

# Robust Watermarking of Grayscale Images using Feature Extraction and DWT

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**Abstract**— The rapid advancement and extensive growth in communication technology is creating a critical need to develop novel methods and techniques to protect copyright, ownership, authentication and content integrity of digital media. An efficient solution to this kind of problem is digital watermarking of multimedia. A watermark refers to a visible or invisible digital data to be embedded in a cover data so as to provide copyright protection at time when need arises. Numerous watermarking and steganographic methods have been presented in the literature and several watermarking software packages have been developed in past decades. Still robustness and security of watermark against a variety of attacks is one of the most important issues to be solved. In this paper, grayscale 8 bit images are considered for watermark embedding. However, techniques are proposed so that the method is directly applicable for watermarking of color images. Discrete wavelet transform is used to provide robustness and Noise Value Function (NVF) and Arnold Scrambling is used to provide security. Watermark generation is done using LL band of NVF function of original image. The watermark is then subjected to Arnold Transform to introduce randomness, thus enhancing security and improving PSNR. Embedding is done in low frequency LL band of original image. Inverse Discrete wavelet Transform is then computed to obtain the watermarked image. The results are evaluated by applying number of attacks on the watermarked image.

**Key words:** Discrete Wavelet Transform, NVF, Grayscale Images, Robust Watermarking

## I. INTRODUCTION

Due to the rapid advancement of digital multimedia tools, the storage, replication and distribution of multimedia content has now become very easy. Security of digital content is a critical issue and there is a vital need for protecting the digital content against counterfeiting, piracy and malicious manipulation. In context of image watermarking, a digital watermark refers to visible or invisible signature embedded inside an image to later prove authenticity or proof of ownership. It is one of the mandatory requirement of watermarking technique that the hidden watermark should be inseparable from the host image, robust enough to resist any manipulations while, at the same time, preserving the image quality. Thus through watermarking, intellectual properties remains accessible while being permanently marked. This digital signature approach used in authenticating ownership claims and protecting proprietary information, discourage unauthorized copying and distribution of images over the internet and ensure that a digital picture has not been altered.

Watermarking system adds the additional requirement of robustness. An ideal watermarking system would embed an amount of information that could not be

removed or altered without making the cover object entirely unusable. So, watermarking is mainly prevent illegal copy or claims the ownership of digital media. There are four essential factors which make watermarking effective. These are

A. *Robustness:*

Watermark should difficult to remove or destroy. It is a measure of immunity of watermark against attempts to image modification and manipulation like compression, filtering, rotation, collision attacks, resizing, cropping etc.

B. *Imperceptibility:*

Quality of host image should not be destroyed by presence of watermark.

C. *Capacity:*

It includes techniques that make it possible to embed majority of information.

D. *Blind watermarking:*

Blind watermarking refers to the ability to extract watermark from marked image without the need of original image. In contrast, in non-blind watermarking, the original image (unmarked) is required at the receiver at the time of extraction of watermark.

Fourier Transform gives the spectral content of the signal, but it gives no information regarding where in time those spectral components appear. Therefore, FT is not a suitable technique for non-stationary signal, with one exception: FT can be used for non-stationary signals, if one is only interested in what spectral components exist in the signal, but not interested where these occur. However, if this information is needed, i.e., if one wants to know, what spectral component occur at what time (interval), then Fourier transform is not the right transform to use.

For practical purposes it is difficult to make the separation, since there are a lot of practical stationary signals, as well as non-stationary ones. Almost all biological signals, for example, are non-stationary. Some of the most famous ones are ECG (electrical activity of the heart, electrocardiograph), EEG (electrical activity of the brain, electroencephalograph), and EMG (electrical activity of the muscles, electromyogram).

When the time localization of the spectral components are needed, a transform giving the Time-Frequency representation of the signal is needed. The wavelet transform is a transform of this type. It provides the time-frequency representation.

Consider a signal which has frequencies up to 1000 Hz. In the first stage, the signal is split up into two parts by passing the signal from a highpass and a lowpass filter which results in two different versions of the same signal: portion of the signal corresponding to 0-500 Hz (low pass portion), and 500-1000 Hz (high pass portion). The filters should satisfy some certain conditions, so-called admissibility condition. Then, in the next step, either portion

(usually low pass portion) or both is taken, and the same procedure is repeated again. This operation is called decomposition. Assuming that the lowpass portion is considered, now there are 3 sets of data, each corresponding to the same signal at frequencies 0-250 Hz, 250-500 Hz, 500-1000 Hz.

