ROBUST COLOR IMAGE WATERMARKING USING DISCRETE WAVELET TRANSFORM, DISCRETE COSINE TRANSFORM AND CAT FACE TRANSFORM

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DEDICATION

To my dear parents who understand me and give me this opportunity for continuing my study.

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ABSTRACT

The primary concern in color image watermarking is to have an effective watermarking method that can be robust against common image processing attacks such as JPEG compression, rotation, sharpening, blurring, and salt and pepper attacks for copyright protection purposes. This research examined the existing color image watermarking methods to identify their strengths and weaknesses, and then proposed a new method and the best embedding place in the host image to enhance and overcome the existing gap in the color image watermarking methods. This research proposed a new robust color image watermarking method using Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT), and Cat Face Transform. In this method, both host and watermark images decomposed into three color channels: red, green, and blue. The second level DWT was applied to each color channel of the host image. DWT decomposed the image into four sub-band coefficients: Low-pass filter in the row, Low-pass filter in the column (LL) signifies approximation coefficient, High-pass filter in the row, Low-pass filter in the column (HL) signifies horizontal coefficient, Low-pass filter in the row, High-pass filter in the column (LH) signifies vertical coefficient, and High-pass filter in the row, High-pass filter in the column (HH) signifies diagonal coefficient. Then, HL_2 and LH_2 were chosen as the embedding places to improve the robustness and security, and they were divided into 4×4 non-overlapping blocks, then DCT was applied on each block. DCT turned a signal into the frequency domain, which is effective in image processing, specifically in JPEG compression due to good performance. On the other hand, the Cat Face Transform method with a private key was used to enhance the robustness of the proposed method by scrambling the watermark image before embedding. Finally, the second private key was used to embed the watermark in the host image. The results show enhanced robustness against common image processing attacks: JPEG compression (3.37%), applied 2% salt and pepper (0.4%), applied 10% salt and pepper (2%), applied 1.0 radius sharpening (0.01%), applied 1.0 radius blurring (8.1%), and can withstand rotation attack. In sum, the proposed color image watermarking method indicates better robustness against common image processing attacks compared to other reviewed methods.

ABSTRAK

Perhatian utama dalam penandaan gambar warna adalah mempunyai kaedah penandaan air yang berkesan yang kuat terhadap serangan pemprosesan gambar biasa seperti pemampatan JPEG, putaran, penajaman, pengaburan, dan serangan garam dan lada untuk tujuan perlindungan hak cipta. Penyelidikan ini mengkaji kaedah penandaan gambar warna yang ada untuk mengenal pasti kekuatan dan kelemahan mereka, dan kemudian mencadangkan kaedah baru dan tempat penyematan terbaik dalam gambar hos untuk meningkatkan dan mengatasi jurang yang ada dalam kaedah penandaan gambar warna. Penyelidikan ini mencadangkan kaedah penandaan air gambar warna yang baru menggunakan *Discrete Wavelet Transform* (DWT), *Discrete Cosine Transform* (DCT), dan Cat Face Transform. Dalam kaedah ini, gambar hos dan tanda air diuraikan menjadi tiga saluran warna: merah, hijau, dan biru. DWT tahap kedua diterapkan pada setiap saluran warna dari gambar hos. DWT menguraikan gambar menjadi empat pekali sub-band: Penapis lulus rendah di baris, penapis lorong rendah di lajur (LL) menandakan pekali penghampiran, penapis lulus tinggi di baris, penapis lorong rendah di lajur (HL) menandakan pekali mendatar, saringan lulus rendah di baris, saringan lulus tinggi di lajur (LH) menandakan pekali menegak, dan saringan lulus tinggi di baris, penapis lulus tinggi di lajur (HH) menandakan pekali pepenjuru. Kemudian, HL_2 dan LH_2 dipilih sebagai tempat penyisipan untuk meningkatkan ketahanan dan keselamatan, dan mereka dibahagikan kepada blok 4×4 yang tidak bertindih, kemudian DCT diterapkan pada setiap blok. DCT mengubah isyarat menjadi domain frekuensi, yang efektif dalam pemprosesan gambar, khususnya dalam pemampatan JPEG disebabkan oleh prestasi yang baik. Sebaliknya, kaedah *Cat Face Transform* dengan kunci peribadi digunakan untuk meningkatkan kekuatan kaedah yang dicadangkan dengan menggegarkan gambar tanda air sebelum menyisipkannya. Akhirnya, kunci peribadi kedua digunakan untuk menanam tanda air pada gambar hos. Hasilnya menunjukkan kekuatan yang lebih baik terhadap serangan pemprosesan gambar yang biasa: Mampatan JPEG (3.37%), menggunakan garam dan lada 2% (0.4%), aras 10% garam dan lada (2%), aras 1.0 pengasahan radius (0.01%), diterapkan 1.0 radius kabur (8.1%), dan berupaya menahan serangan putaran. Ringkasnya, kaedah penandaan gambar warna yang dicadangkan menunjukkan ketahanan yang lebih baik terhadap serangan pemprosesan gambar biasa berbanding kaedah tinjauan lain.

