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Digital image watermarking based on ANN and least significant bit

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ABSTRACT

The tremendous AI benefits, machine learning and deep learning, have led to the adoption of advanced technology and modern applications. Especially in an image, Video processing, natural language processing, speech recognition. AI algorithms have recently overcome many drawbacks, thanks to the DNN models, that have contributed to delivering state-of-the-art results in computing and other areas. But safety and security are always challenging tasks.Our proposed approach provides a secure and efficient watermarking method based on a neural network for digital images using the least significant method. First, we used the least significant bit (LSB) to insert a watermark for the image pixel. Because only LSB -based methods are not robust; they are not sufficient in an attack-free environment and lossless compression. We used an Artificial Application Neural Network (ANN) to detect the presence of sensitive information and extract information from the source image. It is inherently unstable when the proper machine learning algorithm is trained, re-trained, and adapted to a few new applications. The standard solution would have a digital signature there as there are very simple ways to change the neural network model so that it still does the same thing as before, but the overall presentation will be different. This paper highlights the essential needs of the ANN model in watermarking.

KEYWORDS

Watermarking; artificial neural network; least significant bit; embedding; public - key

1. Introduction

In recent years, the information technology, digital data, multimedia are advancing rapidly and directed toward the development of various impediments such as copyright protection and security. Hence, it is very crucial for the data owner to use data hiding techniques such as cryptography, steganography, and watermarking. That's why we're looking for security approaches to protect the content of information. Encryption is the art of writing a message in the form of codes, in which information that is clearly expressed and coded according to an algorithm and only authorized persons who have the algorithm can perform the process of decoding to decrypt it can. Some encryption algorithms are the same ones that are to be coded, but other encryption algorithms may work relative to the message. Decryption is the reverse process of encryption.

Digital watermarking plays a significant role to solve the authentication and security issue because ownership protection of digital data has become an important issue. Generally, the classification of the watermarking approach shown in Figure 1.

The watermarking process can be divided into spatial areas and frequency areas. The spatial-domain watermarking algorithm is straightforward, pixels of the original image is directly altered to hide the watermark, and computational complexity is low and cannot withstand rigorous digital signal processing. In the frequency domain based watermarking method, the embedding process of the watermark is performed by manipulating the coefficients of the original image.

The Transform section uses several robust watermarking methods because they are robust and can embed more watermark bit data. Digital watermarks can be classified as audio watermarks, video and image watermarks. According to the watermark extraction method, the digital image watermark is classified as the invisible and visible watermark. Visible watermark requires the original image for watermark extraction, while invisible watermark is not needed.

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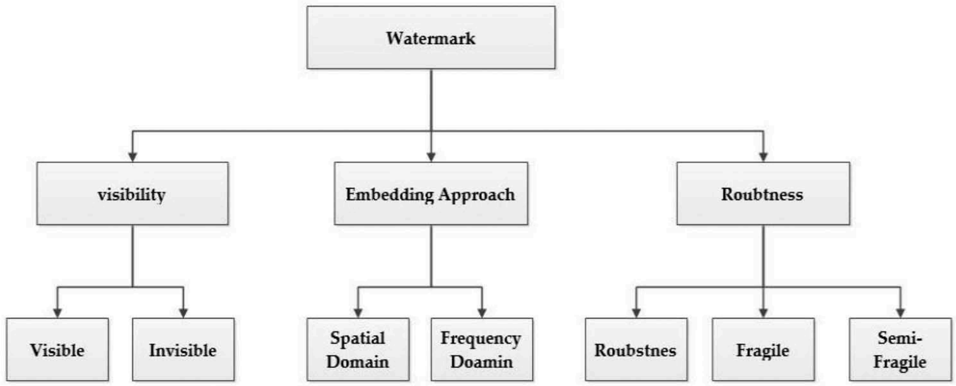

Figure 1. Classification of the watermarking scheme.

The basic process of the watermark embedding process is shown in Figure 2. In the embedding process, the image and the actual watermark are input. Some watermarking methods also use public key or key as input to enhance security. Watermark information can be any digital content and can be converted into the actual watermark. As an output, the system creates an image with a watermark.

The watermark extraction is the opposite of an embedding watermark process. As input, the watermark image which passes through the information channel and may be attacked is taken as input. According to the watermarking method, the key, watermark, and even the original unlabeled image can also be used as input for the extraction process. In the latter case, compared with the blind method original image is not necessary for watermark extraction. This method is called the non-blind method.

