Watermarking Scheme for using YCbCr Based On 2-Level DWT

Myasar Mundher Adnan¹, Hamza A. Mashagba²,³, Raed Alfihi¹, Karrar Aljawaheri¹, Alaa Jaafarz¹, Dalal Abdulmoohsin Hammood⁴, Ahmed Alkhayyat¹, and Hasliza A Rahman²,³

¹ Department of Computer Technical Engineering, College of Technical Engineering, the Islamic University, 54001 Najaf, Iraq
² Advanced Communication Engineering, Centre of Excellence (ACE), Universiti Malaysia Perlis (UniMAP), 01000 Kangar, Perlis, Malaysia
³ Faculty of Electronic Engineering Technology, Universiti Malaysia Perlis (UniMAP), 02600 Arau, Perlis, Malaysia
⁴ Electrical Engineering technical college/ Middle Technical University (MTU) Al Doura 10022, Baghdad, Iraq

Email : haslizarahim@unimap.edu.my

Abstract. Multimedia data for both personal and commercial purposes is now accessible to everyone due to the rapid development of the Internet. Consequently, the issue of copyright protection has surfaced and has triggered the development of several techniques for multimedia copyright protection. Such techniques include digital watermarking in which the important information contained in the host media is concealed by embedment in carriers such as images, videos, or audios. In this paper, the adaptive color image watermarking technique is proposed for the satisfaction of both imperceptibility and robustness demands. There are two main stages involved in this technique – coding/embedding and decoding/extraction. Prior to the coding stage, imperceptibility and robustness are preserved by first converting the host image from RGB to YCbCr color space before selecting the Cb component to apply the DWT embedding technique. Once more, the selected quadrant of the hosted image is decomposed using DWT before extracting the watermarked image. The robustness and efficiency of this technique were proved by exposing the watermarked image to six types of attacks, namely Median filter, Gaussian noise, Sharpening filter, Salt & Pepper Noise, JPEG Compression, and Rotation. The results of the study were benchmarked against other methods that deploy DST on the same images. From the benchmarking process, the proposed algorithm was found to withstand the six types of attacks earlier mentioned and achieved a better performance compared to the DST approach. The quality of the watermarked image was also preserved in the proposed method.

1. Introduction

Over the last few years, multimedia communication has become a major tool for information transfer due to the evolution of communication technologies that moves forward towards embedded computing [1][2]. However, this has resulted in copyright protection issues due to the easy access to multimedia data and its content by everyone [1]. Consequently, several novel protection mechanisms such as
watermarking and steganography techniques have been developed to solve this problem. Steganographic techniques involve the hiding of information in a carrier such that its presence cannot be visually perceived. Watermarking, on the other hand, is a technique where the information is concealed in a carrier such as an image, video, or audio in a manner that cannot be visually or audibly detected. It confers protection and robustness to different forms of attacks, including those that involve image operations (such as rotation, Salt & Pepper Noise, cropping, filtering, Gaussian noise, and JPEG Compression) [3][4]. In the case of multimedia watermarking, it is a form of digital watermarking in which another information is embedded into the watermark. The two main stages of watermarking techniques are embedding and extraction [5]. The embedding stage involves passing the host multimedia through several encryption frameworks based on the type of application or domain. For the extraction stage, the hidden data is retrieved upon fulfilling the copy protection requirements. Figure 1 depicts the whole process in a watermarking system.

2. Research Methodology
The method employed in this paper involves the conversion of the RGB color image to the YCbCr color space before converting it into four sub-bands using DWT technique to ensure its imperceptibility and robustness after watermarking. The two important stages in this process are the embedding and extraction stages, both involving several steps that will be explained later. During the embedding process, the cover image is first converted to the YCbCr color space before getting the four sub-bands using DWT techniques. Next is to choose the best band on which the watermark image will be embedded [6]. The next stage involves the use of an extraction method to extract the hidden image. An important step to note in this process is to ensure how to embed the watermarked image within the cover image to guarantee its robustness, capacity, and imperceptibility. Being that the major concern is copyright protection, watermarking is an important method of achieving this feat. Another important thing to consider is to ensure the quality of the watermarking in terms of imperceptibility (can be achieved by controlling the size of the secret image [7-10]). This involves the conversion of the watermarked image from (0-255) level to (0-15) level, then, changing to 1-D array. The aim of the extraction process is to restore the integrity of the original image without compromising its quality and ensuring no observable differences between the watermarked and the cover images. Lastly, the result of this scheme is checked for high robustness by benchmarking against the Salentlet transform[11-16].

