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Contrast Based Color Watermarking using Lagrange Polynomials Interpolation in Wavelet Domain

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Abstract -Vigorous watermarking with unconscious detection is necessary to realistic copyright protection of digital images. Digital watermarking includes a number of approaches that are used to undetectably communicate the information by embedding it into the original data. The proposed robust and blind color based watermarking scheme is embeds color watermarks in color images using Langrage Polynomial Interpolation (LPI) in wavelet domain. Successful development of uniqueness of proposed method helps to develop a watermarking scheme that fulfills the requirement. The proposed watermarking technique embeds only the watermark key in the diagonal part of the image. The watermark is a color logo and it not going to embed into the image. Only a tiny quantity of information is required to extract the watermark key. From the watermark key easily can retrieved original color watermark from the watermarked image. The watermark key was generated by using chaotic mapping technique. Experimental results show that the proposed watermarking scheme is computationally uncomplicated and fairly robust and good quality image

Index Terms—chaotic mapping, wavelet, watermark key, Langrage Polynomial Interpolation (LPI)

I. INTRODUCTION

The advancement in digital communication technology and the growth of computer power, storage, the difficulties in wide distribution of information over the World Wide Web (www) increasing rapidly. The protection of intellectual property rights has become increasingly important [1]. These information, which include images, video, audio, or text are stored and transmitted in a digital format. Information stored in digital format can be easily copied without loss of quality and efficiently distributed [2]. The color image watermark is then introduced to solve this problem. A color watermark is an invisible signature embedded inside an image to show authenticity and ownership. An effective color watermark should be invisible to prevent obstruction of the original image. It should be statistically inseparable from the host image, robust enough to resist any manipulations such as filtering, additive noise, and compression [3]-[4] while preserving the image quality.

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Color watermarking methods- Spatial domain (like LSB) and transform domain (like DCT, DWT) methods. The spatial domain is the normal image space, in which a change in position in image directly projects to a change in position in space [4]. Transform Domain Method produce high quality watermarked image by first transforming the original image into the frequency domain by the use of Fourier Transform, Discrete Cosine Transform (DCT) or Discrete Wavelet transforms (DWT). Current color image watermarking techniques makes use of frequency-domain transforms include DWT [5]. However, DWT has been used in color image watermarking more frequently due to its excellent spatial localization and multi-resolution characteristics, which are similar to the theoretical models of the human visual system [6]. Further performance improvements in DWT-based color image watermarking algorithms could be obtained by increasing the level of DWT.

This paper describes the well-organized and healthy color watermarking schemes in an attempt to get better watermark strength to attacks. The proposed scheme is not embedding watermark in the cover image. The main advantage of this paper is embedding watermark key using Lagrange Polynomials Interpolation. The proposed scheme embeds a watermark key into a 2nd level wavelet color image of B components. Experimental results demonstrate that there is high degree of perceptual similarity between original image and watermarked image. Further, the proposed method resists different types of attacks. The rest of the paper is organized as follows. Section 2 briefly reviews about DWT and Lagrange Polynomials Interpolation. Section3 describes the proposed color watermarking method and in section 4, the experimental results are discussed. Finally, some conclusions are drawn in section 5.

II. DISCRETE WAVELET TRANSFORMATION

The Discrete Wavelet Transform (DWT) [7] is currently used in a wide variety of signal processing applications, such as in audio and video compression, removal of noise in audio, and the simulation of wireless antenna distribution. Discrete Wavelet decomposition of image produces the multi-resolution representation of image. A multi-resolution representation provides a simple hierarchical framework for interpreting the image information. At different resolutions, the details of an image generally characterize different physical structures of the image. At a coarse resolution, these details correspond to the larger structures which provide the image context. The following section briefly reviews about Two Dimensional Wavelet Transformation [8]-[9]. The original image I is thus represented by set of sub images at several scales;{{Ld,Dnl}|l , , ,n , , , ..., d}, which is multi-scale representation with depth d of the image I. The image is represented by two dimensional signal functions; wavelet transform decomposes the image into four frequency bands, namely, the LL_1, HL_1, LH_1 and HH_1 bands. H and L denote the highpass and lowpass filters respectively. The approximated image LL is obtained by lowpass filtering in both row and column directions. The detailed images LH, HL and HH contain the high frequency components. To obtain the next coarse level of wavelet coefficients, the sub- band LL_1 alone is further decomposed and critically sampled. Similarly LL_2 will be used to obtain further decomposition. By decomposing the approximated image at each level into four sub images forms the pyramidal image tree [10]. This results in two-level wavelet decomposition of image as shown in the Figure 1. Embedding watermarks in these regions allow us to increase the robustness of our watermark, at little to no additional impact on image quality. The fact that the DWT is a multi-scale analysis can be used to the watermarking algorithm's benefit.