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LIST OF ABBREVIATIONS

RGB	-	Red, Green, Blue
HR	-	Host image Red color channel
HG	-	Host image Green color channel
HB	-	Host image Blue color channel
DWT	-	Discrete Wavelet Transform
IDWT	-	Inverse Discrete Wavelet Transform
RDWT	-	Redundant Discrete Wavelet Transform
DCT	-	Discrete Cosine Transform
IDCT	-	Inverse Discrete Cosine Transform
WR	-	Watermark image Red color channel
WG	-	Watermark image Green color channel
WdR	-	Watermarked image Red color channel
WdG	-	Watermarked image Green color channel
WdB	-	Watermarked image Blue color channel
EWR	-	Extracted Watermark image Red color channel
EWG	-	Extracted Watermark image Green color channel
EWB	-	Extracted Watermark image Blue color channel
FRT	-	Finite Ridgelet Transform
ABC		Artificial Bee Colony

LIST OF SYMBOLS

$\oplus$	-	Exclusive or - XOR
μ	-	Population Mean
σ	-	Standard Deviation

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CHAPTER 1

INTRODUCTION

1.1 Overview

Nowadays, by growing internet technology, the common popularity of the internet, and fast development of multimedia technology, sending and receiving digital data has been increased (Bajracharya and Koju, 2017; Su and Chen, 2017). Due to this, the main focus of researches' activities in the last two decades was on multimedia security, such as tamper detection, copyright protection, and authentication of digital data; furthermore, find methods to prevent the illegal sharing of digital data and tampering with it (Su *et al.*, 2017b). Many researchers have proposed many methods to improve digital data safety; for this reason, digital watermarking is considered a powerful method to overcome copyright protection problems, among other methods (Su and Chen, 2016).

Digital Watermarking is one method used to attain copyright protection and authentication of digital data (Bajracharya and Koju, 2017). It provides a promising way for protecting multimedia data from illegal manipulation and duplication since its main idea is to permit access to the host image by inserting a visible or an invisible watermark into it. The insertion of the watermark is based on the concept of the controlled confusion of the host image. According to their ability to resist attacks, there are two types of watermarking: robust and fragile. Depends on what sort of information is needed during the watermark extraction phase, the watermarking algorithm is either blind, semi-blind, or non-blind. In the blind watermarking algorithm, neither the original image nor the watermark is needed during the watermark detection and extraction process. The watermark bit sequence and secret key(s) are needed during the watermark detection and extraction process in the semi-blind watermarking algorithm. In the non-blind watermarking algorithm, either the host image or original watermark is required to extract the watermark. In other words, those who have a copy of the secret key(s) and the host image can only extract the watermark image. Moreover, either transform methods or spatial methods can be used for digital watermarking of images. Transform methods are complex but robust, whereas spatial methods are simples but not robust (Su *et al.*, 2016).