3. EMBEDDING STAGE

The processes involved in the proposed watermarking method in this study are shown in Figure 2. These processes were adopted to ensure that the main goals of watermarking (imperceptibility, capacity, and robustness) are considered during the embedding process.
3.1. Image Re-Quantization

The size of the embedded data is very important in information hiding as it is one of the factors that influence the hiding capacity and PSNR ratio. The efficiency of any hiding technique can be increased by reducing the size of the hidden data [8]. Images can be transformed from 256 level into different levels using image requantization which involves compressing an image in the subsequent stage. The requantization process can be represented by the equation below [9]:

\[ I_{\text{new}} = \frac{I_{\text{old}} - \text{Min}}{\text{Max} - \text{Min}} \times \text{Range}_{\text{new}} + \text{Start} \]  

(1)

where:  
\( I_{\text{new}} \) = obtained value after image stretching.  
\( I_{\text{old}} \) = original image size prior to stretching.  
\( \text{Range}_{\text{new}} \) = targeted value to convert the image value to.  
\( \text{Max} \) and \( \text{Min} \) = maximum and minimum pixel values prior to stretching

Majorly, image stretching is employed when there is a need to convert values from one range to the other. The values in this work were converted from (0-255) range to (0-15) range as discussed in the next subsection. Only 4 representation bits are required for values of this range, as depicted in Figure 3 which depicted the conversion of a Lena image into 2 ranges.

![Fig. 3. Lena image requantization in the a) 0-255 and b) 0-15 ranges.](image-url)
3.2. Image compression
From the previous phase, the values of the image pixel have been converted into a new range. Therefore, these converted values require only 4 bits from each byte to be represented, meaning that in each image byte, 50% of the byte will be empty. Hence, getting 50% of the size of a same requires combining each byte into a 1-D array.

3.3. RGB conversion into YCbCr
Owing to the higher imperceptibility of the YCbCr color space compared to the RGB color space [10], the YCbCr color space is mainly used by researchers. In this color space, Y represents the components’ luminance while the blue and red chrominance components are represented by CbCr. For the RGB color space, R, G, and B represents the red, green, and blue channels, respectively. The process of RGB color space transformation into the YCbCr spectrum is shown in Equation 3.2 [11][17].

\[
\begin{bmatrix}
Y \\
Cb \\
Cr
\end{bmatrix} = \begin{bmatrix}
16 & -37.0797 & 112 \\
128 & -74.2093 & 112 \\
128 & 93.786 & -18.214
\end{bmatrix} \begin{bmatrix}
R \\
G \\
B
\end{bmatrix}
\]

The YCbCr mainly differ from the RGB color space by representing bright colors with 2 or more color signals while RGB represents colors as R, G, or B.

3.4. DWT for the Cover Image
The DWT is a method for hierarchical decomposition of an image [12]. It is based on wavelets (small waves) which differ in frequency and have a limited lifespan. Signals are split during DWT processes into high and low-frequency regions; the high-frequency regions are mainly used for watermarking processes due to the lower sensitivity of the human eye to changes in edges [13][18].

having read the watermarked image and having converted the level to (0-15), the DWT algorithm is used to partition the cover image into 4 sub-bands (LL, HL, LH, and HH) and the best bands are subsequently selected for watermarked image embedment.

3.5. Watermarked Image embedment in the Cover Image
The embedding process involves hiding a secret or private image in a carrier without significantly altering the quality of the carrier. The embedding process is represented in Equation 3, where WI represent the watermarked image, H represents the carrier image, and b represents a suitable scaling factor (0.005), and W is the watermarked image (binary) [14,15,19].

\[
WI = H + b \cdot W
\]

A. Wavelet Reconstruction (IDWT)
An inverse DWT (IDWT) is applied to revert the image to its spatial domain in a process that will produce one watermarked quadrant.

