Use of Multi-Watermarking Schema to Maintain Awareness in a Teleneurology Diagnosis Platform

Mohamed KALLEL[1, 2], Mohamed Salim BOUHLEL[1], Jean-Christophe LAPAYRE[2]

[1]Research Unit: Sciences and Technolog. of Image and Telecomms Higher Inst. of Biotech., Univ. of Sfax, Sfax, Tunisia
[2]Informatics Laboratory of Franche Comte LIFC (EA 4269) Besançon, France

kallel_mohamed2004@yahoo.fr, medsalim.bouhlel@enis.rnu.tn, jean-christophe.lapayre@univ-fcomte.fr

Abstract. *Following the tremendous evolution of transferring images through the Internet, it is necessary to ensure security during this act, especially for medical images. The application of multiple watermarking technique represents a solution to preserve the security of such data on the one hand, and the traceability of medical diagnoses made by doctors on the other hand. This falls under the remote collaborative work. This technique is applied in the TeNeCi (Collaborative tele-neurology) platform. The project allows practitioners to distribute the analyses of the medical images. In fact, we used the multiple watermarking technique in a wavelet field. The theory underlying this technique is to hide information in the medical image and at the same time to ensure its imperceptibility. The diagnosis made by the practitioner is the data inserted in the image. The fundamental challenge of this paper is how to hide the total diagnoses of each practitioner in the image ensuring a good quality of the image at the same time.*

Keywords

Multiple watermarking, medical images, TeNeCi project, wavelet transform, traceability.

1. Introduction

In the recent years, the number of Internet users has increased. Such an increase is automatically accompanied by a growing piracy threat and consequently the insecurity of messages. In the medical field, however, the transfer of images must be protected against piracy [1]. Indeed, the doctor uses the Internet as a means to exchange views with his/her colleagues in order to save time but this communication can be interfered or interrupted by a third person, which would lead to a change in the content of the image or to substitute one medical image by another.

The cooperative application incorporates various domains including networks, distributed systems, multimedia and data consistency. It is therefore useful to make a platform combining the functionalities common to all types of cooperative applications. The TeNeCi project is a platform that establishes an expert solution and support in neurological decision-making and in emergency neurology management. We develop an approach to multiple watermarking in the wavelet field to guarantee a record of diagnoses.

In this paper, we apply a multiple watermarking technique in the wavelet field to preserve the traceability and the record of the medical image diagnosis.

In the second Section, we present the TeNeCi project. In Sec. 3, we specify the different constraints of the watermarking technique in wavelet domain. In Sec. 4, we expose our multiple watermarking technique used to preserve the security and the traceability of medical diagnoses made by doctors. In Sec. 5, we provide simulation results of our technique. Finally, in the last Section, we comprise some concluding remarks.

2. TeNeCi Platform Description

TeNeCi [2] (Collaborative tele-neurology), is a European project created between the CHU of Besançon (France) and the CHU Vaudois of Lausanne (Switzerland) in order to conceive and to develop a platform to establish and develop an expert solution and support in neurological decision-making and in emergency neurology management [3]. Fig. 1 illustrates the basic function of this platform and shows the analyses of the neurology image.

The TeNeCi project contributes to a better organization of the management of neurology emergencies thanks to the development of new techniques, which assist in emergency neurology diagnosis and treatment as well as in the field of neurological pathologies as a whole. These new techniques operating through a telecommunication network provide practitioners with real-time remote access to relevant information [4].

Medical decision-making is thereby facilitated thanks to the cooperative nature of the application. This aspect will contribute to real-time group-based work.

The use of the collaborative work doesn't stock all the diagnoses in the debate thus we have a record problem. For

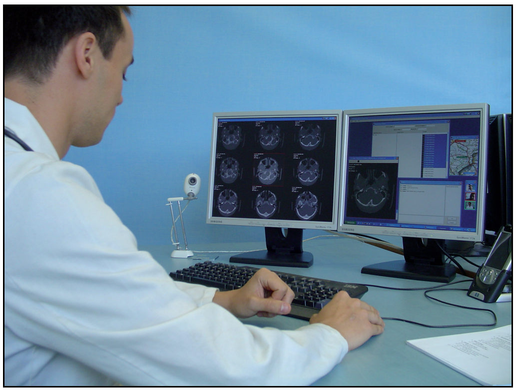

Fig.1. TeNeCi Platform.