Fig.1 Layout of individual bands at second level of DWT decomposition

III. WATERMARKING USING MATHEMATICAL APPLICATIONS

A. *Chaotic system*

B. *Arnold cat map*

The selected Red Component of proposed scheme is shuffled using Arnold cat map, to achieve further authentication and security. 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 [11]. 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).

$$x_n+1 = (x_n + y_n) \bmod 1,$$
$$y_n+1 = (x_n + 2y_n) \bmod 1 \qquad (1)$$

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).

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

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 [12]. 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).

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

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.

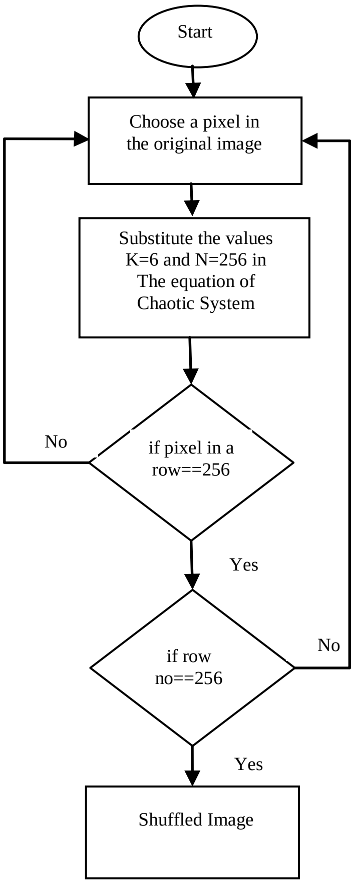

Fig. 2. Process of Chaotic System

C. *Interpolation Polynomial*

In mathematics, a polynomial is an expression of finite length constructed from variables (also known as indeterminate) and constants, using the operations addition, subtraction, multiplication, and non-negative integer exponents [13]. The exponents are only being 0, 1, 2, 3… etc. It cannot have an infinite number of terms. Polynomials appear in a wide variety of areas of mathematics and science. For example, they are used to form polynomial equations which encode a wide range of problems from elementary word problems to complicated problems in the sciences. The derivative of the n degree polynomial is given by Equation (4)

$$a_n x^n + a_{n-1} x^{n-1} + \cdots + a_2 x^2 + a_1 x + a_0 \qquad (4)$$

D. *Lagrange Interpolation Polynomial*

Lagrange Interpolation formula is one of the most commonly used interpolation functions and its computation charge is inferior to the majority interpolation functions. An interpolation is defined as a function which contains independent variable and a number of parameters. When constructing interpolating polynomials, there is a tradeoff between having a better fit and having a smooth well-behaved fitting function [13]-[14]. The more data points that are used in the interpolation, the higher the degree of the resulting polynomial, and therefore the greater oscillation it will exhibit between the data points. Therefore, a high-degree interpolation may be a poor predictor of the function between points, although the accuracy at the data points will be 'perfect'. The Lagrange Interpolating Polynomial can be defined as P(x), which is given in the Equation (5)

$$p(x) = \sum_{i=1}^{n} p_i(x)$$

where $$p_i(x) = y_i \prod_{k=1, k \neq i}^{n} \frac{x - x_k}{x_i - x_k} \qquad (5)$$

Written explicitly,

$$p(x) = \frac{(x - x_2)(x - x_3) \ldots (x - x_n)}{(x_1 - x_2)(x_1 - x_3)(x_1 - x_n)} y_1 + \frac{(x - x_1)(x - x_3) \ldots (x - x_n)}{(x_2 - x_1)(x_2 - x_3)(x_2 - x_n)} y_2$$

$$+ \ldots + \frac{(x - x_1)(x - x_2) \ldots (x - x_{n-1})}{(x_n - x_1)(x_n - x_2)(x_n - x_{n-1})} y_n$$

or

$$p(x) = y_1 L_1^{(n)}(x) + y_2 L_2^{(n)}(x) + \ldots + y_n L_n^{(n)}(x) \qquad (6)$$

$L_1^{(n)}, \ldots. L_2^{(n)}$ stand for the parameters in Lagrange Interpolation formula that can be computed by n+1 given points, as showed in Equation (6).