The watermark should take into account three aspects: capacity, security and robustness. Capacity to define how much information can be hidden in the carrier, security to prevent the interception of the information, and the amount of change in the information to be protected without destroying it as robust. In the case of a watermark, On the other hand, an algorithm for transforming the secret information for high security and high capacity must be sufficient because the confidential data to be transmitted is fragile and any change in the image can destroy it (Barreto PS, Kim HY, Rijmen V. 2002 ; Golestani H, Bakhshi M, G. 2013; Zhang X, Xiao Y, Zhao Z 2015)

In recent years, watermarks for digital images have been investigated, and various methods and techniques introduced. The watermarking scheme is essentially designed concerning its application, and there is none such a watermarking scheme that can perform well under all hostile attacks (Khan, Tahir, Majid, & Choi, 2008). (R. Caldelli, F. Filippini, R. Becarelli, 2010) Gives an overview of watermarking techniques. This article also describes the general classification of

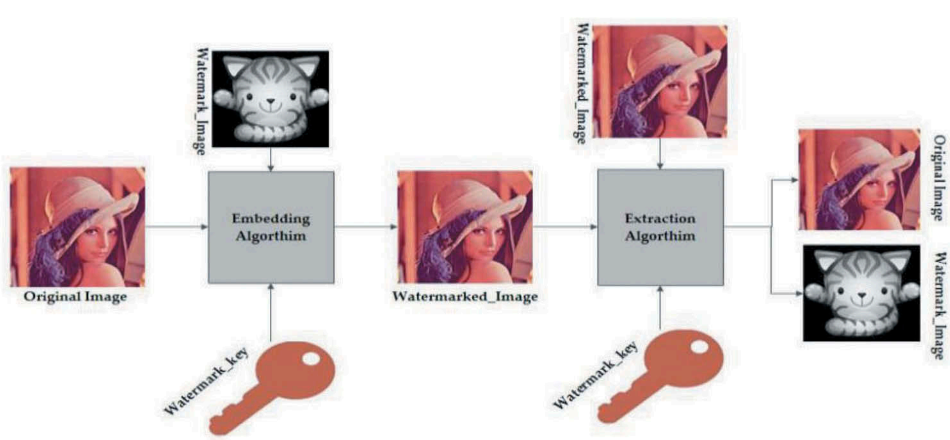

Figure 2. Basic embedding, Extraction process of watermark.

watermark approaches. Based on the embedded and extracted approach, the watermark is converted to a transformed source instead of adding a watermark to the original image. Parthasarath, et al. 2007) designed a DCT content watermarking scheme. In its method, texture, gloss, angle and edge information in the image to generate a watermarking mask. They were found to be theirs the scheme is robust to JPEG compression, median filtering, and contrast sharpening filter However, it is not robust against scaling, rotation, and high noise. For these reasons, the development and evaluation of a water tagging algorithm is a challenging task.

(M. Jianshengn, L. Sukang, T. Xiaomei, 2009) Introduced a watermarking approach based on Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT). In this algorithm, the watermark image is first converted into the discrete cosine transform DCT, and then this transformed watermark is embedded in a high-frequency image band obtained by discrete wavelet transform. Then distil the digital watermark with the original image and a watermark image. (Mohan C, Kumar B, SS. 2009) Introduces the watermark-based approach with Singular Value Decomposition (SVD) with Quantization Index Modulation (QIM) and Multiple Descriptions (MD). The embedding process took place in two phases. In the first stage, they compute the DCT of the odd description of the original image, while in the second phase a copy of the watermark image is embedded in the watermarked image obtained by the implementation of the first phase. In (Paul RT 2011) they introduced the concept of a video watermark and illustrated the essential features required for a robust video watermark watermarking framework. (Luo, Hao SC, Chu ZM, et al. 2008) for digital images introduced a self-embedded watermark approach. The built-in algorithm, the title image, is used as a watermark. It creates a watermark by converting the main image into a halftone image. When the watermark is replaced and embedded in the LSB of the host image, retrieve the watermark from a suspect LSB image and return the permutation. (Yang WC, Wen CY, Chen CH. 2008) They used the public-key infrastructure to develop a novel test and verification approach to digital watermarking for images. The main idea of their paper is to embed an encrypted watermark in the original least significant bit (LSB) image. (Lee GJ, Yoon EJ, Yoo KY 2008) Proposed new digital watermarking LSB method using random mapping functions. The main approach to their algorithm is to randomly embed the watermark in the original image coordinates. By randomly embedding watermarks, it becomes more robust than traditional approaches, more robust than the use of random functions.

In recent years, neural networks have paved the way for the advancement of watermarking technology by mimicking the brain's learning ability. Neural networks are used to enhance watermark extraction or to determine watermark strength (Yang QT, Gao TG, Fan L. 2011). Artificial neural networks are a powerful tool that provides a very computationally intensive optimization method. ANN can be classified as feedforward and feedback, as well as by mistake or unattended for individual training groups. (Majumder S, 2010) Proposed SVD technique of Watermarking Images, Error Control Coding (ECC) and ANN. ANN was used for authentication to increase the robustness of the anti-malware attack.

