Contourlet transform and adaptive neuro-fuzzy strategy–based color image watermarking

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Abstract
In the today Internet era, protection of digital content during transmission is an indigent. Alphanumeric watermarking is a resolution to the copyright defense than the endorsement of information into the system. In exhibit watermarking calculation, wellbeing of such watermarking process is moderately low. For expanding the soundness, an approach is presented, which is contourlet change with neuro-fuzzy-based watermark inserting process. The conventional approaches having loss during data recovery, this situation will be resolved using proposed watermarking scheme and also increase the security of watermarked image. The proposed color image watermarking scheme binary image is embedded over the shading image which utilizes contourlet and converse contourlet calculation for preprocessing of an image and neuro-fuzzy calculation to implant the bits in the green plane of an image. After completing the watermarking process, the results are analyzing using the quality assessment metrics like Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE) etc., It is implemented using MATLAB R2013 software. The developed MATLAB code is converted into Hardware Description Language (HDL) and then implemented for Virtex-5 L110T Field Programmable Gate Array (FPGA) kit.

Keywords
Contourlet, encryption, neuro-fuzzy, robustness

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Introduction
The digital devices and Internet have hugely changed daily lives and our society by making the capture, storage and transmission of digital data extraordinarily convenient and comfortable. It creates a big problem of how to protect data and to avoid unauthorized use.¹ The digital watermarking is a process of data smacking. Data smacking resources statement of data by smacking and recovering after some arithmetical information. The alphanumeric data may be an appearance-based image, an acoustic noise, an audiovisual or just a first script folder. Nowadays, the digital watermarking involves in different fields, such as signal processing, image processing, video processing, cryptography, network technology and additional methods.

Computerized watermarking covers the copyright data into the advanced information through some calculation. The secret data are inserted with some content, creator’s serial number, organization logo and pictures with some different significance. This best mystery data are implanted into the computerized information to guarantee the security, information verification and copyright insurance. The watermark is covered up in the advanced learning either unmistakably or imperceptibly.

The viability of computerized watermarking calculations depends on the heartiness and indistinctness of the implanted watermark against different sorts of assaults. The quality of watermarking is, for the most part, used to sign copyright data of the digital works, and the watermark is not decimated after some assault and still is seen to give accreditation.

The product is utilized to embed data into a picture which is not noticeable. It will not keep the robbery of images along these lines. However, it demonstrates that the picture stolen is unapproved, which is nearly as high. The consequences of the proposed calculation have decent intangibility, high security and power for a

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considerable measure of shrouded assaults. Whatever it might be, the impediment of limit has driven us around an enhanced approach which can be accomplished through equipment execution frameworks with the assistance of a field-programmable gate array (FPGA) board.1–6

Literature survey

Different digital watermarking techniques are available in literature. Abdulmawla Najih et al.7,14 have proposed discrete contourlet transform combined with quantization modulation index–based digital image watermarking which produces high peak signal-to-noise ratio (PSNR) and high imperceptibility of the watermarked image. Karthigaikumar et al.3,15,20 have proposed FPGA execution of discrete wavelet transformation which establishes the same appearance watermarking process for low power and faster applications. Then, the design is applied and computer generated using MATLAB and executed in Virtex-6 FPGA kit.18,19,21 The proposed design was consuming only 1.1% of the available device. Mohammad Ali Akhaee et al.8 have proposed optimal indicator-based contourlet image embedding in a loud surrounding which produces both better continuous imperceptibility and robustness of various common attacks. Jagadeesh and Praveen Kumar9,16,17 have proposed an effective alphanumeric image embedding method using neuro-fuzzy network established; the watermark moments are surrounded and addicted to the middle incidence group of discrete cosine transform (DCT) constants, which yields a better PSNR significance. Manas Ranjan Nayak et al.10 have proposed the design of an embedding procedure using period congruency and singular value decomposition (SVD) system; this architecture was designed using Virtex-7 technology. The proposed method was consuming 26% of the available device, and the self-motivated control feasting is 5.029 mW and deferral subsequently regulator is 1.539 ns only.