Then taking the lowpass portion again and pass it through low and high pass filters; there are now 4 sets of signals corresponding to 0-125 Hz, 125-250 Hz, 250-500 Hz, and 500-1000 Hz. If the procedure is continues like this, until the signal is decomposed to a pre-defined certain level. Then there are a bunch of signals, which actually represent the same signal, but all corresponding to different frequency bands. It is known that which signal corresponds to which frequency band, and if all of them are kept together and plotted on a 3-D graph, then the graph will have time in one axis, frequency in the second and amplitude in the third axis. In this paper, a method of watermarking of grayscale images is presented. The watermarking technique proposed embeds watermark in LL component of the DWT transform of the original image. The techniques proposed in this paper provides a method to embed watermark of the size one fourth of the original image and generated using the feature values of the original image, so as to provide a method of blind watermarking. The generated watermark is embedded in the LL component of DWT transform of the original image. after modification of the LL band, inverse DWT is performed to get the watermarked image.

In digital watermarking systems, the primary concern is robustness, which refers to the recovery or checking for signature even when the embedded image has been changed by image processing operations, like compression or resizing. Thus the embedding scheme should be robust to typical operations such as low-pass filtering and lossy compression. Moreover, for data hiding applications it is important that there should not be any visible changes to the host data that is used to transmit a hidden image. In addition, in both data hiding and watermarking, it is desirable that it is difficult or impossible for unauthorized persons to recover the embedded signatures. The primary motivation for the work is to develop a technique which is robust against common image processing operations while at the same time, provides a way for blind watermarking in which the original image is not required at the receiver end at the time of watermark extraction. Experimental results demonstrate that high quality recovery of the signature data is possible. This paper is organized as follows:

Section 1 gives a brief overview of the paper. It discusses the scope and motivation for the subject matter of the paper in a comprehensive way. Section 2 focuses on the various tools and techniques developed for embedding digital data in images. It further discusses various categories of embedding techniques including fragile and robust watermarking, blind and non-blind watermarking and their application areas. It also covers the fundamental concepts of DWT based watermarking. Section 3 illustrates the proposed technique of NVF and DWT based watermarking algorithm. Section 4 discusses the results derived through simulation code and the quality metrics. Section 5 discusses the conclusion and future scope of the work.

## II. RESEARCH APPROACH

Digital image is subjected to Noise Visibility Function so as to get an approximation of standard deviation and variance of the image. This NVF function is then subjected to DWT transform so as to extract the frequency band corresponding to already modulated image. Also, the original image feature extraction is done using averaging of 2 X 2 non overlapping blocks of the image. The LL component of DWT of NVF and the pixel block averaged image are then processed to get the watermark image. This watermark is generated using image processing operation and hence would carry feature information of the image, thereby providing blind watermarking process. This watermark image is subjected to Arnold Transform so as to introduce randomness, thus enhancing security and providing robustness and at the same time, improving PSNR. The watermark image is embedded in LSB of the LL component of the cover image and inverse DWT is computed to get the watermarked image.

## III. PROPOSED WORK

### A. Watermark Embedding:

The proposed scheme consists of three different phases:

- (1) Watermark Generation
- (2) Watermark Embedding and
- (3) Watermark Detection.

The watermark is generated from pixel value information of original image. This is essential in case of blind watermarking so that original unmarked image is not required at the detector at the time of extraction of watermark. Also, the watermark is to be generated in such a way so as to be invariant under geometrical of image manipulation attacks. For embedding watermark in specific image portion (in spatial or frequency domain), it is necessary that the dimensions of the image portion and the watermark are compatible. Therefore, for embedding watermark in the DWT frequency components, it is necessary that the dimensions of the watermark must be one fourth of that of the original image. For embedding the watermark, a 1-level Discrete Wavelet Transform of the original image is performed. Watermark information is embedded in high frequency band (HH1) as it is robust against various normal image processing operations and attacks. The resultant image is called watermarked image. At the detector end, the watermark is once again generated from watermarked image and is also extracted from HH1 sub band. Comparison is made between those two watermarks to decide authenticity.