(Najafi HL 2010) shows the performance of watermark approaches using the neural network in terms of capacity, transparency and robustness. (Berg G 2003) employed a pattern recognition approach to identify the watermarked and the original image. (Jain N, Meshram S, Dubey S, 2012) proposed a watermark-based scheme for edges; they illustrate how the watermark is embedded in the edges of an original image, and use edge extraction techniques to extract the watermark. (Islam M, Roy A, Laskar RH, 2018) Proposed watermark approach based on LWT; ANN was used to extract watermarks, several attacks were simulated on the watermarked image, and then ANN was used to reconstruct the original image.

(Islam M, Ahsan S, Ullah M, 2019) proposed a digital image watermarking technology based on DWT, entropy and neural network is proposed to protect image authentication. First, a host image and a watermark image are divided into a plurality of frequency bands by using a wavelet transform. Then, the entropy of each frequency subband is calculated to find the maximum entropy subband, so that the maximum entropy subband of the watermark image can be embedded into the maximum entropy subband of the host image. Finally, the neural network is used to determine the relationship between the pixel value of the host image and the watermark image for subsequent watermark extraction process. In addition, to reduce image processing attacks, a moving average filter is used before extraction.

2. Least significant bit

Spatial technology refers to the technique of embedding watermarks by instantaneously changing the pixel values of the primary image. There are several techniques for the spatial area, eg. Patchwork, texture, block coding, least significant bit (LSB) modifications, etc. The most serious disadvantage of the spatial domain technology is limited to robustness. LSB coding Watermarking (Schyndel V, Andrew RG, Tirkel Z. 1994)], the most simple and easiest use the watermarking scheme. As if I can't Attack. But with the development of algorithms various steganalysis surfacing (Ge, Shen Y, Gao R 2007) We found that the LSB is vulnerable to very small images distortion. The researchers later improved the LSB and algorithm, like Patchwork (Bender et al. 1996), correlation-based techniques, feature point and chaotic map were used. The LSB-based steganography is further divided into two methods: LSB replacement and LSB matching (Goel S, Rana A, Kaur M, 2013). The simple approach is the LSB exchange. Three bits of original image pixels are replaced by three bits of secret data. The 1-bit LSB insertion process is shown in Figure 3.

The basic equation of LSB is

$$P = \{X_{ij} | 0 \le i < M_p,\ 0 \le j < N_p | \} \quad (1)$$

$$X_{ij} \in \{0, 1, 2, 3, 4, \ \dots\ \dots\ \dots\ \dots\ \dots\ \dots\ ..255\} \quad (2)$$

$$C = \{c_i | 0 \le I < N,\ c_i \in \{0, 1\} | \} \quad (3)$$

From equation (6), P represents the eight-bit original image, with the size of M_p, N_p. M shows the n-bit hidden information.

Embeds n-bits secret message C into k-LSB of original image P, rearrange hidden message C to form a conceptually k- bits virtual image C* represents as:

$$C^* = \{c_i^* | 0 < n^*, c_i^* \in \{0, 1, 2, 3\ \dots\ \dots\ ..2^{k-1}\} | \} \quad (4)$$

Where$n^* < M_p \times N_p$. The mapping between secret message C = $\{c_i\}$ and embedded image $C^*\{c_i^*\}$is defined as:

$$c_i^* = \sum_{j=0}^{k-1} c_{i \times k + j} X 2^{k-1-j} \quad (5)$$

A subset of n^*pixels $\{\times_{11}, \times_{12}, \times_{13, \dots \dots,} \times_{1n}\}$ is chosen from the original image P in a predefined sequence. Watermark embedding is done by replacing LSB of $\times_{1i}$ by c_i^*. Mathematically, the pixel value $\times_{1i}$ of the chosen pixel for storing the message m_i^* was modified to the stego pixel $\times_{1i}^*$ as

$$X_{1i}^* = X_{1i} - X_{1i} \bmod 2^k + c_i^* \quad (6)$$

Equations from (1) to (6) used for each color channel pixels. The advantage If an image with JPEG compression is used, the original image cannot be reconstituted since the three is the loss of

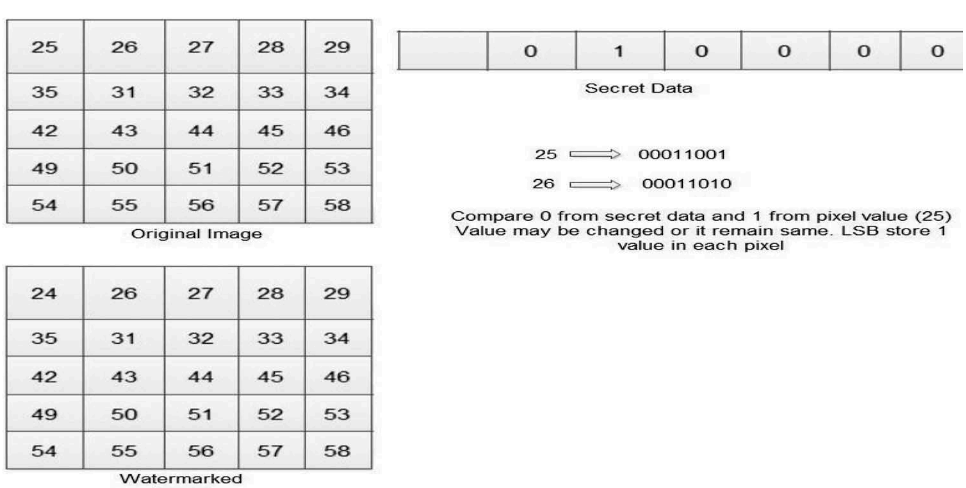

Figure 3. LSB 1 bit insertion process.

information by inserting; therefore, noises in the image created. These noises are extremely useful because they will be responsible for making the identification of messages.