1.2 Problem Background

In the past few years, a high data growth rate has funded the new outlook of e-commerce like electronic marketing, publishing, transmission, and distribution of real-time multimedia data in the form of video, audio, image, and so on. Although there are numerous advantages for multimedia contents to be digitized compared to the analog equivalent, the service providers are too careful to offer the services in their digital structure because they freely copy and distribute copyright resources. Over the last decade, various methods proposed by researchers to protect multimedia data and digital watermarking methods are one of the best methods compared to other methods like steganography, encryption, cryptography, and others (Gupta *et al.*, 2015a).

On the other hand, unauthorized access becomes digital data vulnerability because digital data can be distributed everywhere by a widespread transmission medium. Thus, to protect digital data, intellectual property considers extra attention to them. One of the optimistic methods to protect digital data copyright is digital watermarking. The watermark in digital watermarking is an identification code that carries data about the work inventor, the ownership copyright, legal customer, and so on (Vaishnavi and Subashini, 2015). Watermarks are used to keep safe digital media from unauthorized use, piracy, and any other illegal actions. In the watermarking method, watermark data is embedded into the host signal by modifying its content (Laur *et al.*, 2015).

Moreover, the fast development of multimedia technology and the internet causes many digital data problems such as illegal modifying digital copyright, tampering, and copying. Therefore, many methods, such as digital watermarking, have been proposed to address these problems and maintain information safety. The effectiveness of a digital watermarking depends on the following characteristics (Su and Chen, 2018):

(1) **Imperceptibility:** The watermark needs to be invisible or inaudible in watermarked "image/video" or "digital music," respectively. Human perception must be maintained about the host object after extra data (watermark) has been embedded in it. Imperceptibility evaluation is usually based on a subjective test with specified procedures or an objective measure of quality called Peak Signal-to-Noise Ratio (PSNR) (Su and Chen, 2018).

(2) **Robustness:** Unauthorized distributors should not eliminate or remove the embedded watermark by using common image processing operations such as cropping, compression, quantization, and filtering (Su and Chen, 2018).

(3) **Security:** The watermarking procedure should depend on secret keys to ensure security so that attackers could not be able to remove or detect watermark by statistical analysis from a set of multimedia files or images. An unauthorized user who may even have prior knowledge of the exact watermarking algorithm cannot sense hidden data without having the secret keys used in the embedding procedure (Su and Chen, 2018).

(4) **Real-time processing:** The embedding procedure must be fast, and without having any delay, the watermark should be quickly embedded into the host object (Su and Chen, 2018).

Furthermore, these days with the rapid development of the internet and mobile devices, digital images can be easily captured and stored everywhere. Also, they can be shared on popular social media like Instagram, Twitter, Facebook, and so on (Huynh-The *et al.*, 2018). Wireless communication channels are generally used to directly upload these images to the internet without any primary protection schemes (Yu *et al.*, 2017). This causes numerous urgent issues relating to copyright protection and authentication in transmission, storage, and image usage. For instance, a personal image that has been shared on social media can be illegally accessed, downloaded, modified, and reused by others for some intentions like commercial or other purposes (Huynh-The *et al.*, 2018).

To summarize, most of the researchers work on a grayscale image based on copyright protection and authentication. A few researchers work on the color image. Most of these color image watermarking methods use an only one-color channel or each color channel of a color image to embed the watermark data. So, the color image's redundant data cannot be used sufficiently and cause a low ability to resist attacks, which means the method has low robustness against image processing attacks (Xu et al., 2018). This section overviewed the recent works on image watermarking, and it shows that there are not many researchers' works on color image watermarking. Enhance the color image watermarking method is still one of the main concerns in image watermarking.

