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N-Grams Based A Novel Adapted Watermarking Approach to Secure Health Information Systems Databases: Case of Medical Images

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Abstract:

In regards to data protection, securing medical content must achieve a balance between several factors such as data confidentiality, data integrity, data availability, etc. Health Information Systems (HIS) has been identified for a few years, since establishments have largely computerized their healthcare process and biomedical devices have been developed incorporating complex computer systems. Access to patient information has become purely electronic through Electronic Patient Record (EPR). These records contain information in different formats (textual, images, videos). In the case of securing medical images which is the subject of this paper, it is imperative to find solutions with a tradeoff between the security degree and its complexity in terms of computation time. In this paper, we propose a new approach for medical images watermarking that addresses the problem described above by preserving an acceptable tradeoff between security and complexity. This approach is based on the N-grams technique, with the aim to watermark only the regions of interest (ROI) within the host image. This approach has proven its efficiency in Natural Language Processing (NLP). The results obtained are very encouraging and will be detailed in this paper in terms of imperceptibility, execution time and robustness. For the imperceptibility most of PSNR results are well over 40dB. Regarding the robustness, the values of the normalized correlation coefficients are mostly close to 1. According to these two metrics we can conclude that the proposed watermarking scheme is well imperceptible and robust.

Keywords: Medical images, N-grams, Region of interest, imperceptibility, robustness.

1. Introduction

Securing multimedia content in health information systems is an aspect that cannot be overlooked. The security consists in developing techniques covering the protection of the content as well as the management of the parameters involved directly or indirectly by a clearer and more sustainable strategy. This means that discovering techniques providing higher security with less complexity would be an ideal axe to explore.

Huge number of medical images would be increasingly exposed to malicious attacks due to existing vulnerabilities in the security systems especially for digital medical images. It should be noted that many researches has been achieved to check authenticity, integrity and medical image content protection. Unfortunately this research seems to lack reliable a security.

Medical image watermarking played an important role in recent years and in particular for security goals based on integrity, authenticity and protection of individual and public property rights approaches. Unfortunately, it remains insufficient in term of resistance against intelligent hacker attacks and in term of requiring enormous computing time. Indeed, new avenues applied in other technological axes can contribute significantly to deal with this problem.

Image watermarking is one of the subjects that aim to guarantee the security of medical images exchanged through unsecure networks. Watermarking can be distinguished according to the application field: spatial domain [1, 2] or frequency domain [3, 4] or even the type of used watermarking: blind watermarking [5], semi-blind watermarking [6] and non-blind watermarking [7]. The choice of the watermarking domain and the type is essentially based on the targeted application and the objective to be achieved.

Statistical and probabilistic techniques used in textual analysis and in particular the N-grams approach seems very interesting and very promising to be applied in medical image watermarking. The N-grams approaches have proven their efficiency in Natural Language Processing (NLP) and textual analysis through results obtained in different linguistic applications.

The N-grams of character although having been proposed for a long time and used mainly in speech recognition. The notion of N-grams character gained more importance with the work of [8] on language identification , and [9] on the processing of writing. In other words, it is proved that this division, although different from a division into words, did not lose information. More recent applications of N-grams include work on: textual information retrieval [10]; multilingual automatic hyper-textualization [11] which, through a method of thematic classification of large collections of texts, independent of language, builds hypertext navigation interfaces; or even multidimensional exploratory analysis for searching information in textual dataset.

The organization of this paper is as follows. Section 2 presents recent watermarking methods in the literature. Section 3 presents an overview of the N-grams concepts and its applications. Section 4 details the proposed watermarking approach with application to medical images including the watermark embedding/extraction and a performance evaluation of the proposed approach. Finally, Section 5 concludes this paper.

1. Related work

Authors in [12] suggested an approach to encrypt medical images based on the principle of N-grams. The proposed approach has been proposed to addressee some gaps related in particularly to the symmetric encryption keys and especially to exchange the key securely by extracting the N-grams matrix from the receiver side to extract the same key through N-grams matrix. The approach is pure informed and built from the adjacently pixels by bi-grams and tri-grams values. The application of this approach consists to only medical images. In point of view of integrity, this approach gave remarkable results.

A τ -SS3 approach has been proposed in [13]. τ -SS3 is an extension of τ -SS3 classifier. This classifier became widely used especially for classifying different type of texts and has been also exploited in detecting risk early when streaming texts from different sources. The principle of this classifier is based on bagging-of-word to recognize the significant word sequences. The advantage of this principle is to reduce characterization of visual interpretations. The core of using τ -SS3 is to make able to improve both the obtained results and the richness of visual interpretation.

