New Watermarking Scheme for Security and Transmission of Medical Images for PocketNeuro Project

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Abstract. *We describe a new Watermarking system of medical information security and terminal mobile phone adaptation for PocketNeuro project. The later term refers to a Project created for the service of neurological diseases. It consists of transmitting information about patients « Desk of Patients » to a doctor's mobile phone when he is visiting or examining his patient. This system is capable of embedding medical information inside diagnostic images for security purposes. Our system applies JPEG Compression to Watermarked images to adapt them to the doctor's mobile phone. Experiments performed on a database of 30-256× 256 pixel-sized neuronal images show that our Watermarking scheme for image security is robust against JPEG Compression.For the purpose of increasing the image Watermarking robustness against attacks for an image transmission and to perform a large data payload, we encode with Turbo- Code image-embedded bits information. Fidelity is improved by incorporation of the Relative Peak Signal-to- Noise Ratio (RPSNR) as a perceptual metric to measure image degradation.*

Keywords

PocketNeuro project, multi-resolution field, turbo-code, R.P.S.N.R., robustness, fidelity.

1. Introduction

With the support of European/INTERREGIII funding (with Switzerland), the Distributed System team in the Computer Laboratory of Franche-Comte (LIFC) established a new project with Besançon Institute of Sciences and Technologies of Information (ISTI) coordinated by the University Hospital at Lausanne entitled PocketNeuro. This Project is responsible for mobility between terminals (in Cooperative Tele-neurology). It allows practitioners to use telecommunication technologies to provide medical deontology and facilitate distant diagnosis [1]. This project is created for the services of neurological diseases [2]. The aim of this project is to transmit diagnostic Neuronal images containing information about patients to a doctor's mobile phone when he is visiting his patient (see Fig. 1.).

PocketNeuro project needs to provide security of medical information and adaptation of neuronal images to the doctor's mobile phone.

We propose to use watermarking as solution to preserve the security of medical images for PocketNeuro project, for the reason that image watermarking allows doctors or personnel to hide invisible and robust medical information about a patient inside images with a secret key [3].

Fig. 1. Example of Mobile Phone transmission for PocketNeuro project.

For transmission of the watermarked image at the doctor's mobile phone, the application must be run correctly taking into account its particular hardware peripherals. Furthermore, the received image can be processed by the terminal mobile phone, which necessitates a preliminary adaptation of this image. For this reason, images must be compressed by JPEG Compression to reduce information in images before the transmission process.

This paper presents a new scheme of image watermarking robust against JPEG Compression able to embed large data payloads with keeping fidelity of images. This Watermarking scheme consists of embedding information in the multi-resolution field. The embedded bits information is coded with an Error Correcting Code (ECC): the Turbo-Code. This ECC allows us to embed large data payloads in medical images with keeping intellectual properties of it [4].

For the aim of improving the perceptual fidelity after Watermarking process, we use the Relative Peak Signal-to-Noise Ratio (RPSNR) as a distortion metric to estimate image degradation. We will demonstrate by some simulation results that the RPSNR is the best metric correlated with the Human Visual System (HVS) [5] to evaluate image degradation after different attacks.

Our new watermarking scheme using the RPSNR attempts to attain an optimal trade-off between estimates of robustness, data payload and perceptual fidelity. Results of experiments, carried out on a database of 30- 256× 256 pixel-sized medical images, will demonstrate that our watermarking scheme is robust against different quality of JPEG Compression.

In our paper, images are extracted from DICOM library and we use Matlab and its library as software to experiment our approaches and to validate our results.

The paper is organized as follows: Section 2 explains our choice of the multi-resolution field by the use of the 5/3 wavelet image decomposition and exposes the advantages of Turbo-Code used in our paper.

In Section 3, we introduce the evaluation metric of image quality, the RPSNR and we demonstrate by some simulation results showing that it is the best perceptual metric correlated with the HVS to evaluate the image degradation after different attacks.

Section 4 describes the new scheme of image watermarking and the main steps relevant to our new watermarking algorithm.

