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Fuzzy Based Chaotic and Logistic Method for Digital Watermarking Systems

G.Rosline Nesa kumari, L.Sumalatha, Dr.V.Vijayakumar

Abstract— To overcome the weak robustness problem of embedding the watermark in the spatial domain and to provide high authentication, security and robustness, the present paper proposed a novel watermarking scheme called Fuzzy based Chaotic and Logistic (FCL) method with three steps. In the step one, the proposed FCL method modifies the original image into transform domain and identifies the pixel location to insert the watermark bits in the difference values between the original image and its reference image based on a novel Fuzzy Logic (FL) method. In the second step, the selected bit positions of step one are shuffled using Arnold cat map, to achieve outspreading of orbits over the entire space, for further authentication and security. In step three logistic maps is used, on step two shuffled pixels, to determine the bit positions of host image for watermark embedding. The experimental results indicate the efficacy of the proposed FCL method when compared with the various other methods.

Index Terms— Fuzzy Logic, chaotic mapping, logistic mapping, Arnold cat map.

1 Introduction

Digital technologies have made multimedia data broadly available. In modern times, multimedia applications become general in practice and thus security of multimedia data has become the main anxiety. Therefore, the resistance of image data attracts more and more concentration which makes image encryption technology greatly important. Normally, the most important approaches usually used are to defend digital image by information hiding which includes watermarking, ambiguity and cover channel [23]. Digital watermarking has been generally used as a tool for protecting copyright of digital multimedia information. A watermark is inserted into digital images so that it is imperceptible and indiscernible to a person [1-3]. The watermark must also be strong and robust to typical signal processing operation such as JPEG compression, cropping, resizing, noising, rotation, and so on [6].

Watermark embedding can be performed in spatial or frequency domain. One of the representative data hiding methods in spatial domain is to use the Least Significant Bit (LSB), such as LSB replacement or LSB matching [4-5]. Transform domain watermarking methods employ the well-known transformation techniques such as Discrete Cosine Transform (DCT), Fourier Transform (FT), or Discrete Wavelet Transform (DWT). Spatial domain methods are simpler and have a large capacity compared to transform domain methods, while transform domain methods are more robust and forceful compared to spatial domain methods. The frequently used watermarking techniques in the spatial domain are based on the concept of mixing systems [7-9]. Such approaches are uncomplicated and computationally proficient, because they modify the color, brightness or intensity values of a digital image pixel. Therefore their application is done very easily and requires minimal computational power. In terms of watermark security, the spatial domain is the most horrible place to insert a watermark. Usually, the frequency domain offers good capacity, high excellence and better robustness to attacks. The key factors for the protected communication are high security, high embedding capacity and good imperceptibility to the exposed eye.

In order to gratify these requirements, our proposed FCL algorithm is developed the mishmash of Fuzzy system and chaotic theory with Discrete Wavelet Transform (DWT). The basic issues pertaining to the problem of encryption has been discussed and also a survey on image encryption techniques based on chaotic schemes has been dealt in the present communication. The characteristics of chaotic signals make the chaos system an excellent and robust cryptosystem against any statistical attacks. Therefore, chaos based image encryption is given much attentiveness in the research of information precautions and a set of image encryption algorithms based on chaotic systems are proposed [10-13]. There are many image encryption algorithms based on chaotic maps like the Logistic map [14-16],the Standard map [17], the Baker map [18-19], PWNLCM [20] Cat map [21-22], Chen map [15,22], etc. In order to develop a excellent performance of image watermarking algorithm and provide better robust new Fuzzy system with two dimensional Arnold cat maps [24] is employed to shuffle the embedding position in the present paper. Therefore, watermark signals swell in all places of the chosen image chaotically, which ensures the refuge of watermarking algorithm. To make a transaction between imperceptibility and robustness, watermark bits are used to modify the 4th, 5th, 6th or 7th bits of corresponding shuffled pixels in host image. Original image

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and mapping table are not needed in watermark extraction; hence it is a blind watermark scheme.