In [14], authors introduced a new concept of N-grams called Sn-grams to classify text. The difference between N-grams and Sn-grams is that Sn-grams focus on the weighted elements that can be considered as neighbors. These neighbors are built by a syntactic tree with a necessity of parsing step. Sn-grams is fully independent of the used language. Authors used three classifiers (Naive Bayes, SVM and J48). The obtained results were more significant especially when using SVM.

Authors in [15] suggest an Abstract Syntax Tree (AST) to enhance the defects prediction performance. AST is considered as bottom-up. For test, a non-parametric testing is used to find the link between AST N-grams and faults. A defect prediction model has been built based on some machine learning techniques. The AST N-grams approach provided remarkable results regarding faults in some specified platforms and can have a large impact on the defect prediction models performance.

Authors in [16] proposed an applied technique in NLP field to classify multiclass sentences for Urdu language for different sentences existing in the different social media platforms based on n-grams features. A dataset of size 100000 instances has been used of twelve different types of subjects. The proposed classifier is a Random Forest to classify those sentences. The performance of the proposed technique was efficient especially when using bi-grams.

In the work presented in [17], a novel Arabic text summarization approach was proposed. The approach is mainly based on Knapsack balancing of effective retention. The approach refers maximizing retention when prioritizing salient themes by computing for each sentence an effective retention score. Authors formulated the approach as combinatory optimization issue. Performed results outperform many works related to Arabic summarization.

In this paper, we exploit the characteristics of the N-grams of characters used in the textual analysis which seems to be interesting to apply to images. The approach core is to find pixels as a subject to build an informed watermarks and providing information about the different localization of the built watermark. The approach is purely blind and do not need both for host image or original watermark.

2. N-grams concept

In the textual analysis, an N-grams structure is a subsequence of N elements constructed from a given sequence. The principle is that, from a given sequence of words or characters, it will be possible to obtain the likelihood function of the appearance of the following character. From a training dataset, it is easy to construct a probability distribution for the next character. Indeed, N-grams are sequences of adjacent N-characters. N can be 1 or 2 or any other positive integer: bi-grams for N=2, tri-grams for N=3, quadri-grams for n=4, ..etc. The use of N-grams is based on the simplifying assumption that, given a sequence of *k* elements, the probability of the appearance of an element in position *i* depend only on the previous *n-1* elements.

Suppose we have the following sequence of characters:

abbaacebd

The bi-grams will be: ab bb ba aa ac ce eb bd

And the tri-grams will be: abb bba baa aac ace ceb eb

In image processing and analysis, and in particular for the problem of image classification, N-grams can be an effective tool to designate relevant and significant pixel blocks which helps classifiers to properly classify images according to the distribution of bi-grams represented by adjacent occurrence frequencies. In the case of medical image, figure 1 illustrates an example of the zones in which the bi-grams represents high frequencies of pixels' apparition.