B. Reconstruction YCbCr
The quadrants are finally recombined to get the watermarked image in the YCbCr color space as illustrated in Figure 4.
4. EXTRACTION STAGE
In this stage, the watermarked image of the cover image is separated without significantly altering the quality of the watermarked and cover images. Figure 5 depicts the watermarked image extraction process from the cover image.

Later, the cover image will be converted from the RGB color to YCbCr as earlier described to extract the Cb. Then, DWT will be applied to extract the pieces of the watermarked image (as discussed later). After splitting the image into 4 bands, the HH sub-band is then selected to retrieve the watermarked image [16] using the formula below, where WI represent the watermarked image, H represents the value of the host image, b represents a suitable scaling factor (0.005), and W is the watermarked image (binary)

$$W = \frac{(W_I - H)}{b}$$

5. Robustness Measure
Equation 5 can be used to determine the similarity between the original image and the extracted watermarked image.
where $W_{x y}$ and $W'_{x y}$ represents the value of the pixel at position $(i, j)$ of the original image and the extracted watermarked image, respectively, such that $1 \leq (x, y) \leq 32$.

6. Measure of Imperceptibility

The peak-to-signal-noise ratio (PSNR) measures the variations in the original and watermarked image qualities; higher PSNR values indicate higher image quality. The PSNR can be calculated as follows [15].

$$\text{PSNR} = 10 \times \log_{10}\left(\frac{\text{MAX}^2}{\text{MSE}}\right)$$

Where $m$ is the watermarked image size and $n$ is the host image size, $I(i, j)$ is the host image pixel value, $K(i, j)$ is the pixel value of the watermarked image, MSE represents the mean square error for $(I, K)$.

7. Attacks

The results after applying various attacks on Lena and Baboon images are presented in this section. Some of the applied attacks include Sharpening, JPEG compression, Median filter, Gaussian noise, Salt & Peppers, and Rotation.

7.1. Gaussian Noise Attack (GNA)

This is one of the commonly used statistical attacks deployed in watermarking processes. Its probability density function is proportional to that of the normal distribution. Gaussian noise is the most commonly used attack in applications, where it serves as an additive white noise to produce additive white Gaussian noise.

7.2. Salt & Peppers Attack (S&PA)

This attack involves the deposition of black and white pixels on an image at different density ratios (0.01, 0.02, and 0.03 %). It is clearly observed on the affected image as a small randomly spread noise.

8. Performance Testing and Evaluation

The results of the proposed method are evaluated in this section based on 2 criteria (PSNR and NCC). First, the watermarked image will be tested based on the results of the embedding process of the watermark image in Y, Cb, and Cr components depending on the PSNR. The watermarked image after applying the proposed method is shown in Figure 6 while Figure 7 presented the extracted watermarked image after exposure to two attacks (Gaussian Noise and Salt & Pepper). Tables 1 and 2 presented the results of the watermarked image (with respect to the NCC and PSNR) after the blue colors have been selected and the proposed embedding technique applied on each of the LL2, LL3, and LL4.

![Fig 6. The watermarked image before and after attacks.](image)


**TABLE I**
The watermarked images' PNSR after selecting the blue (B) colors

| Channel | The selected band | Image after watermarking | PSNR (dB) |
|---------|-------------------|--------------------------|-----------|
| B       | LL2               | Y                        | 50.080    |
| B       | LL2               | Cb                       | 45.020    |
| B       | LL2               | Cr                       | 44.180    |
| B       | LL3               | Y                        | 51.550    |
| B       | LL3               | Cb                       | 50.560    |
| B       | LL3               | Cr                       | 51.780    |
| B       | LL4               | Y                        | 50.780    |
| B       | LL4               | Cb                       | 55.510    |
| B       | LL4               | Cb                       | 49.230    |

---

![Extracted watermarked image after exposure to Salt & Pepper attack.](image)

**TABLE III**
The NCC values for the two attacks

| Method | NCC Values          | NCC Values          |
|--------|---------------------|---------------------|
| Ratio  | 0.010%              | 0.020%              |
| Measure| NCC                 | NCC                 |
| Loss   | 0.99620             | 0.99750             | 0.99690   | 0.99620 | 0.97210 | 0.95710 |