The rest of the paper is organized as follows. Section 2 describes about wavelet transform. The watermarking scheme based on chaotic maps and fuzzy system is proposed in section 3. Experiment results are discussed in section 4 and section 5 concludes the paper.

2 WATERMARKING IN THE WAVELET DOMAIN

Among the transform domain watermarking techniques, discrete wavelet transform (DWT) based on watermarking techniques are gaining more popularity. Wavelet based watermarking techniques have multi-resolution hierarchical characteristics. Furthermore, its ability to decompose an image into bands that vary in both spatial frequency and orientation (vertical, horizontal and diagonal) has made it of great relevance when modeling the anisotropic properties of a Human Visual System (HVS). This mimics the human visual perception and allows the independent processing of the resulting components [8]. The high frequency subbands of the wavelet transform include the edges and textures of the image and the human eye is not generally very sensitive to changes in such bands. Also, watermark detection may be achieved at lower image resolutions, which saves computational load. DWT has number of advantages over other transform such as progressive and low bit-rate transmission, quality scalability and region-of-interest (ROI) coding demand more efficient and versatile image coding that can be exploited for both, image compression and watermarking applications. The DWT is very suitable to identify the areas in the host image where a watermark can be embedded effectively. Wavelets are also being used in several emerging image and video compression standards such as JPEG2000 and MPEG 4 [13]. That is the reason the present paper considers the wavelet transform domain for watermarking applications.

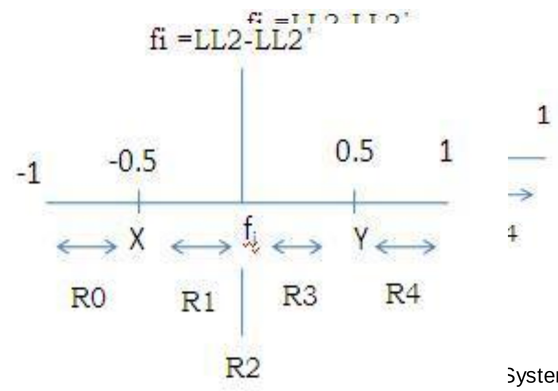
3 THE PROPOSED FCL METHOD

3.1 Embedding watermark for FCL method

The proposed integrated FCL approach of embedding watermark consists of three steps.

STEP 1: Fuzzy Wavelet

In the step one, the proposed FCL method modifies the original image into transform domain and identifies the pixel location to insert the watermark bits in the difference values between the original image and its reference image based on a Fuzzy Wavelet (FW) method. The FW scheme is explained below. The discrete wavelet transform decomposes an image into subbands having a bandwidth approximately equal on a logarithmic scale. To achieve imperceptibility, the lowest band of the image is left unmodified. The gray level image is transformed into a DWT in both vertical and horizontal directions, resulting in one low frequency subband (LL) and three higher frequency subbands (LH,HL and HH). The same is repeated on the LL subband to generate the next level of decomposition. This process can be repeated to n-level decomposition by considering the length of watermark, robustness, fidelity and so on. The determined LL_n can be seen as a reduced version of the original image. Based on this a reference LL_n' is prepared by inverse wavelet transforming the original LL_n by initializing the three high frequency subbands (LH_{n+1},HL_{n+1} and HH_{n+1}) excluding LL_{n+1} as zeros. The self-reference watermarking scheme selects all those pixels that have the difference in LL_n' and LL_n. This makes the scheme easy to break. To overcome this, the present paper adopts the FW scheme; which selects the pixel location based on fuzzy logic, which is dynamic. The difference between LL_n and LL_n' mainly ranges from -1 to +1, because the error content in the wavelet transform is minimum, that is the reason one always obtains the original image by inverse transformation. FW scheme evaluates the difference between (LL_2-LL_2') for selecting the pixel locations. FW divides the range -1 to +1 in to four regions as R0, R1, R2 and R3 as shown in the Figure 1. The process of fuzzy wavelet system is shown in Figure 2. The FW pixel location is selected based on the following fuzzy algorithm.