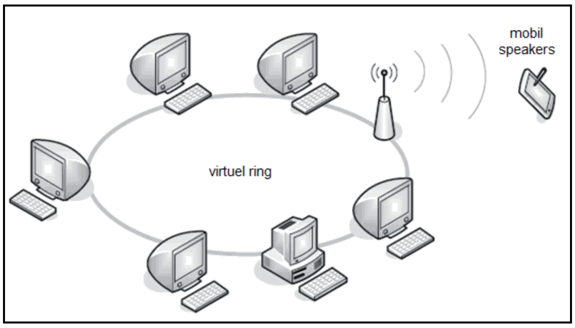

Fig.2. Collaborative work between doctors.

this reason, we elaborate a multiple watermarking approach that ensures a record for these diagnoses.

3. General Context

Our method consists of inserting an invisible signature in a medical image. This signature can be a text, a drawing on the image by the addition of an arrow for example or actions on the image itself following a change of contrast or luminosity. Indeed, a doctor is brought to work on the image and the platform undertakes to transmit the modifications to another doctor. This last recovers the handling of the preceding doctor and gives him his comment and so on. Hence, we obtain the multiple watermarking.

We note that this method can offer a record to the medical image of the patient and give precise report on the medical image since it can be under the control of a medical team. Indeed, each doctor is responsible for all the comments provided in the debate since they will be carried under the judgement of all the speakers. Consequently, the doctor assumes the whole of the actions of which he is the author, and they will be filed in the medical image.

The application of the multiple watermarking technique ensures that each doctor inserts his diagnosis in the medical image without degrading it. With any new insertion, the image must always keep its clarity and its characteristics.

In a virtual ring, collaborative work between the experts lies in the fact that they share the analysis of a medical image among them thus allowing an exchange of information to enhance their knowledge and to diagnose well the medical image within a short time as shown in Fig. 2.

The basic idea of the use of the multiple watermarking approach in this work lies in the fact that all the doctors are able to insert their diagnoses in turn while preserving the traceability of each one. The principle of insertion of the diagnoses is carried out in 4 phases:

- Phase 1: The medical image that will be treated must be available on the whole of the sites of the doctors.
- Phase 2: The doctors connected to the network are at the same time transmitters and receivers of information. Each doctor extracts and analyzes the other comments and delivers his own opinion.
- Phase 3: Each site receives the watermarked medical image of the previous doctor in the ring and extracts the comments to show it to the local doctor. This doctor visualizes it and inserts his own work. This stage is repeated throughout the course of the token (single message) around the virtual ring.
- Phase 4: At the end of the debate the diagnosis is safeguarded. It includes all the operations corresponding to each doctor and summarizes the final report of the treated medical image. This technique is based on multiple insertions on the same medical image.

3.1 Approach Constraints

- In the medical field, the embedded signatures mustn't modify the medical information contained in the image and mustn't affect the image quality.
- Since we applied our approach in the medical field, doctor doesn't allow any falsification and modification in the medical image. So, the least modification can influence the patient diagnosis (inserted signature). For this reason we must use a conservative wavelet transform.
- The underflow and overflow phenomenon [5], [6] can be considered as a potential problem. Fig. 3 explains the problem caused by this phenomenon.

When we apply the inverse wavelet function, we notice that there are some pixels that will be over 255 and some others that will be less than 0. Indeed, each value exceeding the maximum of 255 takes the value 255 and each value less than 0 takes the value 0. Accordingly during the extraction phase we cannot find the signature inserted.

From these constraints, is born the need for introducing new multiple watermarking technique which surmount the precedent constraints.

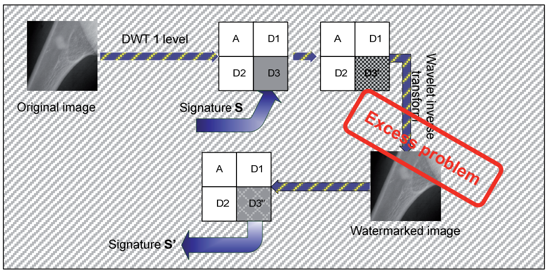

Fig.3. Excess problem.