2.1. Artificial neural network IN watermarking

Neural network-based watermarking methods were successful. This is because the NN based scheme performs well under a specific set of conceivable attacks and work well with the Human Visual System (HVS). Artificial neural networks (ANN) are structures that are able to learn, remember and generalize certain situations and problems. ANN are parallel systems consisting of primary neurons of the unit that compute certain mathematical functions that are usually non-linear and whose operation is inspired by the function of the biological neuron (Haykin ss 2009). ANN's solutions can match the solutions offered by programming traditional solutions. The process by which an ANN finds the solutions goes through a learning process in which your elementary units are presented with a series of input and output examples that themselves find the features needed to present the information provided and define the resulting system. ANN can learn from examples presented to it and generalize the information gained. Therefore, it is possible to classify samples of unknown data, but this is similar to the information contained in the training phase.

There are several artificial neural networks Adaline, backpropagation, Bidirectional associative memory, Boltzmann machine, Counter propagation network, self-configuring map, Adaptive resonance theory network and so on.

Recent work has taken advantage of artificial intelligence design robust watermarking systems in neural networks. Due to the inherent characteristics of neural networks learning and adaptation, pattern mapping and classification and generalization capabilities. Not only are they reproduced previously seen data but also give accurate predictions in similar situations provide an opportunity for trained networks to recover the watermark from the watermark data. ANN utilization in watermarking include capacity estimator, error rate prediction, embedding, and extraction of secret data, etc.

ANN can extract features that are not explicitly given in the form of examples. Because of these features, ANN can be trained to assimilate the process of creating cryptographic keys used in steganography or watermarking, and finally to complete the process of inserting and extracting sensitive data (Naoe K, Sasaki H, Takefuji Y, 2011). It should be noted that the use of ANN for steganography analysis has been performed by several studies.

3. ANN as a watermark capacity estimator

Watermarking is a communication channel, to which you need to send an embedded signal. The basic difficulty is the embedding capacity (Wong, Peter HW, Au OC, 2003; Wu M, Liu B 2003). The digital watermark capacity is determined as the maximum achievable bits that can be embedded in the main signal. There are some existing approaches assessing watermark capacity (Servetto SD, Podilchuk CI, Ramchandran K. 1998, Wong and Au 2003), although not based on ANN. Most from previous watermark approaches focused on the spread spectrum technique, where the secret data is it propagates and modulates with a pseudo-random signal and is added to the original signal. One can detect this by correlation.

Researchers like (Zhang F, Zhang H, 2005) studied the limitations of the capacity in the blind watermarking approaches based on Hopfield's neural network. They used the attraction of the pool over Hamming distance to limit the capacity of the watermark. (Mei, Shi-Chun 2002) introduced the human visual system (HVS) using a Feedforward-based image adaptation approach to decide the watermark robustness of DCT coefficients. Experimental results analyzed that the watermark capacity increased and the robustness also enhanced by the proposed approach. Furthermore, (Jin C, Wang S, 2007) showed that by using ANN the flat textured characteristics of each DCT block and the image brightness can be used to adjust the resolution of the watermark.

4. Proposed methodology

4.1. Watermark-embedding

The general objective of this work is to present an algorithm capable enough to hide the confidential information (digital image) in another digital image by using the LSB watermarking technique, and later applying artificial neural networks to identify the presence of any hidden information and then finally extract that secret information, to confirm the receiving user.

In this process, the secret key used for the watermarking process, it must be the same and known to both the persons who communicate the message and who receives it. Thus, the transmitter transforms the original signal is an encrypted set of data, and the receiver uses this key to perform the inverse process obtaining, at last, getting the original information. It is still a very complicated process to find a key extremely secure.

The concept of the public and the private key was conceived in the sense of making the stage of deciphering the most complicated because to obtain the original information, both keys are necessary. Once you know the key, it is a simple task to find the public, but it requires a lot of computational effort.