Section 5 reports a set of selected simulation results that clearly demonstrate that even after image JPEG Compression application, all 2000 bits are correctly detected in at least 99% of watermarked images while preserving image fidelity after watermarking scheme.

Finally, in the last section we comprise some concluding remarks. Also, we present the issue of Pocket-Neuro project in Neuro-Telemedicine (supported by European Funding) that its first demonstration will take place at the end of 2007.

2. Use of Multi-Resolution Field and Advantages of Turbo-Code in Our New Watermarking Scheme

2.1 Use of Multi-Resolution Field: the 5/3 Wavelet Decomposition

Our choice of using the 5/3 wavelet decomposition in our watermarking algorithm is motivated by many reasons:

- The 5/3 wavelet decomposition is an integer to integer transform adapted for JPEG 2000 Compression and comes in front for its frequent use in JPEG2000 norm. Consequently the image watermarked is robust against JPEG Compression attacks [6], [7], [8].
- For the reason of keeping image fidelity after watermarking process, we need perceptual metric correlated with Human Visual System. Thus, in multi-resolution field the image decomposition in sample bands is near to perception canal decomposition, so, we can easily find a psycho-visual model to measure image degradation [9].

The 5/3 wavelet decomposition's equations are below:

$$d[n] = d_0[n] - \left[\frac{1}{2}\left(d[n] + d[n-1]\right)\right], \tag{1}$$

$$s[n] = s_0[n] + \left[\frac{1}{4}\left(d[n] + d[n-1] + \frac{1}{2}\right)\right]. \tag{2}$$

We use an embedding function or (Secret Key) to hide information inside images. The following function is used to our Watermark image:

$$Y_i = X_i\left(1 + \alpha W_i\right). \tag{3}$$

where Y_i is watermarked image, X_i is the original image, W_i Bits information to be embedded composed of 1000 bits coded with 1/2 ratio Turbo-Coder, and α is the visibility coefficient.

2.2 Advantages of the Turbo-Coder

Turbo-Codes have been successfully used in digital communication systems in order to achieve reliable transmission on a noisy channel [10], [11], [12].

The idea of using Turbo-Code in our algorithm scheme comes from the efficiency of this ECC to increase robustness against channel transmission attacks. Furthermore, the incorporation of Turbo-Code in the formatting of the watermark increases the number of bits to hide in order to achieve higher payloads because the number of repetitions of each bit of the watermark decreases in the same proportion [4]. In this paper, we apply Turbo-Code using the Soft Output Viterbe Algorithm (SOVA) for decoding technique to achieve powerful error-correction capability and higher payloads.

3. Our New Perceptual Quality Metrics

Nowadays, the most popular distortion measures in the image field are the Signal-to-Noise Ratio (SNR), and the Peak Signal-to-Noise Ratio (PSNR). They are usually measured in decibels, i.e., “dB”:

$$MSE = \frac{1}{MN}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1}\left(x(m,n)-y(m,n)\right)^2 \quad (4)$$

where M and N are the numbers of pixels lengthwise and widthwise per image, x and y are the grey scale of the original image and the degraded image, respectively.

$$PSNR = 10\log_{10}\left(X_{\max}^2 / MSE\right) \quad (5)$$

Where $X_{\max}$ is the maximum luminescence in the image. $X_{\max}$=255.

Their popularity is very likely due to the simplicity of the metric. However, it is well known that these distortion metrics are not correlated with the HVS [5]. This might be a problem for their application in digital watermarking since sophisticated watermarking methods exploit in one way or another the HVS. In addition, using the above metric to quantify the distortion caused by a watermarking process might therefore result in misleading quantitative distortion measurements [13]. Furthermore, these metrics are usually applied to the luminance and chrominance channels of images [14], and they give a distortion value for all color channels.