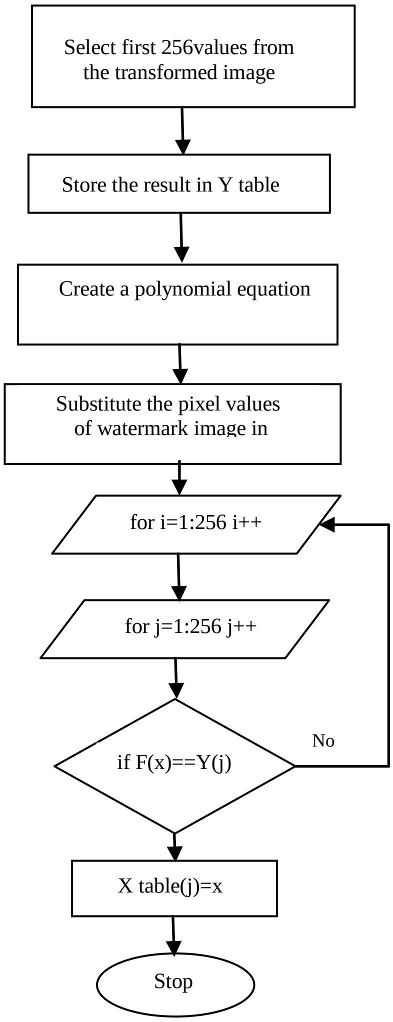

Fig. 3 Flow chart of Lagrange's Polynomial Interpolation

IV. PROPOSED WATERMARKING TECHNIQUES

This paper proposed an original approach for DWT domain vigorous invisible embedding and extraction through a exclusive approach for creation of a compound color image to serve as the successful watermark. One of the most significant skin texture that make the identification of images possible by humans is color. Color is a property that depends on the reflection of light to the eye and the processing of that information in the brain. Usually colors are defined in three dimensional color spaces These could be RGB (Red, Green, and Blue), HSV (Hue, Saturation, and Value) or HSB (Hue, Saturation, and Brightness). The last two are dependent on the human perception of hue, saturation, and brightness [7]. Color represents the distribution of colors within the entire image. This sharing includes the amounts of each color, but not the locations of colors. The complete process of the proposed method is represented in the Fig 4.

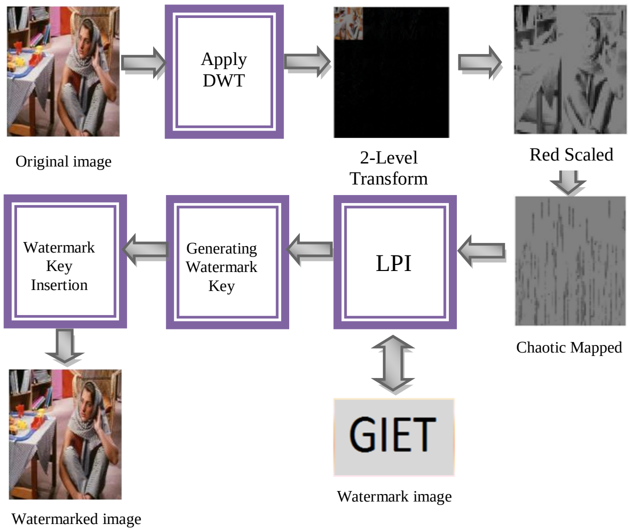

Fig. 4 Overview of Proposed Color Watermarking Scheme

A. Embedding Watermark Procedure

The embedding algorithm uses color image as cover and gray-scale image as watermark as shown in Figure 5. The color image is decomposed into Red, Green and Blue channels [15]. The proposed method is considered R channel to generate the watermark key. Apply chaotic system into R Channel to get scrambled image. Consider n pixel value from the scrambled image and Store them in Table as given in Figure 6.

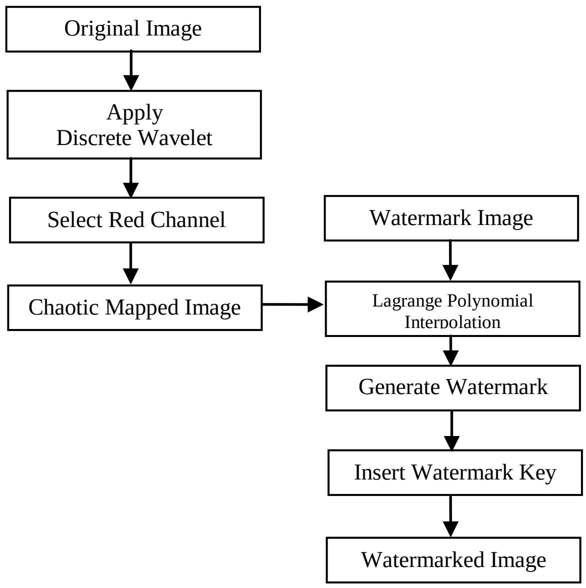

Fig.5 Block diagram of Watermark Embedding Process

1	2					N-1	N
129	55	…	…	…	…	104	54

Fig.6 Table

1	2					N-1	N
45	98	…	…	…	…	244	75

The Figure7 gives the generational of key of n-pixels, arranged in a similar way to above table.