---

7
9. Results Discussion and Conclusion

Digital watermarking was developed to solve at least 3 existing multimedia communication problems, including protection of copyrights, establishing the integrity and authenticity of information, and tracing the unlawful distribution of patented contents. These are the major issues that emanate from wide data distribution over digital networks. Researches have proved that numerous types of attacks exist against watermarking techniques, and experiments have shown previous watermarking approaches to be prone to several types of malicious attacks. As such, the embedded watermarks in digital media must be extracted in order to identify the ownership. Furthermore, some attacks may be complicated for most watermarking methods to handle. Therefore, there is a need for a universal watermarking scheme which can withstand different types of attacks and, concurrently, meet the conventional and embedding capacity requirements.

This paper reported a new embedding method which is based on the conversion of RGB images into the YCbCr color space. Here, each color of an image is transformed into the Y, Cb, and Cr components, resulting in RedYCbCr, GreenYCbCr, and blueYCbCr. To extract the frequency components, a two-level DWT is applied after converting the image on each YCbCr color. For the embedding process, the BlueYCbCr component is the best component. The DWT process gives rise to four frequency sub-bands (LL, LH, HL, and HH). All the bands were selected in this paper to embed the watermarked image in order to test the strength of the proposed algorithm. The performance of the system was determined based on the PSNR and NCC values, where the blue channel of LL4 frequency achieved the best PSNR value of 59.78dB, while the NCC of the similarity between the original image and the watermarked image was 0.9969 %. The system achieved an NCC ratio of 0.03% after exposure to Gaussian attack and 0.03% after exposure to Salt & Pepper attack. The final performance of the proposed algorithm was benchmarked against that of Slant-let algorithm earlier reported in the literature [17][20][21][22][23][24][25][26]. Though there was some difference of about 0.82dB, this is still important when dealing with cryptographic techniques to ensure the accuracy, robustness, and reliability of the transmitted information. Thus, the proposed algorithm in this study is a better image embedding algorithm compared to the Slant-let transform.