In this paper, we introduce a metric of an image-quality evaluation entitled the Relative Peak Signal-to-Noise Ratio (RPSNR). This distortion metric, that has no relation with the content characteristics of the image fits to the HVS. and therefore is more suitable for digital watermarking. In addition, this metric allows a comparison even if the distortion is in a different color channel [15]. The estimation error for RPSNR as a function of packet loss rate and average loss burst length metric that represents path quality under different loss patterns. The Relative Peak Signal-to-Noise Ratio (RPSNR) is used to evaluate the image quality by calculating the Relative Mean Square Error (RMSE) between the images to compare. The equations are as follows:

$$RMSE = \frac{1}{MN}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1}\left[2*\frac{\left|x(m,n)-y(m,n)\right|}{\left|x(m,n)+y(m,n)\right|}\right]^2 \quad (6)$$

$$RPSNR = 10\log_{10}\left(\frac{(\max value\ of\ the\ signal)^2}{RMSE}\right) \quad (7)$$

where M and N are the numbers of pixels lengthwise and widthwise per image, x and y are the grey scale of the original image and the degraded image, respectively.

In order to properly demonstrate the performance of the RPSNR in watermarking schemes and allow a fair comparison between the two different perceptual Quality metrics (PSNR and RPSNR), the setup test conditions are of crucial importance. Tab. 1 lists different mean values of PSNR and RPSNR after the most famous types of distortion and attacks on a database of 30, 256× 256 pixel-sized medical images. Fig. 2 presents some figures from our database.

Distortion type	PSNR	RPSNR
Mean shift	24.6090	64.3123
Contrast stretching	24.6003	57.913
Impulsive Salt and paper noise	24.6499	63.6996
Multiplicative Speckle noise	24.6186	66.9165
Additive Gaussian noise	24.5906	62.4892
floue	24.6054	63.4734
JPEG Compression	24.7849	62.6179

Tab. 1. Different means values of PSNR and RPSNR after different attacks on image banks.

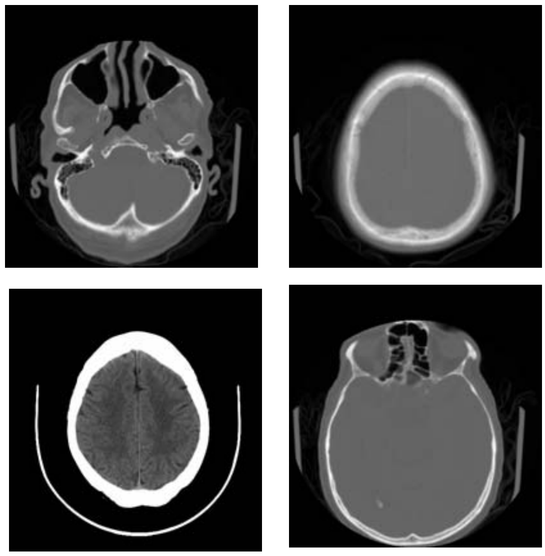

Fig. 2. Some figures from the database of 30 medical images.

4. Our New Image Watermarking Scheme

In this paper, we propose to embed the Bits information in the multi-resolution field by 5/3 wavelet decomposition. Our developed embedding scheme is presented in Fig. 3.

4.1 The Embedding Scheme

- We decompose medical image with 5/3 wavelet image decomposition. The 5/3 wavelet decomposition decomposes medical images on sample bands (Low Frequency (LF), Medium Frequency (MF) and High Frequency (HF)) as it is shown in Fig. 4.b and 4.c.

- Pixels with the high-intensity are selected from the medium-zone frequencies (MF).
- Information is coded with Turbo-Code and after that embedded with embedding function defined at equation (3).
- We rebuilt the image with an inverse 5/3 wavelet image decomposition. Finally, we obtain the watermarked image (see Fig. 4.d).