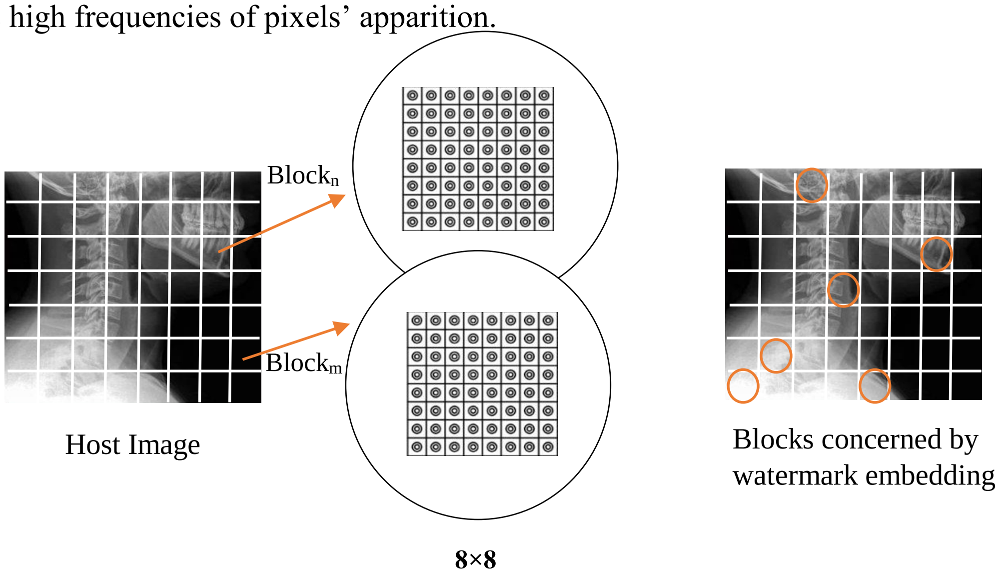


Figure 1. Blocks selection for watermark embedding based on N-grams frequencies

3. Proposed watermarking model

The proposed medical image watermarking schema is based on three main steps: watermark embedding, attacks on the watermarked image and the watermark extraction. Each step is well described in the following sections. The main goal of the proposed watermarking scheme is to select the pixels with high N-grams frequencies (N=2 for bi-grams). The selected pixels in N-grams will represent the built watermark. The pixels describing a gray level medical image (values between 0 to 255) in its whole are often of white intensities or even close to white. This means that the intensities with black values will be ignored. Only blocks with the high frequency of N-grams appearance will be affected by the watermark. Figure 1 illustrates an example of a host image and a watermark which will be embedded.

Figure 1. Example of host image and its corresponding watermark.

3.1.Watermark embedding

In this step, a watermark will be embedded in the pixels with the highest bi-grams frequency appearance from the whole image based on the extracted N-grams matrix. In our tests, we chose n=2 (bi-grams) to indicate all the pixels and their adjacent one as one bi-gram. This process will be applied to all the pixels. Once we build the bi-grams matrix, only bi-grams with the highest appearance frequency will be taken into consideration. Building the matrix of bi-grams concerned by the watermark embedding is based on extracting the positions of the defined bi-grams concerned by the watermarking. A linear interpolation is used to realize the embedding phase as defined in equation 1.

$$i_w = (1 - \alpha)w + \alpha i \qquad (1)$$

Where i_w, i, w are respectively the watermarked, host and watermark images. Knowing that $\alpha \in]0, 1[$. The watermark embedding is summarized in algorithm I.

ALGORITHM I
1. Select a host image
2. Calculate the bi-grams values of adjacent pixel
3. Define the highest bi-grams frequencies apparition
4. Determine the positions of the bi-grams selected in step 3
5. Built the calculated watermark based on positions in step 4 by assigning values 255 to those positions.
6. Embed watermark in the host image in the selected pixels representing the highest bi-grams frequencies based on a linear interpolation equation 1.

Figure 2. Illustrates an example of the selected blocks (in red) concerned by the watermark embedding.

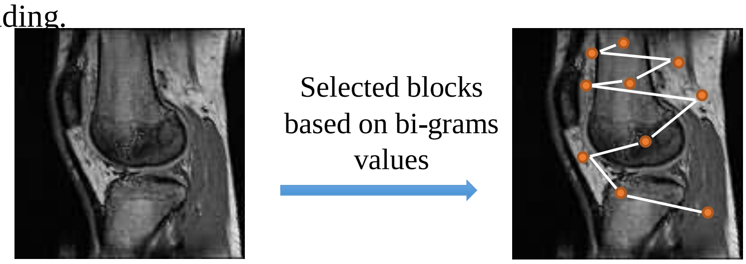


Figure 2. Blocks in red designed by watermark embedding based on bi-grams frequencies.

The main idea by selecting only the pixels concerned by watermarking represented by the high appearing frequency of bi-grams is to reduce the complexity of the algorithm in terms of watermark embedding and extraction time. So that, the approach will be suited for real-time applications. Similarly, the choice to take into account only the pixels with high frequencies of appearance according to the values of the bi-grams allows to build an adaptable watermark. This mean to build a watermark with a different manner comparing to the classical approach where the watermark is fixed. This approach is called "informed watermarking". Informed watermarking helps to generate different watermarks depending on the content of the host image, which makes it difficult to the illegal users to know the approved watermark.

Figure 3 illustrates the used images designed by the watermark embedding and extraction processes in our experimentation.