System

Fuzzy Algorithm:
begin
if $[(LL_2(X_i,Y_i)-LL_2'(X_i,Y_i)]==0$ then the $P_i(X_i,Y_i)$ is not considered
if $((LL_n(X_i,Y_i)-LL_n'(X_i,Y_i))<0.5$) and $((LL_n(X_i,Y_i)-LL_n'(X_i,Y_i) > -0.5$) then the $P_i(X_i,Y_i)$ is considered for finding embedding pixel location
end

The pixel locations are selected for finding an embedding pixel location based on chaos system if they fall in the fuzzy region R1 and R3.

STEP 2: Arnold cat map

The selected bit positions of FW scheme of step one are shuffled using Arnold cat map, to achieve further authentication and security in the second step. Chaotic maps are used to increase the security of a digital watermark system. Chaotic signals are complex in nature and impossible to predict over a long time. They can be generated by a simple dynamic system such as logistic map and Chebyshev map. The chaotic signal can be reproduced easily. In order to shuffle the embedding position of the host image, two dimensional Arnold cat map is employed in our scheme, which is described in Equation (1).

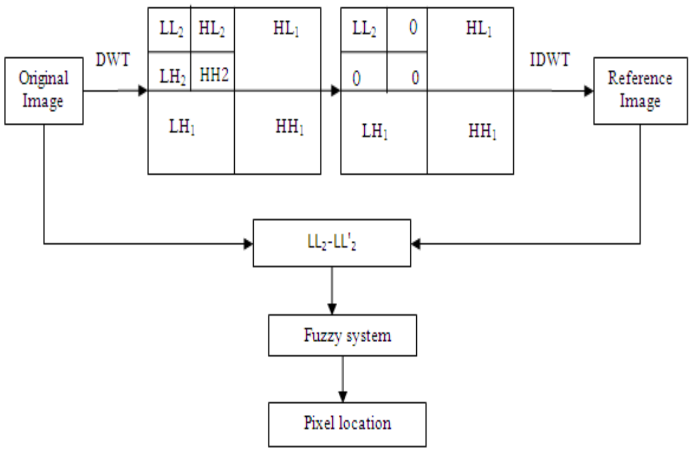


Fig. 1. The process of Fuzzy System

$$x_{n+1} = (x_n + y_n) \bmod 1,$$
$$y_{n+1} = (x_n + 2y_n) \bmod 1 \quad (1)$$

where notation "x mod1" denotes the fractional part of a real number x by adding or subtracting an appropriate integer. Therefore, (x_n, y_n) is confined in a unit square of [0, 1] × [0, 1]. The Equation (1) is represented in matrix form as given in Equation (2).

$$\begin{bmatrix} x_n+1 \\ y_n+1 \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} x_n \\ y_n \end{bmatrix} = A \begin{bmatrix} x_n \\ y_n \end{bmatrix} \bmod 1 \quad (2)$$

To make the determinant of its linear transformation, matrix |A| is made equal to 1. To make the cat map as area preserving, a unit square is first stretched by linear transformation and then folded by modulo operation. This type of map is known to be chaotic and this is a one to one map. In this each point of the unit square is uniquely mapped onto another point in the unit square. Hence, watermark pixel of different positions will get a different embedding position. The cat map above can be extended as follows. Firstly, the phase space is generalized to [0, 1, 2, . . . , N −1]×[0, 1, 2, . . . , N − 1], i.e., only positive integers from 0 to N − 1 are taken, then Equation (2) is generalized to two-dimensional invertible chaotic map as given in Equation (3).

$$\begin{bmatrix} x_n+1 \\ y_n+1 \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x_n \\ y_n \end{bmatrix} = A \begin{bmatrix} x_n \\ y_n \end{bmatrix} \bmod N \quad (3)$$

where a, b, c and d are positive integers, and |A| = ad−bc = 1, therefore, only three among four parameters of a, b, c and d are independent under this condition. In Equation (3) the coordinate (i,j) of watermark pixel is served as the initial value. The three independent parameters of Equation (3) and the iteration time n serves as the secret key. After n rounds of iterations, the iterating result (x_n, y_n) is served as the embedding position of the watermark pixel (i,j). The arbitrary adjacent two watermark pixels will separate apart largely in the host image when the iteration time n is big enough and different watermark pixels will get different embedding positions, so the embedded watermark pixels will spread in host image randomly.