### B. Watermark Generation:

The watermark pattern is generated from the spatial domain information. This technique proposes a way for blind watermarking in which the original (unmarked) image or the watermark image is not required at the detector for watermark detection. This procedure includes the following steps:

- (i) Consider original Image  $I_{M \times M}$  and decompose it into Red, Green and Blue Channels. The Blue sub band of the image,  $I_B$  is considered for the purpose of watermarking operations.
- (ii) Compute the Noise Visibility Function (NVF) of the image using the function

- (1)  $NVF(i, j) = \frac{1}{1 + \sigma_x^2(i, j)}$
- (2) where  $\sigma_x(i, j)$  denotes the standard deviation of the cover image in a window centered on the pixel with coordinates (i, j). By applying the NVF, the watermark in the texture and images becomes stronger than in flat areas
- (3) Acquire the LL1 component of the NVF image to find watermark pattern, which is of size M/2 X M/2. Let this matrix be M.
- (4) An image N of size M/2 X M/2 is obtained from original image by performing the following steps.
  - Partition the original image into non-overlapping blocks of size 2 X 2.
  - Compute one feature value from each block according to the following equation:
- (iii) 
$$B(x, y) = \frac{\sum_{i=1}^2 \sum_{j=1}^2 P(x*2+i, y*2+j)}{2}$$

equation 3.1

where  $0 < x < M/2$  and  $0 < y < M/2$

  - Find the difference between A and B. Let it be C
- (iv) A binary sequence 'W' can be obtained by applying the following constraint.
 
$$W(x, y) = \begin{cases} 0 & \text{if } C(x, y) \text{ is even} \\ 1, & \text{otherwise} \end{cases}$$

equation 3.2
- (v) Disorder the matrix 'W' with the help of Arnold Transform, which is the required watermark pattern to be embedded within the host image.

The above procedure is illustrated with the help of the following example. Let the blue plane, with 8 bit color values (0-255) be as shown below:

12	34	25	34	45	13	56	76
34	43	54	75	77	87	45	33
13	45	66	78	54	67	78	89
34	45	77	86	34	23	66	87
24	56	76	23	22	32	44	76
56	78	43	66	87	98	54	23
43	55	32	45	78	97	54	34
34	65	26	57	22	59	88	78

Fig. 3.1 Sample (Hypothetical Image Blue Color Plane Matrix)

The NVF of the image can be obtained as shown:

0.07	0.02	0.03	0.02	0.02	0.07	0.01	0.01
69	86	85	86	17	14	75	30
0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
86	30	23	12	10	08	09	94
0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.01
14	21	35	15	16	25	21	11
0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01
86	17	10	05	12	09	22	14
0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.01
00	24	14	04	04	12	16	30
0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.04

75	08	23	14	07	04	17	17
0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
27	26	15	17	13	14	11	86
0.02	0.01	0.03	0.01	0.04	0.01	0.01	0.01
86	52	70	72	35	67	12	27

LL =

0.0685	0.0353	0.0475	0.0304
0.0519	0.0033	0.0031	0.0134
0.0304	0.0028	0.0013	0.0290
0.0345	0.0287	0.0314	0.0268

LH =

0.0369	0.0318	0.0457	0.0001
0.0216	0.0018	0.0009	-0.0002
0.0120	-0.0009	0.0002	-0.0144
-0.0092	-0.0255	-0.0287	0.0029

HL =

0.0369	0.0055	-0.0247	-0.0120
0.0481	0.0013	-0.0003	-0.0091
0.0272	0.0009	-0.0003	-0.0257
0.0168	0.0098	0.0134	-0.0145

HH =

0.0114	0.0044	-0.0250	0.0165
0.0212	0.0008	-0.0006	0.0001
0.0104	0.0001	-0.0005	0.0143
0.0034	-0.0100	-0.0134	-0.0130

The feature value generation from the original image is obtained according to equation 3.1 and is shown below. These are the average values of the 2X2 non overlapping blocks of the original image.