4. Our Multiple Image Watermarking Scheme

Wavelet transform constitutes one of the newest topics in the image processing field [7]. It offers a good temporal and frequency localization. This transform decomposes the image into sub bands at different resolution levels as shown in Fig. 4.

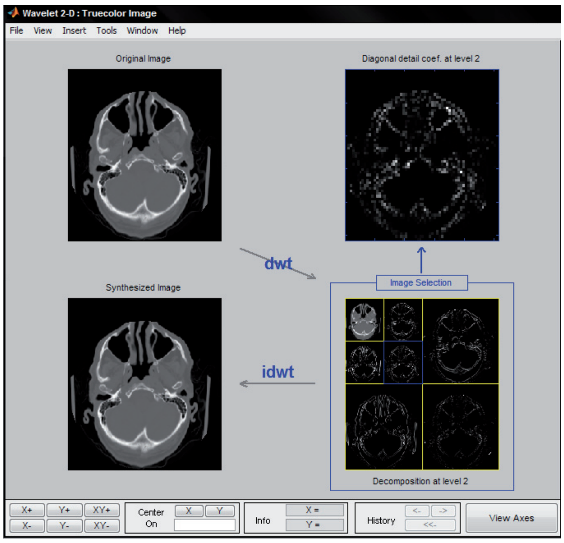

Fig. 4. Decomposition of the image using wavelet transform.

The 5/3 wavelet transform is used in this work since it presents a conservative character.

In fact, by applying this transform on an image we can find it by application of inverse wavelet transform without appearance of any loss.

The forward equations for the conservative 5/3 transform are given by:

$$d[n] = d_0[n] - \left\lfloor \frac{1}{2}\left(s_0[n+1] + s_0[n]\right) \right\rfloor, \qquad (1)$$

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

$x[n]$, $s[n]$ and $d[n]$ are the input signal, low pass subband signal and high pass subband signal, respectively.

We also define the quantities $s_0[n] = x[2n]$ and $d_0[n] = x[2n+1]$.

Another advantage of this transform is the superior modeling of HVS (human visual system). In our technique we use special effect of the HVS that the human eye is less sensitive to change of higher image frequencies [8], this HVS characteristic is used to embed signature imperceptibly in the less significant coefficients.

To surmount the underflow and the overflow problem caused by the insertion of the diagnosis patient in the transformed coefficient; we will apply a dictionary to code the diagnosis. In fact the adopted coding technique is to reduce coefficient. The formula used is the following:

$$X = ASCII(x) - \alpha \qquad (3)$$

with: α: parameter,
x: the original diagnosis letter,
X: the value after conversion.

After an empirical study, we used $\alpha = 96$ in this paper, and we obtain a dictionary to convert each character into a new value. Tab. 1 presents an example to clarify the dictionary.

Diagnosis	Without dictionary	With dictionary
p	112	16
a	97	1
t	116	20
h	104	8
o	111	15
l	108	12
o	111	15
g	103	7
y	121	25

Tab.1. Conversion of the diagnosis.

4.1 Insertion of the Signature

The procedure of inserting of the signature is done as follows:

- The doctor writes his/her report after the examination of the patient.
- We apply the wavelet transformation to the medical image; we shall have 4 plans (a plan of weak frequency which contains the estimate of the image and three plans of details).
- The report is going to be converted by applying the approach developed to surmount the problem of overflow.
- The report is inserted into the image (the zone of higher frequency)
- We apply the inverse wavelet function transform [9] to eventually have the watermarked image.

Fig. 5 explains the principle of the insertion of the signature.

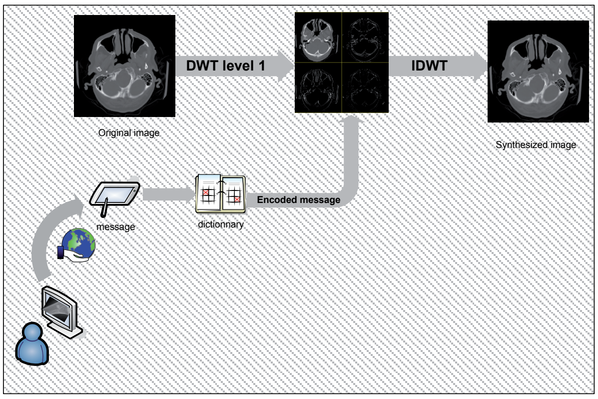

Fig. 5. Insertion phase.

