image by the prior art of digital watermarking, the area except the ROI of the clipped image does not have enough information to reproduce the signature image as shown in Figure 1-d.

On the other hand, our scheme utilizes the EZW bitstream of the signature image, which is embedded into pixels around ROI in the order of significance. The clipped image contains the signature information of about 4000 bit in area except ROI. The information is expanded by EZW to the image shown in Figure 3-a which can be recognized as the signature. Note that since the signature image is 64×64, the information of 4000 bit corresponds to about 1.0 bpp.

In the above example, it takes about 4000 bit ($\simeq$ 1 bpp) to reproduce the signature of the size of 64×64 with moderate quality. Thus it needs 4000 pixels when 1 bit is embedded into 1 pixel. On the other hand, the prior art of digital watermarking requires the area of the size of $64 \times 64 \times 2 \times 2$ to embed the signature because each pixel of the signature is 3 bit, which is embedded into a 2×2 block. Therefore it needs about 4 time more than our scheme. Moreover our

scheme needs about 8000 bit ($\simeq$ 2 bpp) to get the signature with as good quality as the prior art, which is about half of the data required by the prior art (Figure 3-b).

5. Multiple embedding

In general, any clipped area includes ROI area because the ROI is rather important area. However, if the selected ROI is larger than the truly important part, only a part of the ROI may be included in the clipped image, and thus the extracted bitstream is too short to reconstruct the signature image.
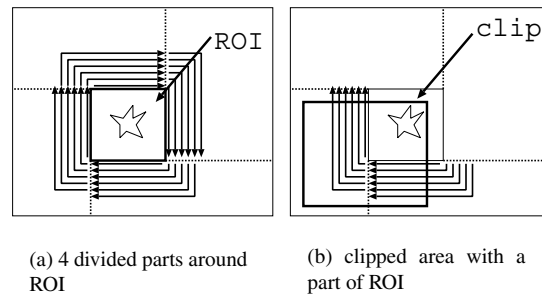

(a) 4 divided parts around ROI   (b) clipped area with a part of ROI

Figure 4. Multiple embedding of signature

In order to overcome the problem, the contour of ROI and the area around ROI should be divided into d parts and the signature is embedded into the divided parts respectively. So, if a clipped area includes at least $1/d$ of the contour of ROI, the signature can be detected by our digital watermarking scheme and the concatenation algorithm mentioned later. We call this *multiple embedding*.

Figure 4 shows an example of 4 divided parts of ROI and a clipped area. Although the clipped area contains only a part of signature, the signature can be verified by using the information below ROI and the information on the left side of ROI.

Figure 5 illustrates the part of algorithm to concatenate signature informations.

This algorithm is for the clipped image shown in Figure 4-b when that the upper left, width and height of ROI area and clipped area is (rx, ry, rw, rh) and (cx, cy, cw, ch). Namely areas A, B and C are defined as in Figure 5 and area A is rotated by 270 degree in clockwise and saved a area T. Then area T is copied into area C and the signature is detected from pixels in area B by the scheme described in the previous section. Note that area C is included area B. The algorithm for other clipping patterns are easily defined as well.

Furthermore, whether the signature can be detected or not depends on the number of divisions and the pattern of

COMPUTER SOCIETY

```
ROI=(rx, ry, rw, rh);
Clip=(cx, cy, cw, ch);
if(cy > ry && cx < rx &&
   cx+cw < rx+rw && cy+ch > ry+rh){
  if(rx-cx > ((cy+ch)-(ry+rh)){
    d=(cy+ch)-(ry+rh);
    e=cx+cw-rx;
    f=d-1+rw-e;
    A=(rx-d, cy+ch-f, d, f);
    B=(rx, ry+rh, d-1+rw, d);
    C=(cx+cw, ry+rh, f, d);
    Rotate(A, T, 270);
    Copy(T, C);
    Detect(B);
  }
  else{
   ..
  }
}
else if (..){
 ..
}
```

Figure 5. Concatenation algorithm (part)

clipping. We will consider the following 3 clipping patterns shown in Figure 6. Pattern A includes the whole ROI area, while patterns B and C include the part of it. Pattern B contains the important part and the left side of ROI and pattern C contains the important part and the lower left side of ROI.

We assume that ROI is 64×64 and the clipped area is 100×100. The number of pixels around the ROI is $5904 (= 100 \times 100 - 64 \times 64)$, $6352 (= 100 \times 100 - 64 \times 57)$, $6751 (= 100 \times 100 - 57 \times 57)$ for patterns A, B and C respectively.