Because of the complexity of deciphering an essential private partnership, this project was developed with both keys. The public key is defined by an algorithm that implements the inclusion of the least significant bit into a grayscale JPEG image, the chosen format concerning their advantages of others such as GIF due to robustness and invisibility. The public key was defined in this way, because this method is, as mentioned above, one of the most disseminated. The private key, in turn, is neural structures responsible, firstly, in identifying the presence of hidden data on the received image, and then on the restoration of the transported image if it exists. Figure 5 shows the process of inserting information into the image. Branches nominated by LSB and ANN are the public and private keys, respectively.

The algorithm is developed to merge the digital information image in the form of a black-and-white image in another eight-bit gray-scale JPEG image. By the fact of the information is transmitted in the least significant bit (LSB), it became necessary to reserve this space.

$$y(n) = 2\left[\left(\frac{x(n)}{2}\right)\right] \tag{7}$$

The equation (7) performs the mathematical operation responsible for rendering null the LSB of the original signal. The confidential information is coded first, after that inserted into the carrier image. This modification is performed by an algorithm whose purpose is to shuffle the info. For testing purposes the system was three-bit binary encoding was performed for each pixel black and white image. Table 1 explains this coding.

An important parameter that can be stored in the own secret information S (x1, y1) is the dimension of this that it is not necessary to go through the entire carrier sample during the extraction process.

The dimensions of the secret sample were coded in 10 bits for both width and height. horizontal (width) dimension was stored starting from the second pixel of the upper left corner of the image and propagating to the right. The second pixel is the bit more significant and the eleventh or the least significant.

To store the vertical dimension (height), the process is similar to the horizontal one, by merely modifying the of the propagation that this time is going down. Due to the transformation ratio of three to one, the carrier image C (x, y), the resulting information has its width triplicate, and the height remains constant, that is, S (x1, y1), for x1 = 3.x and y1 = y.

The carrier image P (x, y) resulting from the Equation (1) presents only zeros in the LSB, if the S (x, y) does not have the same dimensions as P (x, y), the latter will have a vast tangle of blackened pixels and the presence of a hidden image is easily detected. Figure 6 demonstrates this type of situation

In the image of Figure 6, it would not be daring to imagine some information being sent in the

Table 1. Coding of information to priori.

Carrier Image		Encoded Image	
C(x,y)		S(x1, Y1)	
P(x,y)	P(x,y)	P(x + 1,y)	P(x + 2,y)
0	0	0	0
0	0	0	1
0	0	1	0
0	0	1	1
0	1	1	0
1	1	0	0
1	1	0	1
1	1	1	1

upper left corner. To avoid evidence like this, zeros according to Table 1 in the LSB of the carrier and thus obtain an image similar to Figure 7.

After this a priori codification of both information and the carrier, it will be possible to insert it into the LSB. The operation performed is a conventional pixel-by-pixel sum. Let P (x, y) represents the carrier and C (x, y) the secret information; we will have:

$$E(x, y) = P(x, y) + C(x, y) \tag{8}$$

Where E(x,y) represents the coded or embedded image.

The receiver receiving the encrypted image must perform the inverse coding process to obtain the information.

4.2. ANN and watermark extraction

Three neural structures were developed to perform the inverse process to that of coding, one to identify the presence key, another to search the LSB information and another to remove the a priori coding of the image S (x, y).

In this work, multiple layer ANN was adopted: input, hidden and output. As shown in Figure 4 Learning algorithms for the back-propagation algorithm of Levemberg-Marquard were 0.010. The number of cycles for convergence search was 100 for a mean square error of 10–5. For the intermediate layers and of the output layer sigmoid function is used as an activation function.

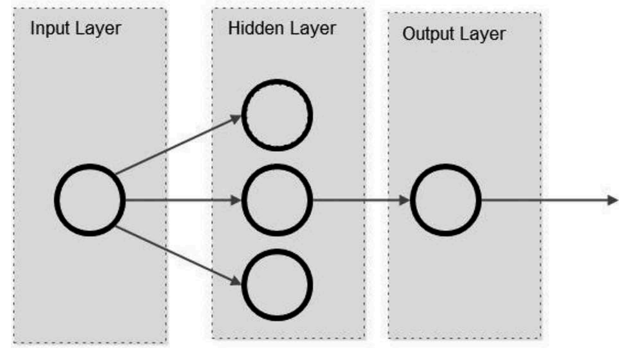

Figure 4. Basic structure of artificial neural network.

For identification of the presence key, an ANN with the structure [4 5 1], i.e., four input parameters, the hidden layer contains five neurons and a neuron in the output layer.

The training was carried out with the intention of to learn and generalize the information in Table 2; the ANN response was true (or equal to one) if it were detected one of the presence keys, and false (or equal to zero) otherwise. If the ANN response was false, the program for the identification and extraction of information hidden steganography would be aborted and would return information "No secret information found." It should be noted that other structures have been analyzed and can be implemented the same way, with the possibility of changing the number of neurons or the activation function.