Fig.7 Watermark key table of N pixels

The proposed method derived a polynomial equation for construction of Watermark key table using mod 255 operator as shown in Equation (7)

$$K(x) = a_n x^n + a_{n-1}x^{n-1} + \cdots + a_1 x + a_0 \pmod{257} \qquad (7)$$

This equation generates a key for each x value ranging from 1 to 255. In the Equation (7) $a_n, a_{n-1}, \ldots a_0$ is the pixel values of watermark represented in Watermark key table. Watermark key table is generated by matching the obtained values of function K(x) with table. If there exists an x, in $K(x)=T_j$ then store x to the j^{th} entry of Watermark key table as shown in Figure 8.

Fig.8 Function values of Watermark key table

The Watermark key table consists of n-pixels, arranged in a similar way to table. The advantage of the Watermark key table is it acts as an encrypted watermark. The novelty of the

1	2	3				63	64
Q_1	5	Q_3	…	…	…	Q_{63}	Q_{64}

proposed method is by using LPI with table and Watermark key table, the proposed method generates the original watermark. The watermark key is converting into binary and inserted in to 6th LSB of 2nd level DWT of B Channel. Apply inverse wavelet to obtain watermarked image.

B. Extracting Watermark Procedure

Extraction procedure is a nature blind extraction which uses only watermarked color image as input. The watermarked color image is decomposed into Red, Green and Blue channels. The DWT is applied on the RGB channel of watermarked color image, which produces the frequency subband coefficients. On this subband apply DWT to obtain the second level decomposition [17]. From B channel get watermark key and using LPI get watermark image. Block diagram of entire extraction process is given in Figure 9.

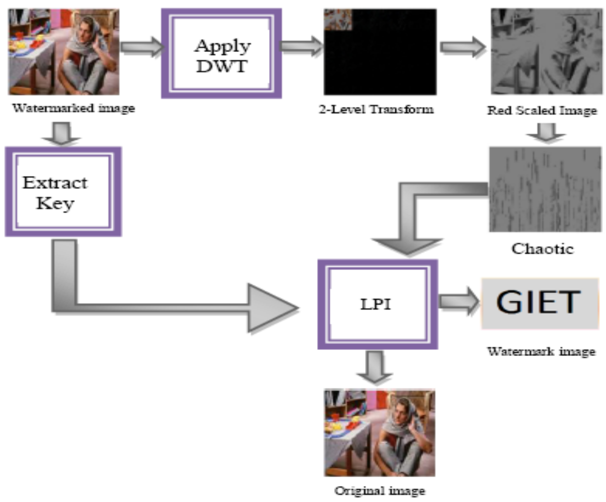

Fig.9 Block diagram of Extracting Watermark

V. RESULTS AND DISCUSSION

The proposed method is experimented on all 8 images "Lena", "Barbara", "Monalisa", "F-16", "Brain", "Gold Hill", "Lake" and "Bricks" of size 256×256 of Figure 10. The gray watermark considered for the experiments is logo 'GIET' of size 16×16 as shown in Figure 11.

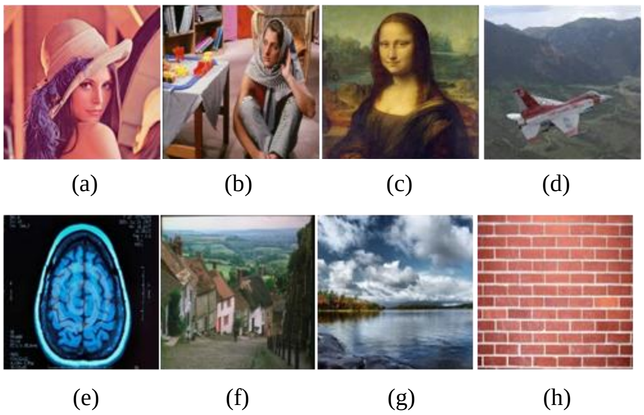

Fig.10 Original Images of (a) Lena (b) Monalisa (c) Barbara (d) F-16 (e)Gold Hills (f) MRI Brain (g) Lake (h) Brick

Fig.11 Watermarked image (a) GIET

The original images are transformed into 2-level using Discrete Wavelet Transform (DWT) as shown in Figure 12. Figure 13 represents the watermarked images using our proposed method.