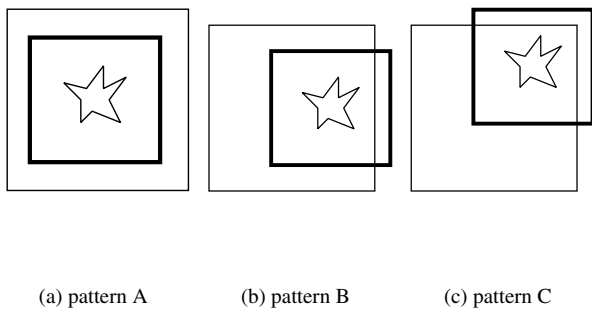We summarize the patterns of clipping, the size of bitstream to be embedded and the image quality (SNR) of the detected signature in Table.1. Note that it seems that the image quality is relatively worse than usual, such that 22.36dB is OK and 18.19dB is good. The reason is that our objective is not to reconstruct the image with high quality but to determine whether the reconstructed image is identical to the original signature image.

Table 1. Multiple embedding

pattern	no division	2 divisions	4 divisions
pattern A	5904bit 22.36dB (OK)	2952bit 18.19dB (good)	1476bit 16.87dB (poor)
pattern B	NG	2628bit 17.87dB (good)	1476bit 16.87dB (poor)
pattern C	NG	NG	4601bit 21.25dB (OK)

As shown in the table, many clipping patterns can be accepted even when the number of divisions is large, but the quality of generated signature image from the image with the large number of divisions is worse than the small number of divisions. For example, the signature can be reproduced for the pattern A from the image with any number of divisions, but the quality of image generated from 4 divisions is not sufficient to verify the identification.

However other pattern is suitable for images with 4 divisions. From the clipped image of pattern C with 4 divisions, the signature can be detected, but the other divisions are not applicable to pattern C.

6. Conclusion

We described a novel digital watermarking scheme for medical images with ROI area which is combined with HS compression algorithm. ROI should be compressed with lossless algorithm or should be stored without compression.

Our experiment shows that 1) from any clipped images which contain ROI area, the signature image can be detected with moderate quality, 2) and by dividing the contour of ROI into some parts, the signature can be generated from the clipped image including only a part of ROI.

(a) pattern A (b) pattern B (c) pattern C

Figure 6. Patterns of clipping

7. Acknowledgements

References

[1] Jacob Ström and Pamela C. Cosman, "Medical Image Compression with Lossless Regions of Interest", Signal Processing, 59, 1997

[2] KT Dockray, "Software for Online Telemedicine Reporting", Proc. 11th IEEE Symposium on Computer-Based Medical Systems, 1998

[3] Myron Frommer, "Telemedicine: The Next Generation is Here", Proc. Academia/Industry Working Conference on Research Challenges, 2000

[4] Laura Pierucci and Enrico Del Re, "An Interactive Multimedia Satellite Telemedicine Service", IEEE Multimedia, Vol.7, No.2, pp.76–79, 2000

[5] Jana Dittman and Frank Nack, "Copyright - Copywrong", IEEE Multimedia, Vol.7, No.4, pp.14–17, 2000

[6] Weidong Cai, Dagan Feng and Roger Fulton, "Web-based Digital Medical Images", IEEE Computer Graphics and Applications, Vol.21, No.1, pp.44–47, 2001

[7] Bruce Davie, Valerie Florence, Andrew Friede, Jerry Sheehan and James Sisk, "Bringing Health-Care Applications to the Internet", IEEE Internet Computing, Vol.5, No.3, pp.42–46, 2001

[8] Jean-Pierre Soula, Claude Baron and Carmel Nestor, "A Shift from Chalk: Multimedia and Instruction", IEEE Multimedia, Vol.4, No.2, pp.5–8, 1997

[9] Junji Onishi and Kineo Matsui, "Image Coding for Copyright Protection by Using Wavelet", IPSJ transactions, Vol.38, No.3, 1997 (in Japanese)

[10] Junji Ohnishi and Kineo Matsui, "Embedding a Seal Into a Picture under Orthogonal Wavelet Transform", Proc. IEEE Multimedia Systems'96, 1996

[11] J.Shapiro, "Embedded Image Coding Using Zerotrees of Wavelet Coefficients", Vol.41, No.12, IEEE Trans. of Signal Processing, 1993

[12] Masaki Yamauchi and Akiyoshi Wakatani, "A New Lossless Compression Scheme for Medical Images by Hierarchical Segmentation", Proc. Data Compression Conference, 2001