Contourlet transform

Contourlet transform filter bank structure is shown in Figure 1. It contains two filter banks to get the smooth contours of images.7 The filter banks Laplacian pyramid (LP) is recycled toward internment argument opportunities and directional filter bank (DFB) is recycled to custom individual fact breaks interested in undeviating constructions.

The filter using the LP breakdown of image is dependent on one particular band of the image that can avoid frequency scrambling. The DFB is adequate for great frequency mean, while the situation will release low-frequency segments in the image on that one moving sub-band. The motivation to consolidate DFB with LP is based on the various breakdowns and evacuates the low frequency of image component. The combination of DFB and LP is named to provide a new discrete contourlet model named as pyramid directional filter bank (PDFB).

Neuro-fuzzy system

Neuro-fuzzy algorithms are a more powerful adaptive method to solve complex and optimization problems. It is one of the creative techniques for optimization problems. Neuro-fuzzy algorithms are more robust and better than conventional algorithms.23 Two types of neuro-fuzzy systems are available to design a system, that is, fuzzy interference schemes intended for implementing neural networks and artificial machine learning for broad systems. From the suggested sequence, the possibility of obtaining analysis data is equivalent to the first programmed information additions, and for the test inputs like the adjusted yields to be acquired, same as the first yields utilized at the embedding process by using the fuzzy-neuro model, the reenactment time of the test data sources can be reduced. Figure 2 shows the fuzzy systems for designing neural networks.24

Back propagation neural network

The proposed back propagation neural network (BPNN) consists of three layers, namely, response layer, yield layer and concealed layer with identity learning. In this work, character establishment has universal compatibility with a standard graphical scheme using back circulated network.11,12 The preferred yields
of the proposed network are mainly based on the contourlet subband constants. The primary input level will provide various inputs to the proposed BPNN for embedding watermark image. Then, the weight function is adjusted to the particular limit value of closed-loop BPNN output besides the effective rules. Finally, the provided inputs and required output functions are triggered to stimulate the deep layer called hidden layer as depicted in Figure 3.

Among adapting, confusion data are offered back to the system and used to refresh the connection weights. It is reiterating the learning ordinarily for each case in the training set until the point that it limits the yield errors. However, it is expected to produce better outcomes with the help trained back propagation neural network at most incredible execution.

Proposed color image watermarking algorithm

There are three steps involved in the proposed watermarking algorithm, namely, embedding procedure in the watermarked image, decaying process of the image and extraction of the watermarked image. During the embedding procedure, binary cover image will be used in watermarking; similarly, BPNN trained features are used in watermark image extraction.

Embedding process of watermarking

The embedding process consists of the following steps: contourlet decomposition, non-overlapping group separation, contourlet embedding process of the watermark, contourlet restoration and testing the quality of image.13 The following Figure 4 shows the embedding procedure during watermarking.

**Steps involved for embedding algorithm**

Step 1: Initially, select the color cover image with pixel sizes of 512 × 512.

Figure 3. Structure of back propagation neural network.

Figure 4. Watermark embedding process.

Step 2: Choose the grayscale watermark image with pixel sizes of 64 × 64 and alter the binary format of the watermarked image.

Step 3: Extract G-plane of an original image is taken from RGB and subdivided into 8 × 8 non-overlapping blocks. Three levels of contourlet transform are performed in each subblock of the original image.

Step 4: The three-level contourlet subband 16 × 16 pixel group coefficient values (CLLH3, CLHH3 and CLHL3) with pixel sizes of 64 × 64 are separated as non-overlapping minor groups with pixel sizes of 4 × 4.

Step 5: Calculate hue saturation and value (HSV) parameters like luminosity, brightness, texture, edge and frequency sensitivity for each subimage.

Step 6: Determine feedback fuzzy interference values designed for the brightness and saturated values.

Step 7: BPNN trained to estimate the texture and frequency sensitivity values to evaluate the fuzzy interference system output.