M =

30.75	47	55.5	52.5
34.25	76.75	44.5	80
53.5	52	59.75	49.25
49.25	40	64	63.5

Matrix C can be obtained by calculating the difference between the LL matrix and the average value of this feature matrix.

The matrix C is illustrated as shown:

C = M - N =

23.9	43.47	50.75	49.46
29.06	76.42	44.19	78.66
50.46	51.72	59.62	46.35
45.8	37.13	60.86	60.82

These values are the values which actually corresponds to  $M - 100 * N$  so as to normalize the values corresponding to NVF transformation. Rounding off the values of the image matrix yields:  
 $C' =$

24	43	51	49
29	76	44	79
50	52	60	46
46	37	61	61

A binary sequence 'W' can be obtained by applying the following constraint.

$$W = \begin{cases} 0, & \text{if } C(x,y) \bmod 2 \text{ is zero} \\ 1, & \text{otherwise} \end{cases}$$

Thus the watermark obtained is :  
 $W =$

0	1	1	1
1	0	0	1
0	0	0	0
0	1	1	1

For a square image of size  $N \times N$  pixels, Scrambling can be obtained through Arnold Transform using the following equation:

$$f(x,y) \rightarrow f(x^1,y^1) \text{ where } \begin{cases} x^1 = (x+y) \bmod N \\ y^1 = (x+2y) \bmod N \end{cases}$$

The scrambling illustration through Arnold Transform is as shown in the following figure:

(0,3) → (3, 2)	(1,3) → (0, 3)	(2,3) → (1, 0)	(3,3) → (2, 1)
(0,2) → (2, 0)	(1,2) → (3, 1)	(2,2) → (0, 2)	(3,2) → (1, 3)
(0,1) → (1, 2)	(1,1) → (2, 3)	(2,1) → (3, 0)	(3,1) → (0, 1)
(0,0) → (0, 0)	(1,0) → (1, 1)	(2,0) → (2, 2)	(3,0) → (3, 3)

The reverse of the Arnold Transform is illustrated in the table below:

(3, 2) → (1, 3) → (0,3)	(0, 3) → (3, 2) → (1,3)	(1, 0) → (1,1) → (2,3)	(2, 1) → (3,0) → (3,3)
(2, 0) → (2, 2) → (0,2)	(3, 1) → (0,1) → (1,2)	(0, 2) → (2,0) → (2,2)	(1, 3) → (0,3) → (3,2)
(1, 2) → (3, 1) → (0,1)	(2, 3) → (1,0) → (1,1)	(3, 0) → (3,3) → (2,1)	(0, 1) → (1,2) → (3,1)
(0, 0) → (0, 0) → (0,0)	(1, 1) → (2,3) → (0,2)	(2, 2) → (0,2) → (2,1)	(3, 3) → (2,1) → (2,1)

	(1,0)	(2,0)	(3,0)
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The scrambled version of the binary watermark is as shown in the matrix below:

1	1	0	1
0	0	1	0
0	1	1	0
0	1	1	0

The binary conversion of the values of LL sub band of original image after rounding off the values is as shown below:

LL =

00111110	01011110	01101111	01101001
01000101	10011010	01011001	10100000
01101011	01101000	01111000	01100011
01100011	01010000	10000000	01111111

The binary watermark embedding in LSB of LL subband coefficients is as shown in the figure:

LL' =

0011111 <u>1</u>	0101111 <u>1</u>	0110111 <u>0</u>	01101001
0100010 <u>0</u>	10011010	01011001	10100000
0110101 <u>0</u>	0110100 <u>1</u>	0111100 <u>1</u>	0110001 <u>0</u>
0110001 <u>0</u>	0101000 <u>1</u>	1000000 <u>1</u>	0111111 <u>0</u>

The underlined values shows the embedded watermark bits. The red bits which are underlined shows the places where the bit values are changed due to LSB encoding. As evident even from this small hypothetical image matrix, about half of the values are changed in LSB encoding and half remains the same.