1.3 Problem Statement

An effective watermarking method that can resist the most common image processing attacks such as JPEG compression, rotation, sharpening, blurring, salt and pepper is the main issue of the color image watermarking addressed by Su and Chen (2018). On the other hand, 92% of the researchers are interested in working on a JPEG compression attack because compression is a tool used by many applications in digital image processing. The embedding method needs to detect the watermark after compression attack, and it should be robust, which means the NCC value must be one or close to one. JPEG compression is one of the most critical procedures for image compression (Najafi, 2017).

Moreover, the digital watermarking effectiveness depends on four characteristics, which are imperceptibility, robustness, security, and real-time processing. Normalized Cross-Correlation (NCC) is used to measure the watermarking method's robustness. According to Bajracharya and Koju (2017), when the NCC value is close to one, there is a high similarity between the original watermark and the extracted watermark after the attack. One is the best value for the NCC, and current research results show that there is still room for improvement in the robustness of color image.

Su and Chen (2016), Su and Chen (2017), Su *et al.* (2017b), Cheema *et al.* (2020) work on JPEG compression with a quality factor of 30%, and the highest NCC results for Lena host image is 0.9735, and for Avion host image NCC value is 0.9546 which is the highest value in their researches. These NCC values can still be improved and enhanced by the watermarking method to achieve higher NCC value and much closer to one or achieved one, which is the best NCC result.

1.4 Research Questions

(a) What are the existing robust color image watermarking methods against JPEG compression attacks?

(b) How to propose an enhanced method for robust color image watermarking against JPEG compression attack?

(c) What is the proposed method's performance?

1.5 Research Objectives

This research has three objectives, which are listed below:

(a) To investigate existing robust color image watermarking methods against JPEG compression attack

(b) To propose an enhanced method for robust color image watermarking against JPEG compression attack

(c) To evaluate and analyze the proposed method's performance

1.6 Significance of the Research

The significance of this research are as follows:

(a) Study existing methods for color image watermarking. Then compare them to find out their characteristics, strengths, and weaknesses.

(b) Proposed a new method by enhancing the watermarking method to improve the robustness against JPEG compression attacks for copyright protection purposes.

(c) Finding the best embedding place in the host image keeps a tradeoff between capacity, imperceptibility, and robustness.

1.7 Scope of the Research

The Scope of this research is listed below:

(a) Use 24-bits 512 × 512 RGB color host image from CVG-UGR image database.
(b) Use 24-bits 32 × 32 Peugeot logo as RGB color watermark image.
(c) This research is limited to use the combination of three methods only which are Discrete Wavelet Transforms (DWT), Discrete Cosine Transforms (DCT), and Cat Face Transform (Arnold Transform).
(d) The watermarked image quality will be evaluated by using Peak Signal to Noise Ratio (PSNR) and Structural Similarity Index Measure (SSIM) only.
(e) The proposed method robustness will be evaluated by using the Normalized Cross-Correlation (NCC) only.
(f) Using Matlab for implementation.

1.8 Thesis Organization

This thesis is divided into six chapters, where first, chapter one introduces the existing problem and objectives. In this chapter, watermarking is presented as the method to be used in the research. Second, the literature review clarifies watermarking basics, various types of watermarking, its applications, and its characteristics. It also explains the advantages of watermarking, the difference expansion method, and the application using it. Third, chapter three describes the research methodology, design, and procedures. Fourth, chapter four describes the implementation of the proposed embedding and extraction methods. Fifth, chapter five illustrates the result analysis of the proposed method. In conclusion, the novelty of the proposed method, contribution, and future work are provided.