Step 8: Watermark blocks are embedded into contourlet coefficient blocks by using this formula

\[ W(x, y) = I(x, y) + \delta(e - 1) \]  

where \( W(x, y) = \) watermarked image coefficients, \( I(x, y) = \) original image coefficient of selected blocks, \( e = \) embedding bit and \( \delta = \) embedding coefficient strength.

Step 9: Find watermarked image using inverse contourlet transform.

The extraction process of watermarking

The input color cover image is managed and converted into the grayscale image during the embedding process.
Contourlet transformation is applied to split subbands (CLLH3, CLHH3 and CLHL3) in the watermarked image. Then, the probability function of contourlet constants with corresponding pixel sizes of watermarked images was trained using BPNN. In the extraction process, watermarked images were established from trained BPNN network using inverse contourlet coefficient function. Finally, the extracted watermarked image can be evaluated as follows,

\[
\text{If } C \cdot O(i) > 0 \\
\quad e(i) = 1 \\
\text{else} \\
\quad e(i) = 0 \\
\]

\( C \) = Constant value of contourlet transformation  
\( O(i) \) = Output bit of BPNN  
\( e(i) \) = Embedding bit for watermarking

The flowchart for the extraction process of watermarking is depicted in Figure 5.

**Experimental results and discussion**

**The proposed method for grayscale image**

Grayscale image of size 512 × 512 is hidden in another image of size 512 × 512. Contourlet transform is applied to both cover image and the image to be hidden. Contourlet transform performs well in point singularities, and also it is applicable only for fixed area windows. For hiding an image in the cover image, neuro-fuzzy algorithm is used. Let A and B be two samples of an image taken for watermarking.

**Encryption and decryption**

In the first sample A of watermarking in Figure 6, Barbara image is taken as the cover image and the vegetable image is hidden over it (Figure 8).

In the second sample B of watermarking in Figure 9, Barbara image is taken as the cover image and trapezium star cluster image is hidden over it.

**The proposed method for color image**

Color image of size 512 × 512 is hidden in another image of grayscale size 512 × 512. Contourlet transform is applied to both the cover image and the image to be hidden. For hiding an image in the cover image, neuro-fuzzy algorithm is used.

**Encryption and decryption**

In this process, the cover image of the color image acts as a base image through which a grayscale image is hidden over it. In the first sample A of watermarking in Figure 7, Lena image is taken as the cover image and Niagara Falls image is hidden over it.

Table 1 indicates the performance analysis and evaluation of conventional system with the suggested color image watermarking system concerning PSNR and mean square error (MSE) values of different samples of an image taken for analysis.

**Synthesis results**

The script-level code is developed by using MATLAB R2013. MATLAB code is converted into hardware description language (HDL) code by using inbuilt HDL converter function available in MATLAB. The synthesis report contains a device’s utilization summary as estimated during the synthesis of FPGA. Figures 10 and 11 show the Virtex-5 FPGA kit interfaced with the laptop and the schematic diagram of invisible watermarking.

The overall summary report for the proposed color image watermarking design structure using Virtex-5 device target is tabulated in Table 2.

**Results and discussion**

The performance metrics of proposed neuro-fuzzy-based color image watermarking is analyzed and evaluated under various factors. The design of lookup tables using to reduce the area leads to reduced power consumption with less time delay, and it is the critical factor for the proposed design. The conventional watermarking algorithms in previous studies are compared with proposed neuro-fuzzy-based color image watermarking schemes concerning power constraints, area requirements, delay metrics and functional rate. The proposed neuro-fuzzy-based color image watermarking schemes contribute to the extreme frequency of 346.256 MHz with 1% area deployment as listed in Table 3.
Figure 6. Proposed results for grayscale Barbara image. (a) Cover image. (b) Hidden image. (c) Watermarked image (PSNR = 37.36, MSE = 0.154). (d) Decrypted cover image. (e) Decrypted hidden image.