In the case of a true ANN response, they would continue, and a new ANN would be responsible for

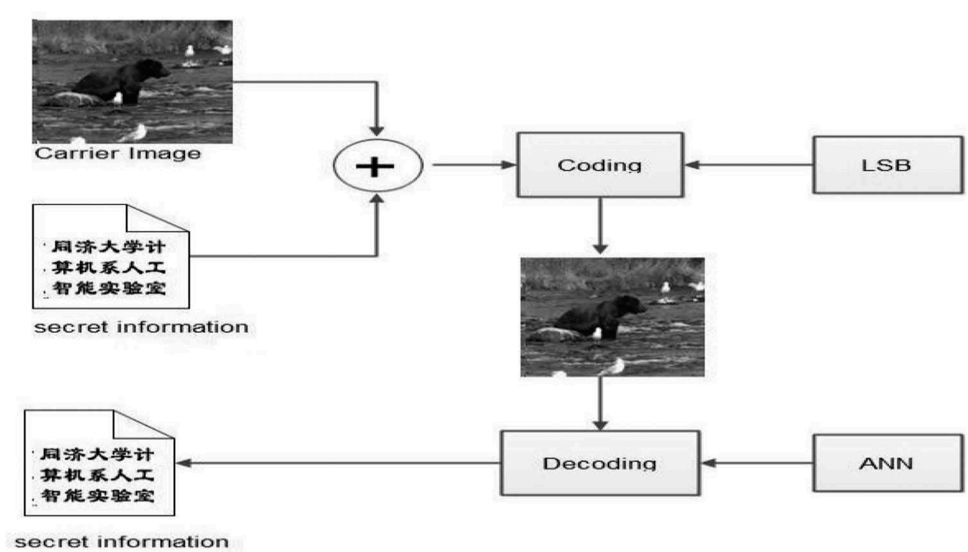

Figure 5. Proposed methodology with the insertion and extraction process of confidential information in the original image.

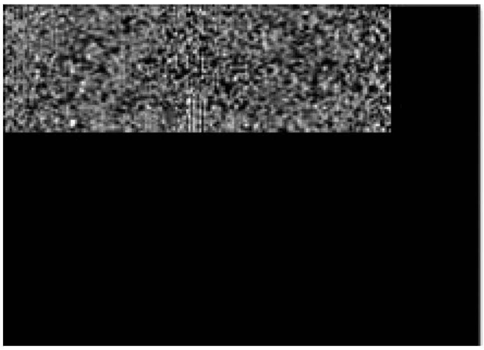

Figure 6. Coded secret information sample inserted into the LSB of the carrier.

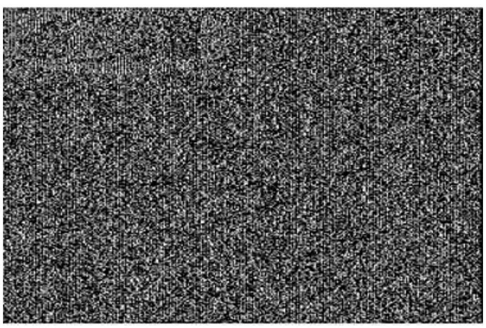

Figure 7. Carrier LSB zeros encoding.

Table 2. Presence key coding.

Edge Presence Key	Upper Left Border	Right Top Border	Bottom Left Border	Bottom Right Border
0	0	1	1	1
1	1	0	1	1
2	1	1	0	1
3	1	1	1	1

the information. This new ANN, whose objective is to extract the LSB of each pixel of the received image, presents the structure [8 2 1]. The training of this structure was carried out in a way Boolean output similar to ANN previous. For this ANN is given the name of the public key, because the LSB information is available to all and anyone else.

And, finally, an ANN called a private key is trained to carry out the reverse operation to that presented in the Table 1. The structure used was [3 3 1]. The private key besides ANN it consists of a search algorithm of the dimension's horizontal and vertical information S (x1, y1) so that it is not necessary to perform the search on every image E (x, y) as cited above.

In the possession of the dimensions of I (x1, y1) a loop is made with the objective of traversing the image E (x, y) to the limit of these dimensions and apply to each trio of pixels the private key and reconstruct the hidden image C (x, y) that was transported.

5. Results and discussions

5.1. Watermark embedded results

An example application to protect the image of Figure 8 which passes through an a priori coding who's the resulting image can be visualized in Figure 9, for the carrier image of Figure 10 is shown below.

Figure10 represents the carrier image while Figure11 refer to the carrier image embedded with

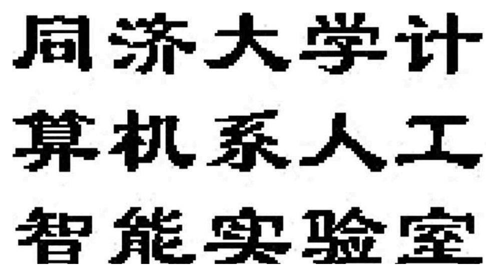

Figure 8. Information to be transmitted.

Figure 9. Secret information coded by using Table 1.