Thus, the modified LL (= LL') in decimal values will be:  
LL' =

63	95	110	105
68	154	89	160
106	105	121	98
98	81	129	126

The watermarked image can be constructed with all the four subbands, including the modified LL' band, using inverse Fourier transform. The watermarked image is as shown below:

12.7	34.7	25.5	34.5	44.5	12.5	56.0	76.0
500	500	000	000	000	000	000	000
34.7	43.7	54.5	75.5	76.5	86.5	45.0	33.0
500	500	000	000	000	000	000	000
12.7	44.7	66.2	78.2	54.0	67.0	78.0	89.0
500	500	500	500	000	000	000	000
33.7	44.7	77.2	86.2	34.0	23.0	66.0	87.0
500	500	500	500	000	000	000	000
23.5	55.5	76.5	23.5	22.7	32.7	43.7	75.7
000	000	000	000	500	500	500	500
55.5	77.5	43.5	66.5	87.7	98.7	53.7	22.7
000	000	000	000	500	500	500	500

42.7	54.7	32.5	45.5	78.5	97.5	53.5	33.5
500	500	000	000	000	000	000	000
33.7	64.7	26.5	57.5	22.5	59.5	87.5	77.5
500	500	000	000	000	000	000	000

The Rounding off of the values is depicted in the table shown below:

13	35	26	35	45	13	56	76
35	44	55	76	77	87	45	33
13	45	66	78	54	67	78	89
34	45	77	86	34	23	66	87
24	56	77	24	23	33	44	76
56	78	44	67	88	99	54	23
43	55	33	46	79	98	54	34
34	65	27	58	23	60	88	78

This block represents the watermarked image. The original image block is repeated here for ready reference:

12	34	25	34	45	13	56	76
34	43	54	75	77	87	45	33
13	45	66	78	54	67	78	89
34	45	77	86	34	23	66	87
24	56	76	23	22	32	44	76
56	78	43	66	87	98	54	23
43	55	32	45	78	97	54	34
34	65	26	57	22	59	88	78

The mean square error between original and watermarked image is:

$$MSE = 8.149003$$

Section 4 discusses the results and compare the results with the benchmarks.

#### IV. ANALYSIS OF PROPOSED WORK

##### A. 4.1 Watermarking Process in MATLAB:

Consider the benchmark image lena illustrated in Fig 4.1. The 2D dwt transformation can be done directly in MATLAB giving the images shown in Fig 4.2, 3,4 and 5.



Fig. 4.1: Lena.jpg (400 X 400)

Matlab code for the transformation of the image is

as follows:

```
//code starts here
clear all;
close all;
```

```
i=imread('lena.jpg');
i=rgb2gray(i);
sX=size(i);
[LL,LH,HL,HH]=dwt2(i,'haar');
figure(1)
subplot(2,2,1);imshow(LL);title('LL band of image');
subplot(2,2,2);imshow(LH);title('LH band of image');
subplot(2,2,3);imshow(HL);title('HL band of image');
subplot(2,2,4);imshow(HH);title('HH band of image');
Xrec = idwt2(LL,LH,HL,HH,'haar',sX);
Xrec=max(max(abs(i-Xrec)))
figure(2)
imshow(Xrec);
//code ends here
```

The subband partitioning of the image is as shown:

HH band of image

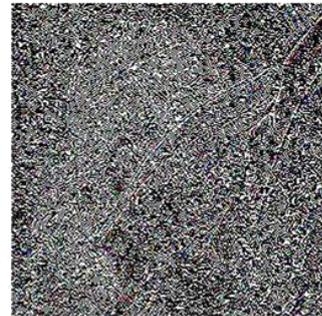


Fig. 4.2, HH Band

HL band of image



Fig. 4.3: HL Band

LH band of image

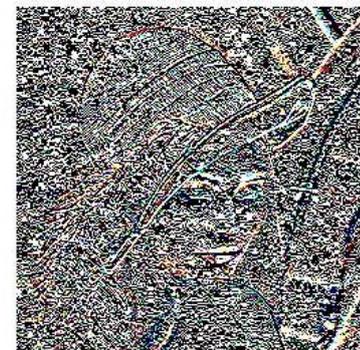


Fig. 4.4: LH Band

As the LL band consists of Least value frequency components, on direct plotting of its gives the white canvas.

The NVF plot of lena.jpg can be obtained from MATLAB code as provided in appendix A. The NVF plot of lena.jpg is shown in the figure 4.5.