Figure 7. Proposed results for grayscale baboon image. (a) Cover image. (b) Hidden image. (c) Watermarked image (PSNR = 34.88, MSE = 0.006). (d) Decrypted cover image. (e) Decrypted hidden image.
Conclusion

The proposed neuro-fuzzy-based color image watermarking schemes dealt with operational improvement and color image watermarking along with high safety. This work provides validation by using contourlet wavelet transformation–based subband coefficient constants in color image watermarking and permits undisclosed communication with high security. For exchanging classified image, a substance scrambles the first uncompressed color image. At that point, image hider utilizes neuro-fuzzy calculation for concealing the secret picture. The bits are inserted in center recurrence coefficients and high recurrence coefficients. It provides better PSNR and MSE values than conventional methods. The watermarked image will be

Table 1. Performance analysis and evaluation of conventional system with the suggested color image watermarking using the neuro-fuzzy system for various image sets.

| S.no. | Type of image                                      | Conventional for grayscale | Proposed for grayscale | Proposed for color image |
|-------|----------------------------------------------------|----------------------------|------------------------|-------------------------|
|       | PSNR      | MSE   | PSNR      | MSE   | PSNR   | MSE   |
| 1     | Lena image | 39.65 | 0.037 | 36.70 | 0.024 | 45.06 | 0.024 |
| 2     | Airplane image | 44.51 | 0.013 | 35.53 | 0.010 | 45.43 | 0.010 |
| 3     | Baboon image | 40.26 | 0.013 | 34.88 | 0.006 | 44.33 | 0.006 |
| 4     | Satellite image of the Salina Porto Ingles | 47.01 | 0.959 | 43.48 | 0.905 | 48.37 | 0.905 |
| 5     | VLSI die layout image | 51.25 | 0.75  | 52.74 | 0.640 | 53.49 | 0.640 |
| 6     | Niagara Falls image | 43.41 | 0.152 | 36.37 | 0.134 | 45.30 | 0.134 |
| 7     | Satellite image of Papua forest destruction | 37.95 | 0.423 | 40.24 | 0.380 | 42.57 | 0.379 |
| 8     | Trapezium star cluster image in the Orion Nebula infrared camera | 40.25 | 0.233 | 40.51 | 0.113 | 42.31 | 0.113 |
| 9     | Barbara | 44.41 | 0.162 | 37.36 | 0.154 | 46.76 | 0.134 |

PSNR: peak signal-to-noise ratio; MSE: mean square error; VLSI: very-large-scale integration.

Figure 8. Proposed results for Lena image. (a) Cover image. (b) Hidden image. (c) Watermarked image (PSNR = 45.06, MSE = 0.02). (d) Decrypted cover image. (e) Decrypted hidden image.
actualized in FPGA to calculate speed and memory requirements, and in future, reach out to apply this idea from image to video.

Table 2. Overall summary report for LUTS used.

| The quantity of slice registers | 4010/393600 (1%) |
| The quantity of lookup tables | 3922/196800 (1%) |
| Time delay (minimum) | 2.505 ns |
| Concentrated occurrence | 346.256 MHZ |
| Response appearance period before clock (minimum) | 0.347 ns |
| Yield period (maximum) | 4.147 ns |

Table 3. Performance comparison of proposed neuro-fuzzy-based color image watermarking schemes with conventional schemes concerning area, time delay and operation frequency.

| Authors | Virtex-5 L110T |
|---------|----------------|
|         | Slice/available | Time (ns) | Frequency (MHz) |
| Proposed work | 4010/393600 (1%) | 2.505 | 346.256 |
| Karthigaikumar et al. | 4708/393600 (1.1%) | 2.9 | 344.34 |
| Baskaran and Karthigaikumar | 457/NA | NA | NA |
| Mohamed Zuhair and Mohamed Yousef | 122/NA | NA | NA |
| Kaur and Mehra | 1112/NA | NA | NA |
| Mohamed Zuhair and Mohamed Yousef | 278/1200 | 6.991 | 143.04 |

Figure 9. Proposed results for Barbara image. (a) Cover image. (b) Hidden image. (c) Watermarked image (PSNR = 46.76, MSE = 0.134). (d) Decrypted cover image. (e) Decrypted hidden image.

Figure 10. Virtex-5 FPGA kit interfaced with laptop.
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