4.2 Extraction of the Signature

The procedure of extraction is done in the same way as the procedure of insertion.

At first, we have to recuperate the coded diagnosis located in the high frequencies of the image and to resort the hidden data.

The stages of extraction are made as follows:

- We apply the wavelets transformation on the watermarked image.
- We extract the possible signature of the plan of high frequencies.
- We cross the signature to the dictionary so that the second doctor gets back the signature inserted by the previous doctor.

Fig. 6 shows the stages of the procedure of the signature extraction.

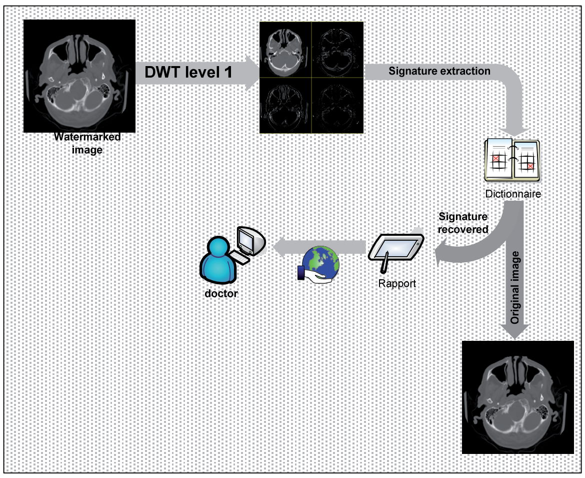

Fig. 6. Extraction phase.

The second doctor extracts the diagnosis drafted by the previous doctor to give his notice of consent or refusal. This approach allows to enrich the knowledge of doctors to ensure a diagnosis sure of the medical examinations.

In our method we verified the comprehensibility of the extracted signature (doctor diagnosis) and if the message is not comprehensible, the watermarked image was considered as an altered image and was rejected. So, our target is to guarantee the traceability and the record of the diagnoses.

5. Experimental Study

In our experimental study, we tested 40 gray-scale images of 256 x 256 pixels that had been saved in BMP format. The images had been acquired from the DICOM standard.

The insertion would be in an invisible way and only the receiving doctor would be able to detect the signature correctly.

Fig. 7 presents the original image and the watermarked image after the insertion phase of the diagnosis using the described method.

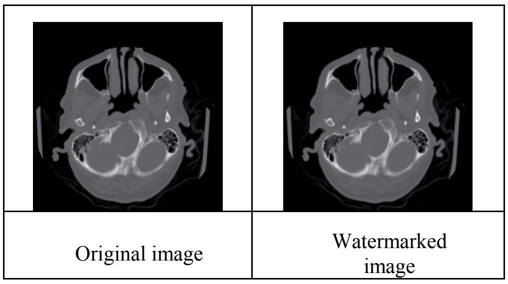

Fig. 7. Watermarked image.

The addition of signatures to the medical image has given no modification or change with regard to the original, this means that visually the watermark is imperceptible and does not appear in the image. To analyze better this phenomenon, we used the metrics PSNR [10] defined as:

$$\mathrm{PSNR} = 10\log_{10}\left(\frac{X_{\max}^2}{\mathrm{MSE}}\right) = 10\log_{10}\left(\frac{255^2}{\mathrm{MSE}}\right) \quad (4)$$

where $X_{\max}$ is the maximum luminance in the image. The MSE (Medium Square Error) is used to quantify the distortion generated by the digital watermarking. In fact, we use an additive scheme to watermark the image. This modification could affect the quality of the image. The MSE is defined as

$$\mathrm{MSE} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m}\left(I_{ij} - I_{ij}^{*}\right)^2}{nm} \quad (5)$$

where I and I^* are the original image and the watermarked one, respectively.