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Appendix A Psuedo Code

```
clc
clear
close all
im=imread('avion.ppm');
im = imresize(im,[512 512]);
sizeIM=[size(im,1) size(im,1)] ;
im_org=im;

level = 2;

wname = 'db1';
for i=1:3

[DWT_level(i,1).CA,DWT_level(i,1).CH,DWT_level(i,1).CV,DWT_level(i,1
).CD] = dwt2(im(:,:,i),wname);
end

for i=1:3
    for j=2:level

[DWT_level(i,j).CA,DWT_level(i,j).CH,DWT_level(i,j).CV,DWT_level(i,j
).CD] = dwt2(DWT_level(i,j-1).CA,wname);
    end
end
vecW=[0 1 1 0];
step=4;
key=[0 0 0 0 1];


Cap=FindCAP(DWT_level(1,level).CA,step);
Cap=sum(vecW)*Cap;

%% watermark image saaakhtam

im1=imread('peugeot.jpg');

RW=size(im1,1);
CW=size(im1,2);
lengthW=RW*CW;
im1=im2uint8(im1);
im3=im1;
watermark=im1;
alarm=0;
if  size(im1,1)*size(im1,2)>Cap
    disp('size of watermark image is larger than capacity of defined
subbands')
    alarm=1;
end
if alarm==0
    %% ba raveshe arnold scramble shod.
    for i=1:3
        [ scramble_watermark(:,:,i)] = arnold1( watermark(:,:,i),
13);
    end
    imshow(watermark,[]),title(' watermark')
    cnt=zeros(3,1);
```

```
    for i=1:3
        scramble_watermark_binary(:,:,i) =
dec2bin(scramble_watermark(:,:,i)',8);

vec_scramble(i,:)=reshape(scramble_watermark_binary(:,:,i)',[1],[]);
    end

    mat_level=cell(3,4);
    vecminmax=cell(3,1);
    for i=1:3
        for j=1:4

            if vecW(j)==1 && j==1

[mat_level{i,j},cnt(i,:),mask,vecminmax{i}]=embedd_NEW(DWT_level(i,l
evel).CA,step,key,vec_scramble(i,:),cnt(i,:),vecminmax{i});
            elseif vecW(j)==1 && j==2

[mat_level{i,j},cnt(i,:),mask,vecminmax{i}]=embedd_NEW(DWT_level(i,l
evel).CH,step,key,vec_scramble(i,:),cnt(i,:),vecminmax{i});
            elseif vecW(j)==1 && j==3

[mat_level{i,j},cnt(i,:),mask,vecminmax{i}]=embedd_NEW(DWT_level(i,l
evel).CV,step,key,vec_scramble(i,:),cnt(i,:),vecminmax{i});
            elseif vecW(j)==1 && j==4

[mat_level{i,j},cnt(i,:),mask,vecminmax{i}]=embedd_NEW(DWT_level(i,l
evel).CD,step,key,vec_scramble(i,:),cnt(i,:),vecminmax{i});
            end

        end
    end

    for i=1:3
        for j=1:4

            if vecW(j)==0 && j==1
                mat_level{i,j}=DWT_level(i,level).CA;
            elseif vecW(j)==0 && j==2
                mat_level{i,j}=DWT_level(i,level).CH;
            elseif vecW(j)==0 && j==3
                mat_level{i,j}=DWT_level(i,level).CV;
            elseif vecW(j)==0 && j==4
                mat_level{i,j}=DWT_level(i,level).CD;
            end
        end
    end


    for i=1:3
        X_CA(:,:,i) =
idwt2(mat_level{i,1},mat_level{i,2},mat_level{i,3},mat_level{i,4},wn
ame);
    end

    for i=1:3
        for j=level-1:-1:1
```

```
X(:,:,i)=idwt2(X_CA(:,:,i),DWT_level(i,j).CH,DWT_level(i,j).CV,DWT_l
evel(i,j).CD,wname);
        end
    end

    X=uint8(X);
    IMw=cat(3,X(:,:,1),X(:,:,2),X(:,:,3));

    figure,
    imshow(IMw,[]),title('watermarked image')



    % im=uint8(im);
    figure,imshow((im_org)),title('original image')
    % sum(sum((abs(X-im)))

    %attack
    attack=1;