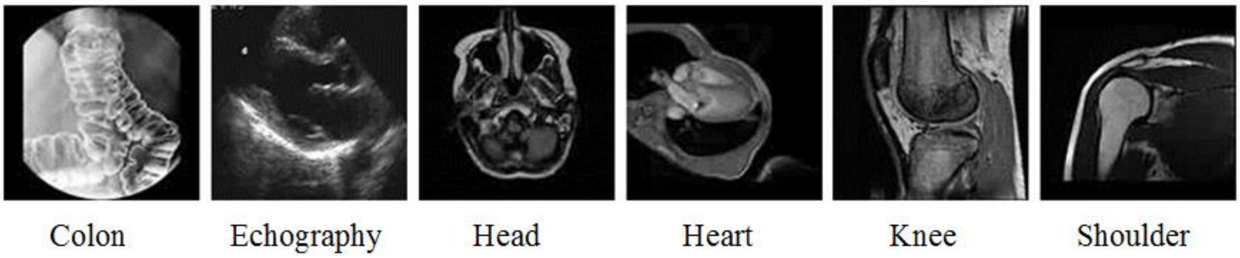
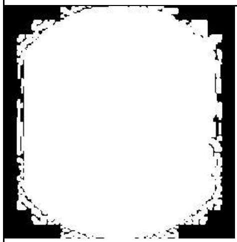
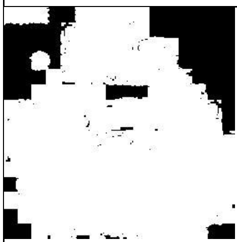
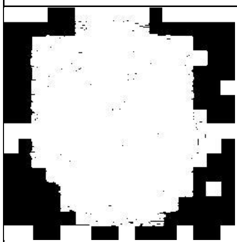
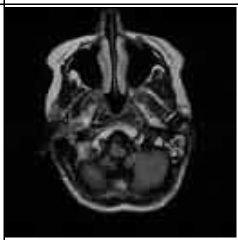
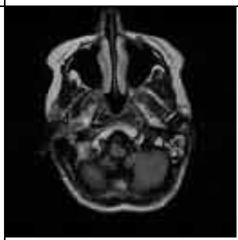
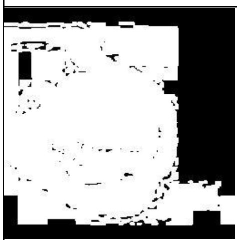
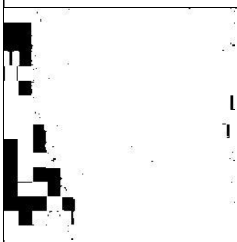
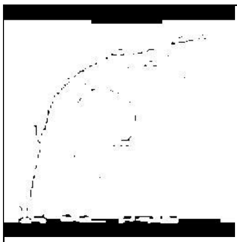


Figure 3. The used images in experimentation

Table 1 shows the tested host images, the corresponding built watermarks based on the bi-grams frequencies of apparition and also the corresponding generated watermarked images using equation1. In the watermark images, only black pixels are concerned by the embedding process.

Table 1. Watermark embedding process.

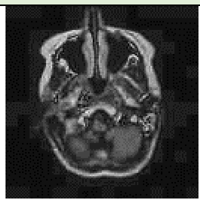
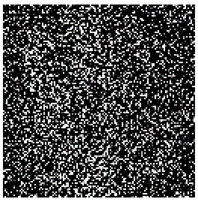
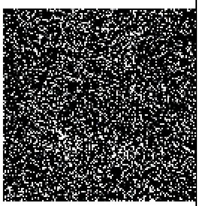
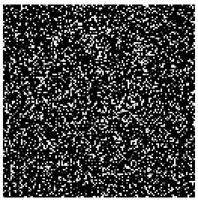
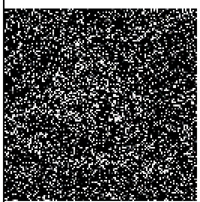
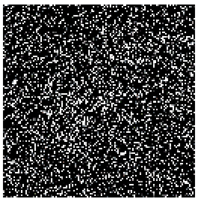
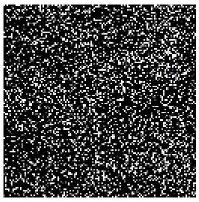
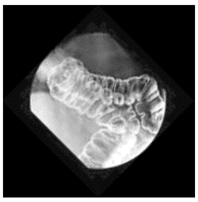
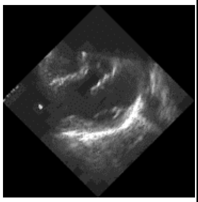
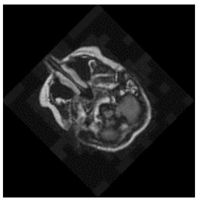
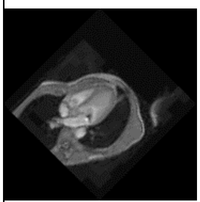
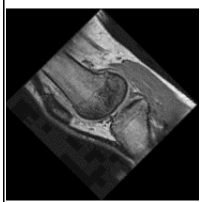
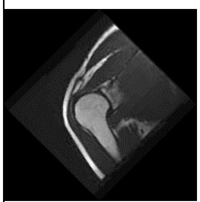
Built watermark	Host images	Watermarked images
		