STEP 3: Logistic chaotic map

After shuffling process of step two, the present method adopted logistic map in step three, to determine in which bit positions of image pixels, the watermark is to be embedded. Logistic map is an example chaotic map, it is described as follows in Equation (4).

$$z_{n+1} = \mu z_n(1 - z_n) \quad (4)$$

Where μ€ [0,4], z_n € (0, 1), n = 0,1, 2 .. . The system is in chaotic state under the condition that 3.569945 < μ ≤ 4. With different initial values different sequences are generated. The advantage of this system is, i) the sequence is normally distributed in the interval of (0, 1) and is non-periodic. ii) The interval of (0, 1) can be divided into several sub intervals which correspond to different pixel bits for watermark embedding.

4 EXPERIMENTAL RESULTS AND ANALYSIS

Five 256 × 256 sized cover images Lena, Baboon, Barbara, Aeroplane and Milkdrop are used by the proposed FCL approach in the experiments, as shown in Figure 3. A binary image "Baby" of size 32×32 is used as the watermark image as shown in Figure 3. In the proposed FCL method, a = 2, b = 3 and c = 4 are chosen as three independent parameters of Arnold cat map. The initial watermark position (i,j) is chosen as (2, 0). The watermark pixel is embedded to the kth bit of pixel P(x,y) of the 2 level fuzzy wavelet image. The k value is determined by the subinterval of z_n generated by logistic map (4). The initial value of logistic map z_0 = 0.5 and μ is taken as 4 for the experiments. By this the watermark bits are embedded into 4^{th}, 5^{th}, 6^{th} or 7^{th} bits of the pixel P(x,y) in wavelet image randomly. Let the embedded watermark pixel be denoted as P'(x,y). if w(i, j) is the same as the kth bit of P(x,y), then P'(x,y) = P(x,y), i.e., the pixel value is kept unchanged; otherwise, the kth bit of P(x,y) is substituted by w(i,j). The procedure is repeated until all watermark pixels are embedded.

Peak Signal to Noise Ratio (PSNR) and Normalized Cross Correlation (NCC) are utilized to estimate the watermarked image quality. A quantitative estimation for the quality of extracted watermark image W'(x,y) with reference to the original watermark W(x,y) may be expressed as Normalized Cross Correlation (NCC) as given in Equation (5).The maximum value of NCC is one.

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$$NCC = \frac{\sum x \sum y W(x,y) W'(x,y)}{\sum x \sum y [W(x,y)]^2} \quad (5)$$

.

The PSNR is defined in Equation (6)

$$PSNR(dB) = 10 * \log\left(\frac{255^2}{MSE}\right)$$

$$MSE = \sum_{i=1}^{x} \sum_{j=1}^{y} \frac{(|P_{ij} - Q_{ij}|)}{M * N} \quad (6)$$

Here, P_{ij} is the pixel of the cover image, where (i,j) is the coordinate position, Q_{ij} is the pixel of the watermarked image, M and N represents the size of the image, where MSE is the mean square error between the original image and the distorted one. PSNR is often a useful tool to measure perceptibly level. It takes into consideration the importance of the human visual system and its characteristics and therefore it is more suitable for digital watermarking. A larger PSNR value indicates the fact that the discrepancy between the cover image and watermarked image is more invisible to the human eyes.