    attack_kind='salt'; % or 'jpeg compression', 'rotate', 'sharp',
'salt', 'blurring'

    if attack==1 && strcmp(attack_kind,'blurring')==1
        %blurring
        filter=fspecial('disk',.2);
        X_blur=imfilter(X,filter,'replicate');
        IMwA=X_blur;
        imwrite(IMwA,'blurring_attack.jpg');
        PSNR_P=psnr(X,im)
        ssimval_p = ssim(X,im)

        X=X_blur;
    elseif attack==1 && strcmp(attack_kind,'jpeg compression')==1
        % jpeg compression
        imwrite(X,'compressed_image.jpg','jpg','Quality',10)
        X_jpeg=imread('compressed_image.jpg');
        X_jpeg=im2double(X_jpeg);
        IMwA=X_jpeg;
        imwrite(IMwA,'compresion_attack.jpg');
        PSNR_P=psnr(X,im)
        ssimval_p = ssim(X,im)

        X=im2double(X_jpeg);
    elseif attack==1 && strcmp(attack_kind,'rotate')==1
        %rotate
        X_rotate = imrotate(X,-30,'bicubic','loose');
        X_rotate= imresize(X_rotate,sizeIM);
        IMwA=X_rotate;
        imwrite(IMwA,'rotate_attack.jpg');
        PSNR_P=psnr(X,im)
        ssimval_p = ssim(X,im)

        X=X_rotate;
    elseif attack==1 && strcmp(attack_kind,'salt')==1
        %salt
        X_salt= imnoise(X,'salt & pepper',.01);
        IMwA=X_salt;
```

```
        imwrite(IMwA,'salt & pepper_attack.jpg');
        PSNR_P=psnr(X,im)
        ssimval_p = ssim(X,im)
        X=X_salt;
    elseif attack==1 && strcmp(attack_kind, 'sharp')==1
        % sharpen
        X_sharpen = imsharpen(X,'Radius',1);
        IMwA=X_sharpen;
        imwrite(IMwA,'sharp_attack.jpg');
        PSNR_P=psnr(X,im)
        ssimval_p = ssim(X,im)
        %     X_scale = imresize(X,4);
        X=X_sharpen;
    end

    if attack==1
        figure,
        imshow(X,[]),
        title('attacked image')
    end
    for i=1:3
        im_extract(:,:,i) = X(:,:,i);
    end

    for i=1:3

[DWT_levelE(i,1).CA,DWT_levelE(i,1).CH,DWT_levelE(i,1).CV,DWT_levelE
(i,1).CD] = dwt2(im_extract(:,:,i),wname);
    end

    for i=1:3
        for j=2:level

[DWT_levelE(i,j).CA,DWT_levelE(i,j).CH,DWT_levelE(i,j).CV,DWT_levelE
(i,j).CD] = dwt2(DWT_levelE(i,j-1).CA,wname);
        end
    end

    ex_watermark=cell(3,1);
    for i=1:3
        for j=1:4

            if vecW(j)==1 && j==1

ex_watermark{i,:}=extract_watermark_NEW(DWT_levelE(i,level).CA,mask,
key,step,lengthW,ex_watermark{i,:});
            elseif vecW(j)==1 && j==2

ex_watermark{i,:}=extract_watermark_NEW(DWT_levelE(i,level).CH,mask,
key,step,lengthW,ex_watermark{i,:});
            elseif vecW(j)==1 && j==3

ex_watermark{i,:}=extract_watermark_NEW(DWT_levelE(i,level).CV,mask,
key,step,lengthW,ex_watermark{i,:});
            elseif vecW(j)==1 && j==4

ex_watermark{i,:}=extract_watermark_NEW(DWT_levelE(i,level).CD,mask,
key,step,lengthW,ex_watermark{i,:});
            end
        end
```

```
    end
    ex_watermark = cell2mat(ex_watermark);

    for i=1:3
        for j=1:length(ex_watermark)/8
            recover_watermark_seq(i,j) =
bin2dec(num2str(ex_watermark(i,(j-1)*8+1:(j-1)*8+8)));
        end