		
		
		
		

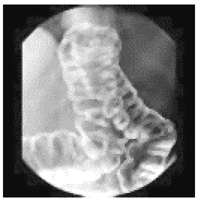
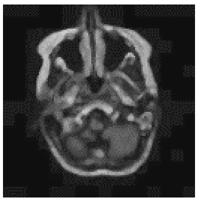
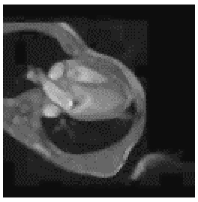
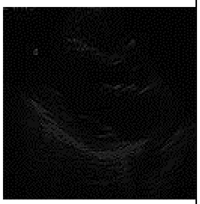
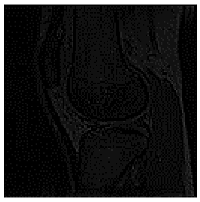
		

3.2.Attacks on the watermarked images

After embedding watermarks in their corresponding host images, we apply attacks on those watermarked images. The scenario of attacks represents a variety of geometric and non-geometric attacks such (JPEG compression, adding noise, rotation, cropping, filtering, etc…). These attacks are applied using a well-known benchmark called Stirmark [18]. The used images database contains 50 medicals images for a variety of organs with different textures and contrast. Table 2 illustrates some applied attacks on each watermarked image.

Table 2. Sample of attacks on the watermarked images.

Attacks	Colon	Echography	Head	Heart	Knee	Shoulder
JPEG compression (QF=50)						
Noise_80						
Rotation 45°						

Median_3						
Conv_2						

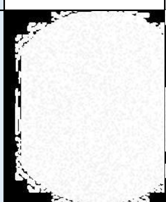
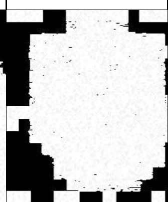
3.3.Watermark extraction

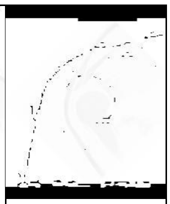
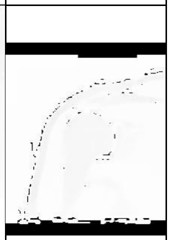
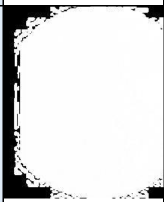
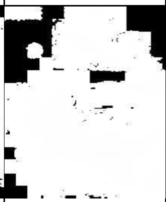
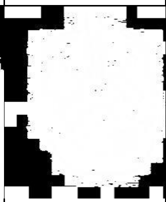
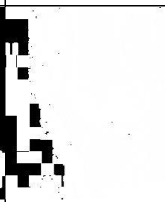
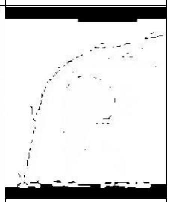
Watermark extraction phase consists to retrieve the attacked watermark w_a from the attacked watermarked image iw_a. This phase is the reverse operation of watermark embedding. The extraction of the attacked watermark is achieved as defined in equation 3.

$$w_a = \frac{1}{\alpha} w - \frac{1-\alpha}{\alpha} iw_a \qquad (2)$$

The different extracted watermarks after applying attacks are presented in table 3. In this step we extract every attacked watermark from its corresponding attacked watermarked image including all the illustrated attacks. Table 3 shows these attacks such (JPEG_90, Conv_2, Rotate_45, Noise_80 and Median_9).

Table 3. Extracted watermarks after applying attacks.

Attacks	Colon	Echograp hy	Head	Heart	Knee	Shoulder
JPEG compres sion (QF=50)						
Noise_8 0						

Rotation 45°						
Median _3						
Conv_2						

3.4.Results analysis

We conducted evaluations through a dataset of grayscal medical images containing 50 images of size 256×256 [19]. Results are discussed based on two main arguments: imperceptibility, and robustness.