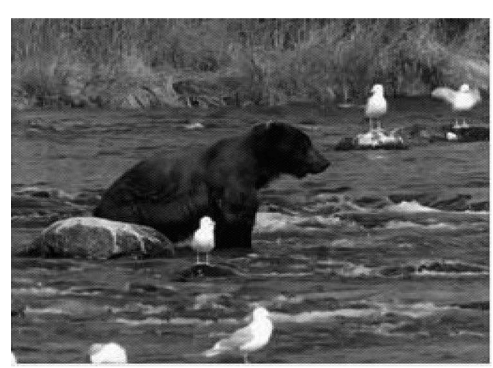

Figure 10. Carrier image.

Figure 11. Embedded image.

coded secret information by the LSB technique, respectively. This coding is somewhat indefinite and can be confused with possible noises that might come to be inserted into the carrier. This way it is impossible to detect the hidden image without resorting it. The presence of some nonrandom shape in the image, by checking patterns or histograms, it could the presence of a hidden image. But such information does not imply the probable extraction of this information hidden in the transmitted image.

5.2. Watermark extraction result

Figure 12 is substantially identical to Figure 8 showing small imperfections, the result of the dimensions of the information to be transported. Both samples require the same amount of disk space to be stored.

6. Conclusion

In this article, ANN-based watermarking process is carried out by using LSB method. ANN-based algorithms performed efficiently. Concerning the information to be transmitted is interesting to communicate those that are not well-defined as continuous traces, contours absence of details, since it makes the identification of standards, even using this work. The proposed method allows the use of infinite combination keys. By using Watermarking, it is possible to hide other types of files like sound and text, as the only consideration is that the binary data is entered correctly into the carrier LSB using the proposed approach. The proposed study concentrates on the insertion of watermarks and small hidden data in the image, not being performed studies for the inclusion of high-definition information or significant volume.

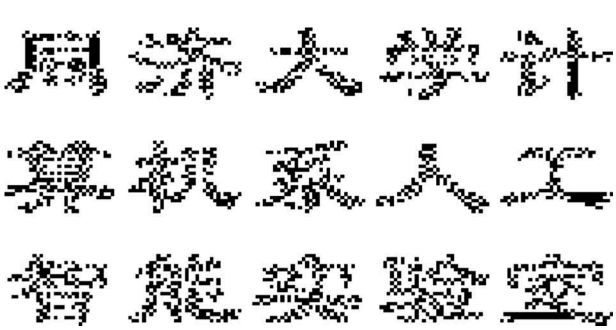

Figure 12. Secret information extracted using ANN

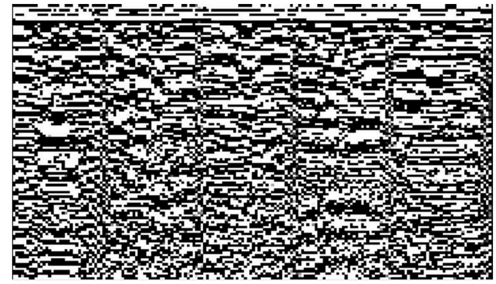

Figure 13. Extraction of the LSB of each pixel from the carrier image.

For future study,by utilizing different structures and compositions of ANNs, varying the number of hidden layers, activation functions, efficiency of watermark detection and extraction may vary.

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References

Barreto, P. S., Kim, H. Y., & Rijmen, V. (2002). Toward secure public-key blockwise fragile authentication watermarking. *IEE Proceedings-Vision. Image and Signal Processing.*, *149*, 57–62. doi:10.1049/ip-vis:20020168

Bender, W., Gruhl, D., Morimoto, N., & Lu, A. (1996). Techniques for data hiding. *IBM Systems Journal*, *35*, 313–336. doi:10.1147/sj.353.0313

Berg, G. Searching for hidden messages: Automatic detection of steganography. IAAI. 2003;.

Ge, S. Y., & Gao, R. (2007). Least significant bit steganography detection with machine learning techniques. Proceedings of the 2007 international workshop on Domain driven data mining, San Jose, California.

Goel, S., Rana, A., & Kaur, M. (2013). A review of comparison techniques of image steganography. *Global Journal of*

Computer Science and Technology 13, 4-F (2013), ISSN 0975-4172.

Golestani, H., & Bakhshi, M., . G. (2013). Minimisation of image watermarking side effects through subjective optimisation. *IET Image Processing*, *7*, 733–741. doi:10.1049/iet-ipr.2013.0086

Haykin, S. (2009). *neural networks and learning machines/ simon haykin*. New York, USA: Prentice Hall.

Islam, M., Ahsan, S., & Ullah, M. (2019). An imperceptible & robust digital image watermarking scheme based on DWT, entropy and neural network. *Karbala International Journal of Modern Science*, *5*(1), Article. doi:10.33640/2405-609X.1068.