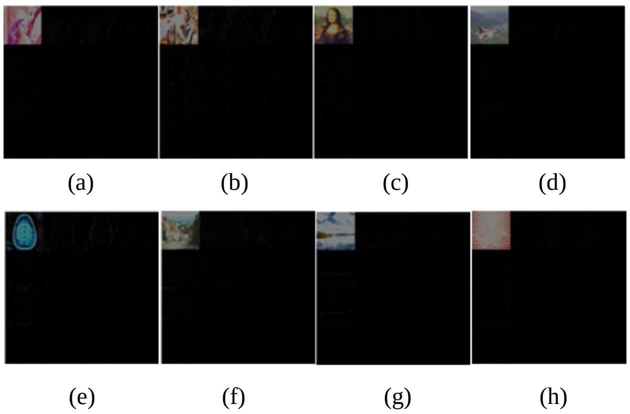

Fig.12 Transformed Images of (a) Lena (b) Monalisa (c) Barbara (d) F-16 (e)Gold Hills (f) MRI Brain (g) Lake (h) Brick

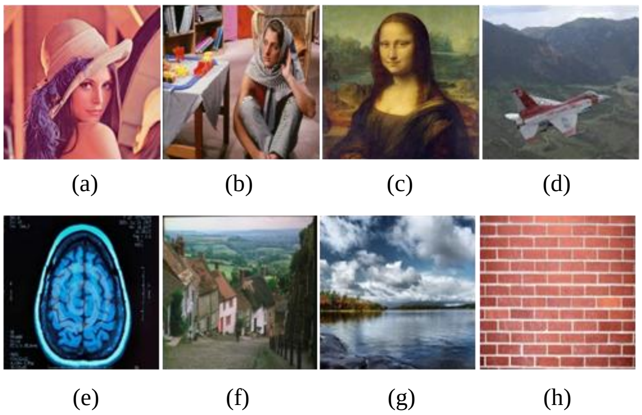

Fig.13 Watermarked Images of (a) Lena (b) Monalisa (c) Barbara (d) F-16 (e)Gold Hills (f) MRI Brain (g) Lake (h) Brick

Table 1 and Table 2 show the PSNR and NCC values for all the 8images. The PSNR values for the different images will be calculated using the formula

$$\text{PSNR}=10\log_{10}\frac{A^2}{\frac{1}{n\times m}\sum_{i=1}^{n}\sum_{j=1}^{m}[f(i,j)-f'(i,j)]^2}$$

$$\text{MSE}=\sum_{i=1}^{x}\sum_{j=1}^{y}\frac{(|A_{ij}-B_{ij}|)^2}{x*y}$$

PSNR is the acronym for Peak Signal to Noise Ratio whereas MSE is Mean Square Error. The experiments are conducted on nearly 8 images. These images are of color images and the watermark image is used as a common image. From the Table 1 and Table 2 it is clearly evident that all the images shows high PSNR and NCC values which indicates high robustness and high quality of image after watermark insertion.

Table 1. PSNR values of proposed method

Original Image with size (256 ×256)	PSNR
Lena	38.47
Monalisa	38.71
Barbara	39.03
F-16	38.45
Gold Hill	39.17
Brain	38.96
Lake	39.04
Bricks	38.95

Table 2. NCC values of proposed method

Original Image with size (256 ×256)	NCC
Lena	0.98
Monalisa	0.97
Barbara	1
F-16	1
Gold Hill	0.98
Brain	0.99
Lake	0.98
Bricks	0.99

VI. CONCLUSION

In this paper, a Color image watermarking using Wavelet Transform based on RGB Channel has been proposed. This proposed method applies DWT in the RGB channel and get pixels from scrambled 2nd level DWT coefficient using chaotic system. The frequency domain technique are good for applications where exact watermark need to be extracted and channel do not consists any noise. In the proposed color digital watermarking method, the watermark key bits are inserted in the image in such a way that they cannot be identified by unauthorized persons and show resilience against attempts to remove the hidden data. This method is used in implementing the robust watermarking. There are several mathematical applications like Chaotic System, polynomial and Lagrange's Interpolation Polynomial. The extraction of watermark is completely based on the reference table. There will be no further watermarking possible if the values in the reference table are lost or modified. Since we are extracting the values of the watermark from the reference key and the watermark image we can say that it is a blind watermarking technique. Various experiments have been conducted by implementing this scheme and the results suggested that the implemented algorithm is the best and it's a highly robust method. Furthermore, it is also a secure plan, only the one with the correct key can extract the watermark signal.

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