3.4.1. Imperceptibility

Imperceptibility means that the visual quality of the host image concerned by watermarking should not be distorted by the incrustation of the watermark. Imperceptibility is measured based on two most metrics [20]: PSNR (Peak Signal to Noise Ratio) as defined in equation 3 and MSE (Mean Squared Error) in equation 4.

$$MSE = \frac{1}{m \times n} \sum_{i=1}^{m} \sum_{j=1}^{n} (I(i,j) - Iw \quad (i,j))^2 \qquad (3)$$

$$PSNR = 10 \times log_{10} \left(\frac{max^2}{MSE} \right) \qquad (4)$$

Where *max* is the highest pixel intensity. The image is 8-bits grayscale, then *max* =255.

And *I(i, j)* is and $I_w(i, j)$ are respectively the host image and the watermarked one.

3.4.2.Robustness

The Normalized Cross correlation (NCC) is a metric used in the literature to measure the robustness of the watermark against different scenario of attacks. Equation 5 shows how to calculate the NCC between the original watermark and the extracted one.

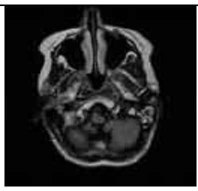
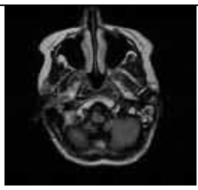
$$NCC = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}(w(i,j) - w_a(i,j))}{\sum_{i=1}^{m}\sum_{j=1}^{n}(w(i,j))^2} \qquad (5)$$

Where w is the original watermark image and w_a is the extracted one from the attacked watermarked image.

3.4.3. Performance analysis

To evaluate the performance of the proposed approach, two metrics have been measured in terms of imperceptibility and robustness. The PSNR expresses the degree of the visual similarity between the host image and the watermarked image. As well as the NCC measures the robustness between the original watermark and the extracted one. Through table 4 and 5, we can notice that our approach gives better results through the obtained values of PSNR and NCC.

Table 4. PSNR between the original images and their corresponding watermarked images.

Host image i						
Watermarked image i_w						
PSNR(i, i_w)	**53.47dB**	**51.94dB**	**52.61dB**	**52.86dB**	**51.92dB**	**53.12dB**

We conclude a strong similarity between two images if the PSNR between these two images exceeds 40dB which means that imperceptibility is achieved. Table 4 shows the results obtained. We note that the PSNR values in all cases between the host image and its corresponding watermarked image exceeds 51 dB. The obtained PSNR values on the different used images in our tests mean that there is a strong similarity between the host images and their corresponding watermarked images.

Table 5. NCC between the original watermark and their corresponding extracted ones.

Attacks	Colon	Echography	Head	Heart	Knee	Shoulder
	Normalize correlation coefficients NCC values					
JPEG compression (QF=50)	0.999	0.9996	0.9997	0.9997	0.999	0.9995
Noise_80	0.999	0.9993	0.9995	0.9995	0.9981	0.999
Rotation 45°	0.9988	0.9996	0.9997	0.9997	0.9989	0.9996
Median_3	0.999	0.9996	0.9997	0.9997	0.999	0.9995
Conv_2	0.9998	0.9999	0.9999	0.9999	0.9997	0.9998

For robustness, we used one of the most widely used and reliable metrics in watermarking. This metric is based on the NCC calculation between the original watermark and its extracted one for each attack. If the value of NNC is close to 1, this means that the original watermark and the extracted one are very similar which expresses that the watermarking scheme is robust. Through the table 5, the NCC values in all cases are very close to 1.

The proposed approach represents a very minimal computation time compared to watermarking methods in which the watermarking represents the same size of the host image. Through our approach, few areas selected by the watermarking represented by the bi_grams with the highest number of appearance frequencies. This novelty reduces significantly the watermark embedding / extraction processes and make it applicable for real time applications.

4. Conclusion

In this paper, we presented a new informed watermarking approach for medical image watermarking based on an approach called N-grams. This approach has proven its efficiency in the field of natural language processing under different application. The approach consists in achieving a watermarking on medical images through the selection of pixels which represents high frequencies of appearance according to the values of the bi-grams for watermark embedding. This pre-selection focuses on indicating the image texture areas which enhance the watermark imperceptibility. The approach offers a low computation time both for watermark embedding/extraction by preserving an acceptable robustness of watermark against different scenario of attacks. Attacks were applied on the watermarked images to evaluate the performance of the approach. The results obtained are very motivating in terms of imperceptibility and robustness. In almost cases, the imperceptibility measured by PSNR exceeds 52db. For the watermark robustness measured by the Normalized Cross Coefficients are also in almost cases close to 1.

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