Figure 3 shows the original, watermarked, and extracted images with NCC and PSNR values. Figure 3 indicates that NCC coefficient is nearly one for all extracted watermarks, which indicate the quality of the watermarked image is not degraded by the FCL method. The PSNR values of Figure 3 clearly indicate the high robustness of the proposed FCL method. The proposed FCL method is experimented with different number of iterations n = 5, 10, 15, 20 and 25 and observed the quality statistical parameters of digital watermarking. By increasing number of iterations, there is no change in PSNR and NCC values. The security levels and authentication levels will be high, as the numbers of iterations are increased.

The proposed FCL method is also tested with various attacks such as Gaussian noise (15%), Blurring (3%), Cropping (3%), Rotation (4^0), Motion Blurring (2%), Filtering (3×3), Sharpening (5%) and Resizing (25%) on Lena image. Figure 4 and 5 shows the watermarked and extracted images with the above attacks. Table 1 and Table 2 show the PSNR and NCC values respectively with various attacks on the considered images. Table 1 and Table 2 clearly indicate the high robustness and image quality of the FCL method even in the presence of various attacks.

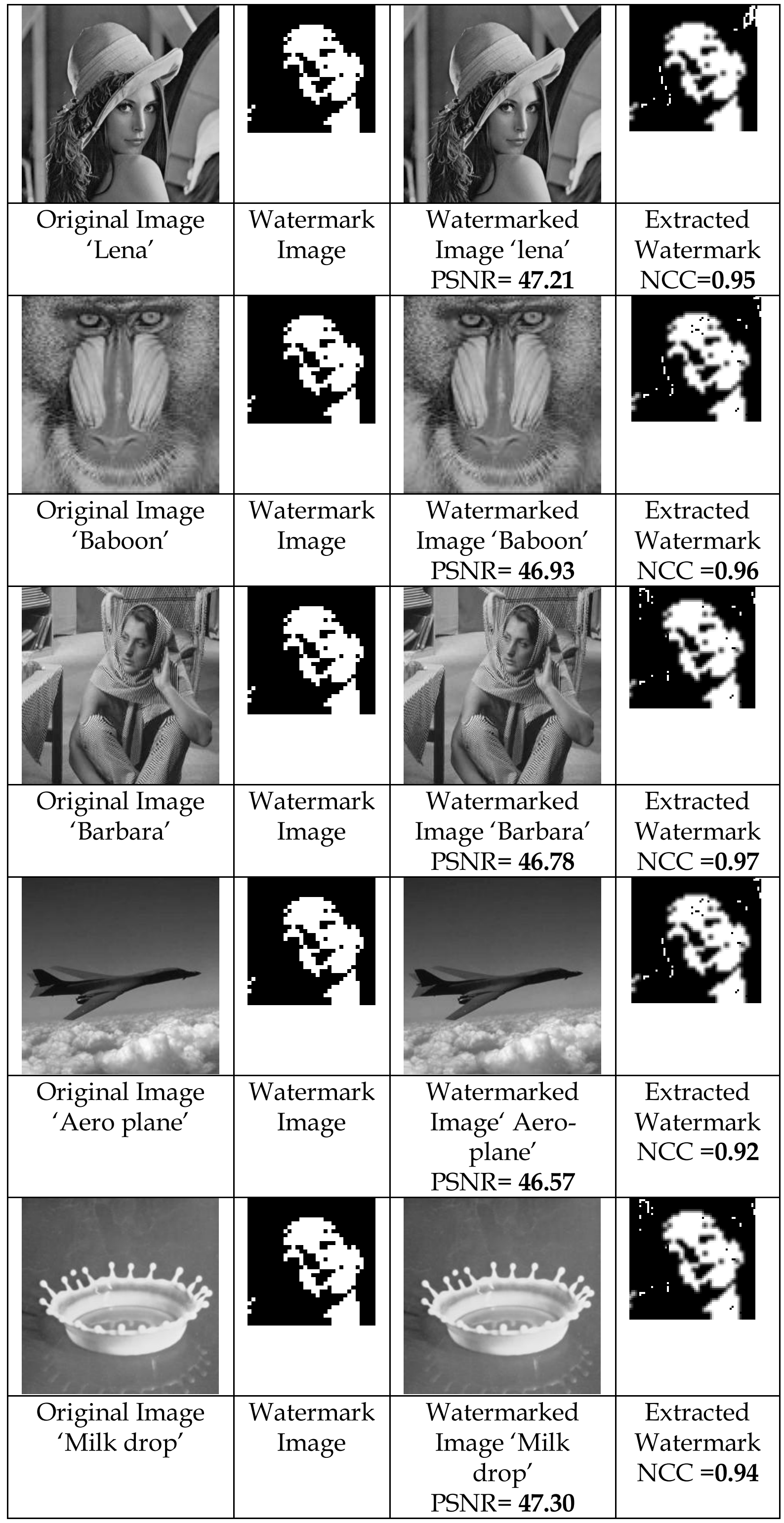

Fig. 3. Watermarked and Extracted images by the proposed FCL method with PSNR and NCC values

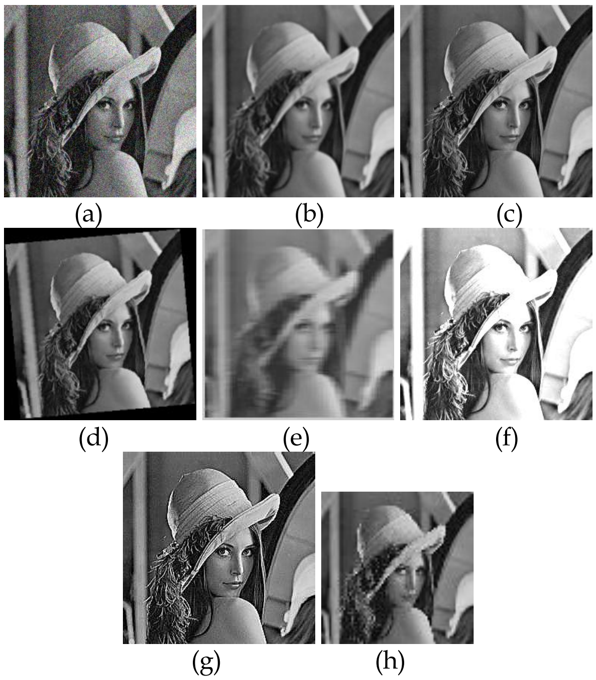

Fig. 4. watermarked image with various attacks by FCL method (a) Gaussian noise 15% (b) Blurring 3% (c) Cropping 3% (d) Rotation 40 (e) Motion Blurring 2% (f) Filtering (3×3) (g) Sharpening 5% (h) Resizing 25%

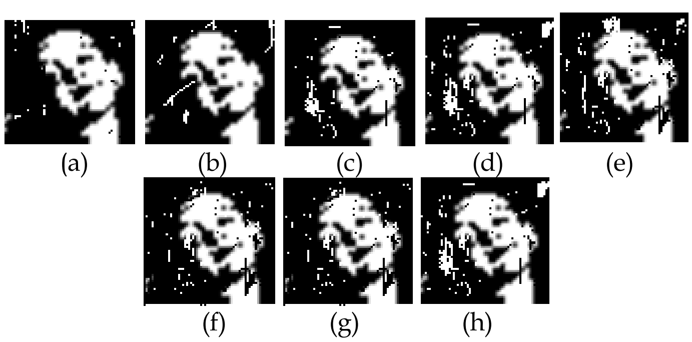

Fig. 5. Extracted watermark images with various attacks (a) Gaussian noise 15% (b) Blurring 3% (c) Cropping 3% (d) Rotation 40 (e) Motion Blurring 2% (f) Filtering (3×3) (g) Sharpening 5% (h) Resizing 25%