Indeed, the variation of the PSNR suited with care of the multiple watermark [11] in the field of wavelets is illustrated in Fig. 8.

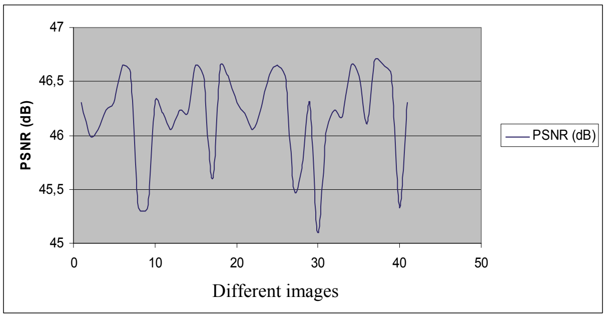

Fig. 8. PSNR variation.

The PSNR metric is used to determine the degradation of the quality of the image after the insertion of the signature.

The medical images can undergo numerous transformations during their transmissions thus altering the information contained in the image. The doctors avoid working with examinations which are attacked and exclude any types of attacks [12]. Therefore, we should be interested in the fact that our developed approach must be sensitive to hostile or innocent attacks. Tab. 2 illustrates different manipulations taken in the simulation:

- Histogram equalization,
- Gaussian noise with a variance of 0, 02,
- unsharp filter with α =0.5,
- JPEG compression with compression quality 70%,
- rotation 2°,
- median filter [3x3].

According to this illustration, we note that the application of any attack on any image generates a wrong message during the extraction stage. In fact, the doctor is certain of the integrity of the transmitted image and every modification was detected in the extracted phase.

6. Conclusion

The discrete wavelet transform is an analysis in sub-bands, the bi-dimensional sign is divided into 3 details sub-bands and one approximation sub-band. The mostly used method to calculate the function in wavelets is the method of benches of filters. The 5/3 wavelet is used in our case due to its reversible character. The problem is met, because during the insertion of signatures, the coefficients of the transforming wavelets are changed during their transformation. A problem was encountered that we are not going to recuperate the inserted signatures, and they will have overflow. With this effect, we used a code which

		Inserted message: pathology	Extracted message
Without attacks		X	pathology
Attacks	Unsharp filter	X	Wh}q~hri`
	Gaussien noise	X	p tholi`išaZZ
	Median filter [3X3]	X	^a` a``b a_b`a
	Rotation 2°	X	````_a``a``a
	Compression JPEG 70%	X	```````````````
	Histogram egalisation	X	a~Šwud

Tab. 2. Behavior of the approach against attacks in the field of wavelets.

allows overcoming these problems. We have proposed an insertion and extraction phase, then validated our approach by an experimental study. This work is applied in the European platform TeNeCi that is supported by the INTERREGIII association.

Acknowledgments

The authors extend their thanks both to the Besançon Institute of Information Technology (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).

References

[1] OSBORNE, D., ABBOT, D., SORELL, M., ROGERS, D. Multiple embedding using robust watermarks for wireless medical images. In *3rd international conference on mobile and ubiquitous multimedia MUM 2004*. College Park (USA), 2004, p. 245 – 250.

[2] GARCIA, E., GUYENNET, H., LAPAYRE, J.-C., RAMADASS, S., BUDIARTO, R., KASSIM, N., BOUHLEL, M. Collaborative telemedicine components integration in a multimedia conferencing system. In *20th APAN Meeting: Advanced Network Conference.* Taipei (Taiwan), 2005, p. 59 – 67.

[3] GUYENNET, H., LAPAYRE, J.-C. The group approach in distributed system. *Progress in Computer Research, vol III.* Commack (USA): Nova Science Publishers, 2001.

[4] MOULIN, T., BERGER, E., LEMOUNAUD, P., TATU, L., VUILLIER, F., SABLOT, D., TABAILLOUX, D., REVENCO, E.,

NEIDHART, A., RUMBACH, L. Consultations de neurologie en urgence dans un centre hospitalier universitaire: Apport du neurologue dans la prise en charge du patient. *Revue Neurologique*, 2000, vol. 156, no. 10, p. 727 – 735.