10. References

[1] M. I. Ahmad, Z. Husin, R. B. Ahmad, H. A. Rahim, M. S. Abu Hassan and M. N. Md Isa, "FPGA based control IC for multilevel inverter," 2008 International Conference on Computer and Communication Engineering, Kuala Lumpur, 2008, pp. 319-322.
[2] Abdulmohsin Hammood D, Rahim HA, Alkhayyat A, Ahmad RB, “Body-to-Body Cooperation in Internet of Medical Things: Toward Energy Efficiency Improvement,” Future Internet. 2019; 11(11):239.
[3] Ahire, V. K. and Kshirsagar, V. (2011), “Robust Watermarking Scheme Based on Discrete Wavelet Transform (DWT) and Discrete Cosine Transform (DCT) for Copyright Protection of Digital Images,” IJCSNS International Journal of Computer Science and Network Security. 11 (8), 208-213.
[4] Jebur, R. S., Der, C. S., & Hammood, D. A. (2020, December), “A Review and Taxonomy of Image Denoising Techniques,” In 2020 6th International Conference on Interactive Digital Media (ICIDM) (pp. 1-6). IEEE.
[5] Al-Haj, A. (2007) , “Combined DWT-DCT Digital Image Watermarking,” Journal of Computer Science 3 (9), 740-746.
[6] Aliwa, M. B., Fahmy, M., Nasr, M. S., and 3 El-Aziz, M. H. (2010), “A New Novel Fidelity Digital Watermarking Based on Adaptively Pixel- Most-Significant- Bit-6 in Spatial Domain Gray Scale Images and Robust,” American Journal of Applied Sciences (7), 987-1022.
[7] Myasar, Dzulkifli, Amjad, Tanzila, and Firdous. (2014), “Improved watermarking scheme based on blue channel selection using discrete slant-let transform (DST),” Appl. Math.Inf.Sci.8, 2823 – 2830
[8] Hongqin, S. and Fangliang, L.V. (2010). A Blind Digital Watermark Technique for Color Image Based on Integer Wavelet Transform. ICBECS. Wuhan. P 1-4.
[9] Fridrich, M.G.J. (1999). Protection of Digital Image Using Self-Embedding. New Jersey Institute of Technology May.
[10] Khalili, M.(2011), A Novel Secure, Imperceptible and Robust CDMA Digital Image Watermarking in JPEG-YcrCb Channel using DWT2. Institute for Informatics and Automation Problems, National Academy of Science Yerevan, Armenia.
[11] Vetro, A. (2004). MPEG-21 digital item adaptation: enabling universal multimedia Access. IEEE Multimedia, 11(1). p. 84–87.
[12] Tao, H., Liu, J. and Tian, J. (2001), “Digital watermarking technique based on integer Harr transforms and visual properties,” SPIE Image Compression and Encryption Tech. 4551(1). p. 239–244.
[13] González, R. C., and Woods, R. E. (2008). Digital Image Processing. Prentice Hall.
[14] Chai, D. and Bouzerdoum, A. (2000), “A Bayesian Approach to Skin Classification in YCbCr Color Space,” IEEE. School of Engineering and Mathematics Edith Cowan University Perth, Australia.
[15] Hong, W. and Hang, M. (2006), “Robust Digital Watermarking Scheme for Copy Right Protection,” IEEE Trans. Signal Process, 12, 1-8.
[16] Kashyap, N. and Sinha, G. R. (2012), “Image Watermarking Using 3-Level Discrete Wavelet Transform (DWT),” IJ.Modern Education and Computer Science. (3), 50-56.
[17] Sulong, G. B., Hasan, H., Selamat, A., Ibrahim, M., and Saparudin(2012), “A New Color Image Watermarking Technique Using Hybrid Domain,” IJCSI International Journal of Computer Science Issues. 9(1), 109-114.
[18] Hajisami, A., Rahmati, A. and Zadeh, M. B. (2011), “Watermarking Based on Independent Component Analysis In Spatial Domain,” UKSim 13th International Conference on Modelling and Simulation, IEEE, 299-303.
[19] Sulong, G. B., Hasan, H., Selamat, A., Ibrahim, M., and Saparudin(2012), “A New Color Image Watermarking Technique Using Hybrid Domain,” IJCSI International Journal of Computer Science Issues. 9(1), 109-114.
[20] Basu, D., Sinharay, A. and Barat, S. (2010), “Bit Plane Index Based Fragile Watermarking Scheme for Authenticating Color Image,” ICIIC '10 Proceedings of the First International Conference on Integrated Intelligent Computing, 136-139.
[21] A. Alkhayyat, S. J. Fathil and S. B. Sadkhan, “Cooperative Communication based: Efficient Power Allocation for Wireless body Area Networks” In 2019 1st AL-Noor International Conference for Science and Technology (NICST) 2019, Oct 25, pp. 106-111, IEEE.
[22] A. Alkhayyat and M. S. Mahmoud, “Hybrid network coding and cooperative communication in WBAN,” In 2019 2nd International Conference on Engineering Technology and its Applications (ICICETA) 2019, Aug 27, pp. 79-82, IEEE.
[23] A. Alkhayyat, K. Al Attabi and Q. H. Abbasi, “Single Relay Selection in the Cognitive Cooperative Network: Toward Bandwidth Efficiency Improvement,” 2019 4th Scientific International Conference Najaf (SICN), Al-Najef, Iraq, 2019, pp. 222-226.
[24] A. Alkhayyat, S. B. Sadkhan and Q. H. Abbasi, “Multiple Traffics Support in Wireless Body Area Network over Cognitive Cooperative Communication,” 2019 2nd International Conference on Electrical, Communication, Computer, Power and Control Engineering (ICECCPCE), Mosul, Iraq, 2019, pp. 199-203.
[25] H. R. Al-Mishmish, B. Preveze, A. Alkhayyat, “Improvement of Underlay Cooperative Cognitive Networks Bandwidth Efficiency under Interference and Power Constraints,” KSII Transactions on Internet and Information Systems (TIIS), vol. 13, No. 11, pp.5335-53, 2019.
[26] D. A. Hammood, H. A. Rahim, A. Alkhayyat, R. A. Badlishah, M. Abdulmalek, S. Y. Ali, I. S. Mahmoud, “An energy-efficient optimization based scheme for low power devices in wireless body
area networks,” Journal of Computational and Theoretical Nanoscience. 2019 Jul, vol. 16, No. 7, pp. 2934-40.