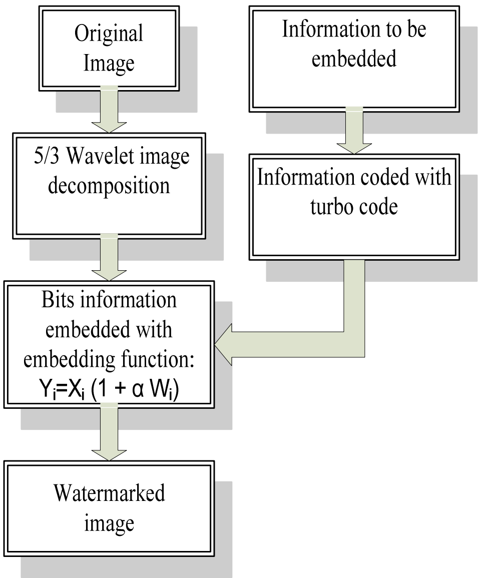

Fig. 3. Our new embedding watermarking algorithm.

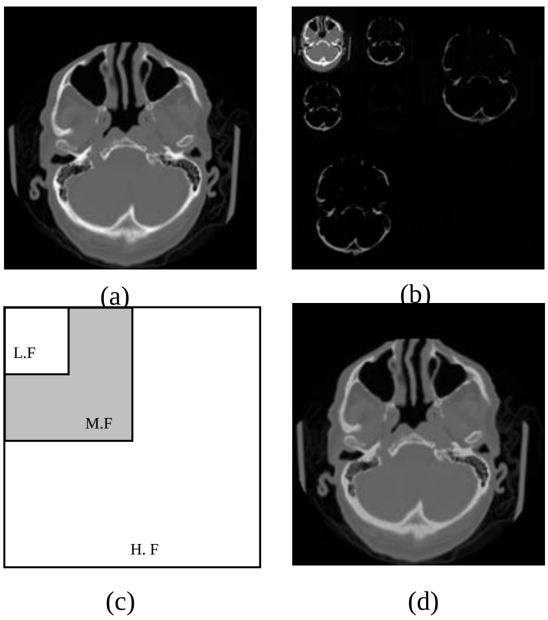

Fig. 4. (a) Original image, (b) 5/3 image wavelet decomposition, (c) Image decomposed in (LF), (MF) and (HF) after a 5/3 image Wavelet decomposition, (d) Reconstructed image.

4.2 The Blind Watermarking Detection Algorithm

- We decompose medical image with 5/3 wavelet image decomposition.
- Pixels with the high-intensity are selected from the medium-zone frequencies (MF).
- Then, we extract Bits information from multi-resolution field with binary inverse transformation.
- Extracted Bits information is decoded by the use of the SOVA.
- We use Correlation between the extracted, decoded Bits information and the original one to declare if the information is perfectly extracted from images.

5. Preliminary Results and Discussion

5.1 Robustness against Attacks

This section displays first the experimental results carried out on a 30 images from our database. We use correlation to make a comparison between the extracted, decoded bits information and the original one.

The original bits information embedded into image belongs to a bank of 800 bits medical formations. Each bits information of this bank is supposed to be the information embedded in the image.

We can determine the inserted information by computing the correlation between the extracted bits information and every element of the bank (dictionary). This comparison allows us to identify the degree of similarity between extracted, decoded information and the original one embedded inside images.

If the reference information (original bits information) presents the high value of correlation with the extracted and decoded information, we can say that the detection of bits information has succeeded. However, if the reference bits information hasn't the maximum of correlation with the extracted and deciphered information, detection of the information is lost. The correlation is maximal when it has a value of 1.

From Fig. 5, we remark that all the 1000 bits are correctly detected from our simulation results after JPEG Compression of quality 70. Fig. 6 shows the correlation for all the test images of our database after JPEG Compression of quality 60. The medium correlations are maximal and equal to 0.99 for all the test images. Consequently, our new watermarking scheme is robust against JPEG Compression. Tab. 2 below resumes the correlation values for different JPEG Compression quality.