TABLE 1
PSNR VALUES WITH VARIOUS ATTACKS BY THE PROPOSED FCL METHOD

Type of Attack	**Lena**	**Baboon**	**Barbara**	**Aeroplane**	**Milkdrop**
	PSNR(dB)				
Gaussian noise 15%	44.59	44.60	45.12	44.34	44.28
Blurring 3%	43.56	43.56	43.04	44.10	43.67
Cropping 3%	41.18	41.45	41.37	40.12	42.01
Rotation 4^0	42.87	42.56	42.79	42.47	42.91
Motion Blurring 2%	40.45	40.38	40.29	40.55	40.26
Filtering (3×3)	45.89	45.67	45.20	45.38	45.82
Sharpening 5%	44.38	44.67	44.28	44.58	44.81
Resizing 25%	41.26	41.45	41.48	41.49	41.26

TABLE 2
NCC VALUES WITH VARIOUS ATTACKS BY THE PROPOSED FCL METHOD

Type of Attack	**Lena**	**Baboon**	**Barbara**	**Aeroplane**	**Milkdrop**
	NCC				
Gaussian noise 15%	0.82	0.81	0.83	0.81	0.82
Blurring 3%	0.79	0.80	0.79	0.78	0.79
Cropping 3%	0.71	0.72	0.73	0.71	0.72
Rotation 4^0	0.75	0.74	0.76	0.74	0.75
Motion Blurring 2%	0.70	0.71	0.69	0.70	0.69
Filtering (3×3)	0.87	0.88	0.86	0.87	0.86
Sharpening 5%	0.81	0.80	0.79	0.82	0.81
Resizing 25%	0.73	0.72	0.71	0.73	0.72

4.1 Comparison of the proposed FCL method with various other methods

The PSNR values of the proposed FCL method are compared with Xianyong Wu et.al method [24] and Rinaldi Munir et.al method [25] and results are furnished in the Table3. The results of Table 3 clearly indicated the efficacy of the proposed FCL method when compared to other two methods. Figure 6 shows a bar graph comparison between the proposed FCL method and other methods.

TABLE 3
COMPARISON OF THE PROPOSED FCL METHOD WITH VARIOUS OTHER METHODS

Test Images	**Xianyong Wu , et.al**	**Rinaldi Munir, et.al**	**Proposed FCL method**
	PSNR(dB)		
Lena	46.37	32.84	47.21
Baboon	46.12	33.65	46.23
Barbara	45.08	32.98	46.78
Aero plane	46.11	33.16	46.57
Milkdrop	46.69	32.76	47.30

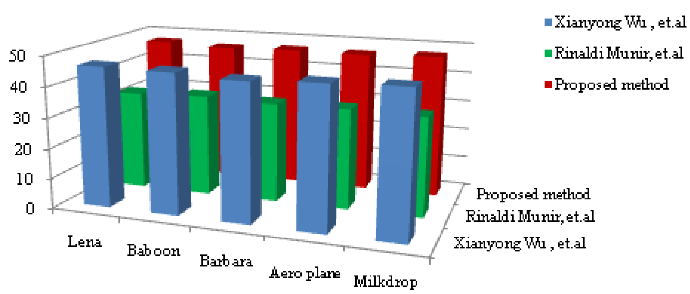

Fig. 6. Bar graph showing the PSNR values of the proposed FCL method with various other methods

5 CONCLUSION

The present paper proposed an integrated watermarking scheme called FCL with many excellent properties, such as the sensitive dependence on system parameters and initial conditions, no periodicity, pseudo-random property and topological transitivity, etc. These properties meet the requirements of watermarking, such as diffusion and mixing. The Fuzzy Wavelet (FW) scheme of step one eliminates the requirement of original image for the watermark extraction and overcomes the disadvantages of self reference schemes. The high PSNR value of the proposed integrated FCL method indicates that it is robust to various attacks. The high NCC value of the proposed FCL method with or without attacks indicates that an embedded watermark is still recoverable. Thus the proposed FCL method achieves high security, authenticity, robustness, good quality, with bulk data capacity, high data redundancy, and high sensitivity to secret keys even in the presence of various attacks.

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