    end


    for i=1:3

recover_watermark(:,:,i)=reshape(recover_watermark_seq(i,:),RW,CW);
%scramble
        recover_watermark(:,:,i) = iarnold(
recover_watermark(:,:,i)', 13 );
    end

    figure,imshow(uint8(recover_watermark),[]),title('recovered
watermark')

    watermark = double(watermark);

NCC=mean(sum(sum(recover_watermark.*watermark))./sum(sum((watermark.
^2))))
    PSNR=psnr(X,im)
    ssimval = ssim(X,im)
end
 function
ex_watermark=extract_watermark_NEW(mat,mask,key,step,lengthW,ex_wate
rmark)
num_midband=numel(find(mask==1));
[PN0,PN1]=pn_gen(num_midband,key);
i=1;
j=1;

mask_sequence = reshape(mask',1,[]);

lengthW = (size(mat,1)/step)^2;

for repeat=1:lengthW
    patch=mat(i:i+(step-1),j:j+(step-1));
    patch = dct2(patch);
    patch_sequence = reshape(patch',1,[]);
    patch_seq_masked = patch_sequence(mask_sequence == 1);

    cor_0 = corrcoef(patch_seq_masked, PN0);
    cor_1 = corrcoef(patch_seq_masked, PN1);

    if abs(cor_0(2))>abs(cor_1(2))
        patch_bit = 0;
    else
        patch_bit = 1;
    end

    ex_watermark=[ex_watermark patch_bit];

    j=j+step;
```

```
    if j>size(mat,2)
        i=i+step;
        j=1;
    end
    if i>size(mat,1)
        break;
    end
end
function
[mat_embed,cnt,mask,vecminmax]=embedd_NEW(mat,step,key,vec_scramble,
cnt,vecminmax)
mask=zeros(step,step);
dismin=.4*sqrt(2*(step^2));
dismax=.8*sqrt(2*(step^2));

for i=1:step
    for j=1:step
        if sqrt((i)^2+(j)^2)>=dismin && sqrt((i)^2+(j)^2)<=dismax
            mask(i,j)=1;
        end
    end
end

num_midband=numel(find(mask==1));
mat_embed=mat;
[PN0,PN1]=pn_gen(num_midband,key);

alpa=40;
i=1;
j=1;
alarm=0;
minp=10000;
maxp=-10000;
while alarm==0

    patch=mat(i:i+(step-1),j:j+(step-1));
    patch = dct2(patch);


    patch_n=zeros(step,step);
    cnt=cnt+1;



    cntt=0;
    for k=1:step
        for l=1:step

            if cnt<=numel(vec_scramble)
                if mask(k,l)==1 &&  vec_scramble(cnt)=='0'
                    cntt=cntt+1;
                    patch_n(k,l)=patch(k,l)+alpa*PN0(cntt)   ;
                    vecminmax=[vecminmax patch_n(k,l)];
                elseif mask(k,l)==1 &&  vec_scramble(cnt)=='1'
                    cntt=cntt+1;
                    patch_n(k,l)=patch(k,l)+alpa*PN1(cntt)   ;
                    vecminmax=[vecminmax patch_n(k,l)];
                else
                    patch_n(k,l)=patch(k,l);
```

```
                end
            else
                alarm=1;
            end

        end
    end

    patch_n=idct2(patch_n);
    mat_embed(i:i+(step-1),j:j+(step-1))=patch_n;

    j=j+step;
    if j>size(mat,2)
        i=i+step;
        j=1;
    end
    if i>size(mat,1)
        break;
    end

end
```

LIST OF PUBLICATIONS

Amir Hesam Yaribakht[1], Mohd Shahidan Abdullah[2], Alireza Ghobadi[3]. A Novel Color Image Watermarking Method based on Digital Wavelet Transform and Hungarian Algorithms, International Journal of Advanced Trends in Computer Science and Engineering, Volume 8, No.2, March - April 2019. Scopus Index.