[5] FOURATI KALLEL, I., BOUHLEL M.-S., LAPAYRE, J.-C., GARCIA, E. Control of dermatology image integrity using reversible watermarking. *International Journal of Imaging Systems and Technology*, 2009, vol. 19, no. 1, p. 5 – 9.

[6] KAMSTRA, L., HEIJMANS, H. J. A. M. Reversible data embedding into images using wavelet techniques and sorting. *IEEE Transactions on Image Processing*, 2005, vol. 14, no. 12, p. 2082 – 2090.

[7] BOUHLEL, M.-S., TRICHLI, H., KAMOUN, L. A review of watermarking techniques, applications, properties and domains. *Journal of testing and evaluation for applied sciences and engineering*, 2003, vol. 31, no. 4, p. 357 – 360.

[8] FOURATI KALLEL, I., BOUHLEL, M.-S. A new fragile watermarking for medical images based on the human visual system. In *3rd International Symposium on Image/Video Communications over fixed and mobile networks ISIVC 2006*. Hammamet (Tunisia), 2006,

[9] CHEMAK, C., LAPAYRE, J.-C., BOUHLEL, M.-S. New watermarking scheme for security and transmission of medical images for PocketNeuro project. *Radioengineering,* 2007, vol. 16, no. 4, p. 58 – 63.

[10] KALLEL, M., LAPAYRE, J.-C., BOUHLEL, M.-S. A multiple watermarking scheme for medical image in the spatial domain. *International Journal on Graphics,Vision and Image Processing*, 2007, vol. 7, no. 1, p. 37 – 42.

[11] KALLEL, M., BOUHLEL, M.-S., LAPAYRE, J.-C. A new multiple watermarking schema for medical image in frequency field. In *4th International Conference: Sciences of technologies of Information and Telecommunications SETIT 2009*. Hammamet (Tunisia), 2009.

[12] LI, Q., LI, T., Zhu, S., Kambhamettu, C. Improving biomedical data classification performance by wavelet preprocessing. In *Proceedings of 2002 IEEE International Conference on Data Mining*. Maebashi City (Japan), 2002, p. 657 – 660.

About Authors ...

Mohamed KALLEL was born in Sfax (Tunisia) in May 1979. He received the engineering diploma from the National Engineering School of Sfax (ENIS) in 2004, the DEA in electronics and the degree of Doctor Engineer from the National Engineering School of Sfax (ENIS). Currently, he is a research member in the Research Unit Sciences and Technologies of Image and Telecommunications (SETIT) ISBS – Tunisia and in the Laboratory of Franche Comte (LIFC) Besançon – France. His research interests include multiple watermarking and data hiding, telemedecine and image processing.

Mohamed-Salim BOUHLEL was born in Sfax (Tunisia) in December 1955. He received the engineering diploma from the National Engineering School of Sfax (ENIS) in 1981, the DEA in automatization and informatics from the National Institute of Applied Sciences of Lyon in 1981, the degree of Doctor Engineer from the National Institute of Applied Sciences of Lyon in 1983. He is actually the head of Biomedical Imagery Department at the Higher Institute of Biotechnology Sfax (ISBS). In 1999, he received the gold medal with the special mention of jury in the first International Meeting of Invention, Innovation and Technology (Dubai). He was the vice president of the Tunisian Association of the Specialists in Electronics. He is actually the vice president of the Tunisian Association of the Experts in Imagery and president of the Tunisian Association of the Experts in Information technology and Telecommunication. He is the editor in chief of the International Journal of Electronic, Technology of Information and Telecommunication, chairman of the international conference: Sciences of Electronic, Technologies of Information and Telecommunication: (SETIT 2003,SETIT 2004 ,SETIT 2005, SETIT 2007 and SETIT 2009) and a member of the program committee of a lot of international conferences. In addition, he is an associate professor at the Department of Image and Information Technology in the Higher National School of Telecommunication ENST-Bretagne (France).

Jean-Christophe LAPAYRE has been a professor at the Com-puter Science Laboratory of Franche Comte (LIFC France) since 2002. He is the head of the Computer Science Teaching Department from Besançon and the head of Distributed Algorithmic for Tele-applications Research Group. His general field is in distributed systems and his present research interests are medical telediagnosis and telemedicine applications.