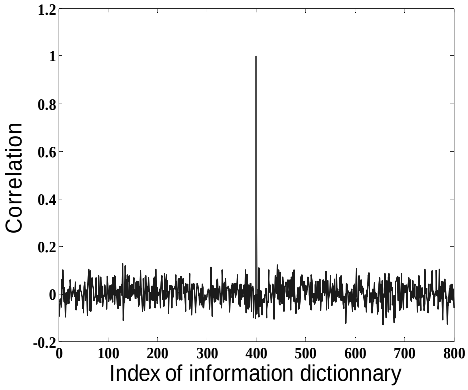

Fig. 5. Succeeded detection of original bits information after JPEG Compression of quality70.

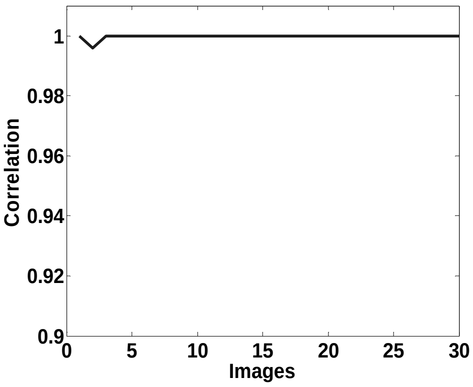

Fig. 6. Correlation between extracted, decoded bits information and the original ones for the 30 images test after JPEG Compression with quality 60.

Evaluation	Med. Corre.	Validation
JPEG Compression(90)	1	100 %
JPEG Compression(70)	1	100 %
JPEG Compression(60)	0.99	99 %

Tab. 2. Robustness of images watermarked against different JPEG Compression quality.

5.2 Fidelity of Watermarked Images against JPEG Compression

We often need to apply JPEG Compression to the medical images for transmission purposes. We tried to test the robustness of our scheme with different compression ratio from 90%, 70%, 50%, 30% and 10%. From Fig. 7, we can remark that the Medium RPSNR is higher than 30 dB after the different qualities of JPEG Compression application. Consequently fidelity is kept after applying the watermarking process and after the different JPEG Compression quality.

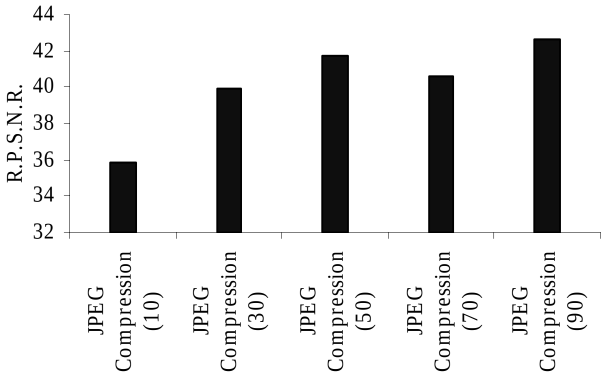

Fig. 7. Mean values of RPSNR for 30 test images watermarked and attacked by different ratio of JPEG Compression.

6. Conclusions and Further Works

The aim of this paper is to provide a new scheme for secure transmission of medical information and to outline adaptability of terminals to our new watermarking image transmission scheme for PocketNeuro Project in the field of emergency neurology. PocketNeuro will allow the neurologist to access relevant medical information for any given patient in the "patient file”. It should allow patient-related medical information to be consulted and modified in a secure mode.

Adaptation of watermarking images to the terminals is made by scaling image with JPEG Compression. Simulation result shows that after JPEG Compression, all bits are detected in at least 100% from operated images. Furthermore, for different tested attacks the perceptual metric incorporated the RPSNR that is correlated with the HVS (Human Visual System) allow us to keep perfect values of images distortions above 30 dB. Consequently, we have good perceptual fidelity in images after our watermarking scheme.

Tests performed on this first PocketNeuro release have given good results, and allow us to hope for a large experimentation between French and Swiss hospitals using secured connections between the Tele-Neurology platforms in Lausanne (Switzerland) and terminal mobile phones of doctors in France.

Acknowledgements

The authors extend their thanks both to the Besançon Institute of Sciences and Technologies of Information (ISTI), for initiating this project and the European Union for financing this project as part of the INTERREGIII program in collaboration with Swiss partners (Vaud University Hospital at Lausanne, and EPFL Lausanne).

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