Fig. 4.5: NVF values of Lena, (window size = 2)

It is clear from NVF values that the plane areas are of low intensity values whereas the border areas are of high intensity values.

The LL subband of NVF values of lena is shown in Fig, 4.6,



Fig. 4.6: LL sub band of NVF Function of Lena

The mean value of the 2X2 image blocks, taking the average is shown in fig. 4.7



Fig 4.7: Average of 2 X 2 blocks of the image

Watermark image is generated as the binary image of the difference between the images shown in Fig 4.7 and 4.8, normalized to 0 or 1 depending upon even and odd values.

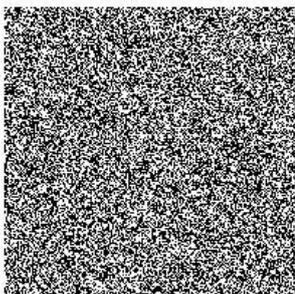


Fig 4.9: Watermark Image Generated (in accordance with the equation 3.2)

The Arnold Transformed watermark image is shown in Figure 4.10.

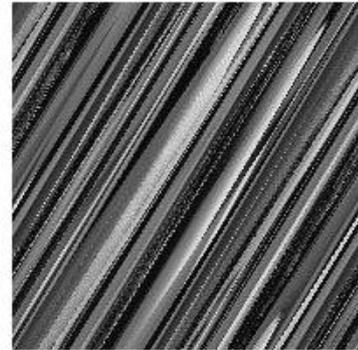


Fig. 4.10: Arnold Transformed Watermark Image

The watermark is then embedded in LL component of the original image using LSB encoding and then the watermark image is obtained by combining the LL, LH, HL and HH bands. The watermarked image is as shown in Figure 4.11.



Fig. 4.11: Arnold Transformed Watermark Image

**B. Analysis and Comparison of the results:**

The watermarking operation as described in section 4.1 on three different benchmark images of size 150 X 150 and the corresponding PSNR values are illustrated in table 4.1 given below.



Fig. 4.12: Benchmark images for watermarking Process

Techniques	lena		camramen		Baboon	
	MS E	PSNR	MS E	PSNR	MS E	PSNR
[2]	67	29.87006	65	30.00167	69	29.74231
Proposed	66	29.93536	64	30.069	68.5	29.7739

Table 4.1: Comparison Of The Results

The qualitative comparison of the results can be done as follows:

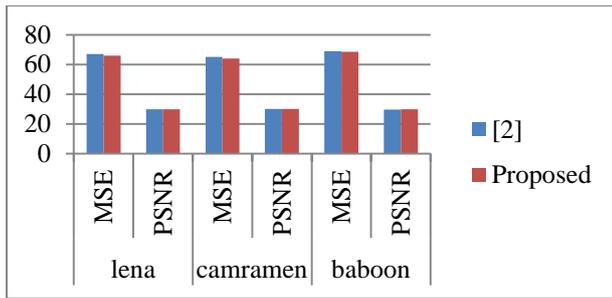


Fig 4.13: Comparison of the results on standard images

Table 4.1 and Figure 4.13 gives the quantitative and qualitative comparison between the method proposed by S. S. Sujatha, et. al [2] and the proposed method.

Section 5 discusses the results and draws outline for conclusion and future scope.

## V. CONCLUSION AND FUTURE SCOPE

A robust blind watermarking is proposed which provides a complete algorithm that embeds and extracts the watermark information effectively. In the proposed method, a watermark pattern is constructed from host image itself using feature extraction and Noise Visibility Function. Watermark signal is disordered with the help of Arnold Transform. The designed method makes use of the low frequency component of Discrete Wavelet Transform for watermarking construction, embedding and extraction processes. The authentication process provides qualities like imperceptibility, robustness and security. The efficiency and robustness of the watermarking scheme is evaluated with common image processing attacks such as noising, filtering, intensity adjustment, histogram equalization, JPEG compression, Scaling and rotation. Experimental results shows that the watermark is robust against these attacks. The simulation results of currently devised method are compared with that of previous work [2], and the results obtained show that the proposed technique is highly robust against attacks such as JPEG compression, scaling and rotation.

As a future scope of the process, it is proposed to devise techniques do that watermarking process will be robust against cutting and cropping effects using invariant features of the images.

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