Islam, M., Roy, A., Laskar, R. H., Thampi, S. M., El-Alfy, E. S. M., Mitra, S., & Trajkovic, L. (2018). Neural network based robust image watermarking technique in LWT domain. *Journal of Intelligent & Fuzzy Systems*, *34*, 1691–1700. doi:10.3233/JIFS-169462

Jain, N., Meshram, S., & Dubey, S. (2012). Image steganography using LSB and edge-detection technique. *International Journal of Soft Computing and Engineering*, *2* (3), 223.

Jin, C., & Wang, S. (2007). Applications of a neural network to estimate watermark embedding strength. Eighth International Workshop on Image Analysis for Multimedia Interactive Services, Santorini, Greece. (WIAMIS'07).

Khan, A., Tahir, S. F., Majid, A., & Choi, T.-S. (2008). Machine learning based adaptive watermark decoding in view of anticipated attack. *Pattern Recognition*, *41*, 2594–2610. doi:10.1016/j.patcog.2008.01.007

Lee, G. J., Yoon, E. J., & Yoo, K. Y. (2008). A new LSB based digital watermarking scheme with random mapping function. International Symposium on Ubiquitous Multimedia Computing, Washington, DC, USA.

Luo, H. S. C., Chu, Z. M., & Lu, Z.-M. (2008). Self embedding watermarking using halftoning technique. *Circuits, Systems & Signal Processing*, *27*, 155–170. doi:10.1007/s00034-008-9024-0

Majumder, S. (2010). SVD and neural network based watermarking scheme. In: International Conference on Business Administration and Information Processing. Poznań, Poland: Springer.

Mei, S.-C. (2002). Decision of image watermarking strength based on artificial neural- net- works. Proceedings of the 9th International Conference on Neural Information Pro- cessing, Singapore. 5:2

Mohan, C., & Kumar, B., . S. S. (2009). Robust multiple image watermarking scheme using discrete cosine transform with multiple descriptions. *International Journal of Computer Theory and Engineering*, *1*, 1793–8201.

Najafi, H. L. (2010). A neural network approach to digital data hiding based on the perceptual masking model of the human vision system. *International Journal of Intelligent Comput- Ing and Cybernetics*, *3*, 391–409. doi:10.1108/17563781011066693

Naoe, K., Sasaki, H., & Takefuji, Y. (2011). Information hiding by machine learning: A method of key generation for information extracting using neural network. *International Journal of Organizational and Collective Intelligence (IJOCI)*, *2*(1), 21–48. doi:10.4018/IJOCI

Parthasarathy, A., & Kumar, S., . K. (2007). An improved method of content based image water- marking. *IEEE Transactions on Broadcasting*, *53*, 468–479. doi:10.1109/TBC.2007.894947

Paul, R. T. (2011). Review of robust video watermarking techniques. *IJCA Special Issue on Com- Putational Science*, *3*, 90–95.

Schyndel, V., Andrew, R. G., & Tirkel, Z. (1994). A digital watermark. Proceedings of 1st Inter- national Conference on Image Processing, Austin, TX, USA. 2.

Servetto, S. D., Podilchuk, C. I., & Ramchandran, K. (1998). Capacity issues in digital image watermark- ing. Proceedings 1998 International Conference on Image Processing ICIP98 (Cat No 98CB36269), Chicago, IL, USA, USA. 1.

Sukang, M., & Xiaomei, L., . T. (2009). A digital watermarking algorithm based on DCT and DWT. The 2009 International Symposium on Web Information Systems and Applications, Lisbon, Portugal.

Wong, P. H. W., & Au, O. C. (2003). A capacity estimation technique for JPEG-to-JPEG image watermarking. *IEEE Transactions on Circuits and Systems for Video Technology*, *13*, 746–752. doi: 10.1109/TCSVT.2003.815949

Wu, M., & Liu, B. (2003). Data hiding in image and video. I. Fundamental issues and solutions. *IEEE Transactions on Image Processing.*, *12*, 685–695. doi:10.1109/TIP.2003.810588

Yang, Q. T., Gao, T. G., & Fan, L. (2011). Lossless robust data hiding scheme based on histogram shifting. In *Electronics and Signal Processing.* Lecture Notes in Electrical Engineering, vol 97.(pp. 937–944). Berlin, Heidelberg: Springer.

Yang, W. C., Wen, C. Y., & Chen, C. H. (2008). Applying public-key watermarking techniques in forensic imaging to preserve the authenticity of the evidence. In: International Conference on Intelligence and Security Informatics. Taipei, Taiwan: Springer.

Zhang, F., & Zhang, H. (2005). Applications of a neural network to watermarking capacity of digital image. *Neurocomputing*, *67*, 345–349. doi:10.1016/j.neucom.2004.12.007

Zhang, X., Xiao, Y., & Zhao, Z. (2015). Self-embedding fragile watermarking based on DCT and fast fractal coding. *Multimedia Tools and Applications*, *74*, 5767–5786. doi:10.1007/s11042-014-1882-9