Abstract—The rapid growth of image processing softwares and advancement in digital cameras has given rise to large amount of doctored images with no obvious traces. When altering an image like copy-paste or splicing to conceal traces of tampering, it is often necessary to resize the pasted portion of the image. The resampling operation may highly likely disturb the underlying inconsistency of the pasted portion, that can be used to detect the forgery. In this paper, an algorithm is proposed that can blindly detect rescale operation and estimate the rescaling factor in zoom-in or zoom-out using properties of the zero-crossings of the second difference of the tampered image. Experimental results have proved the validity of the algorithm under different interpolation schemes.

Keywords: Image manipulation detection, passive authentication, image interpolation, discrete fourier transform

I. INTRODUCTION

Digital image forgery is the process of tampering the original image in order to alter the information. In the modern age, rapid growth of image processing softwares like Adobe photoshop, GIMP and the advancement in digital cameras has given rise to large amount of doctored images with no obvious traces of tampering, generating a great demand for automatic forgery detection algorithms in order to validate the originality of candidate images. Verifying the authenticity of images and detecting traces of tampering requiring no prior knowledge of the image content or any embedded watermarks is an important research field. A good forgery detection algorithm should be passive or blind, requiring no prior knowledge of the image content or any embedded watermarks.

Image forgery detection algorithm aims to verify the trustworthiness of a digital image. Image authentication solution is classified into two types. (1) Active forgery detection and (2) Blind or passive forgery detection [1] - [2]. An active forgery detection technique, such as digital watermarking or digital signatures, uses a known authentication code embedded into the image content before the images are sent through an unreliable public channel. However, this method requires special hardware or software to insert the authentication code inside the image before the image is being distributed. Passive or blind forgery detection technique uses the received image only for assessing its integrity. It is based on the assumption that tampering may highly likely disturb the underlying statistical property or image consistency of a natural scene image which introduces new artifacts resulting in various forms of inconsistencies. These inconsistencies can be used to detect the forgery.

In most of the tampered images rotation, rescaling and contrast enhancement are often involved and blind image forgery detection algorithm aims to detect these alterations in image. In copy-paste or image splicing forgery, certain transformations such as scaling, skewing or rotation (i.e. geometrical transformations) are very likely to be used including a frequent use of rescaling. Image rescaling may be accomplished in post-processing using software, and can also be done directly within the camera having a digital zooming function which is achieved with some kind of pixel interpolation.

In this paper, we propose a method to detect global rescaling and estimate the image rescaling factor based on properties of the zero-crossings of the second difference of the tampered image first described in [3]. The technique is applicable to different interpolation schemes.

II. RELATED WORK

The resampling processes do not leave perceivable artifacts, they introduce specific periodic correlations between image pixels which then can be used to detect image manipulation. A \( \frac{M}{N} \) resampling of a \( 1 - D \) discrete sequence \( x[n] \) involves following steps [4]:

1) Upsample: Create a new signal \( x_u[n] \) by inserting \( M - 1 \) zeros after every \( x[n] \).
2) Interpolate: Convolve \( x_u[n] \) with a low pass filter:
   \[ x_i[n] = x_u[n] * h[n] \].
3) Decimate: Collect every \( N^{th} \) sample: \( y[n] = x_i[Nn], k = 0, 1, \ldots \).

Resampling in two dimensions can be extended in both spatial directions. Different types of resampling algorithms (linear, cubic) differ in the form of the interpolation filter \( h[n] \) in step 2. In image processing applications, the most widely used interpolation filters are bi-linear and bi-cubic; hence we investigated the properties of a resampled signal, which uses these filters.

Several passive techniques for image authentication based on resampling detection and rescale factor estimation have been already reported. A method is presented to find the rescaling traces hidden in any portion of an image without resorting to a reference image by using expectation maximization (EM) [4]. Gallagher [5] proposed a rescaling detection
method which exploits periodicity in variance function of their second-order derivative in the interpolated image for detecting the traces of rescaling. This periodicity is computed using discrete Fourier transform (DFT) of an averaged signal obtained from the second derivative of the investigated signal. Author verified that interpolation makes the signal and its derivatives periodical,

\[ V\{ D^{(n)} f_0(x + \mu \Delta x) \} = V\{ D^{(n)} f_0(x) \}, \quad \mu \in Z \]  

(1)

where \( D^{(n)} f(x) \) is \( n \)th derivative of \( f(x) \) and \( V \) is the variance. From eq. (1) it is clear that \( V\{ D^{(n)} f_0(x) \} \) is periodic over \( x \) with a period \( \Delta x \) as the sampling rate. This periodicity depends on the interpolation kernel used. The commonly used methods are nearest neighbor, bilinear, bi-cubic and B-spline interpolations.

In [6], a blind and automatic method to estimate scaling factors of some image region of interests (ROI) is proposed based on the fact that interpolated signals and their derivatives contain specific detectable periodic properties. The method also uses radon transformation to find presence of affine transformation. Multidimensional relation between the signal and its derivative has a specific periodicity due to interpolation. It is given by,

\[ V\{ D^{(n)} f_0(x + \mu \Delta x, y + \mu \Delta y) \} = V\{ D^{(n)} f_0(x, y) \}, \quad \mu \in Z \]  

(2)

Detection of resampling in pixel domain is proposed in [3]. Additionally, frequency domain techniques are employed to localize the portion of the image that has been tampered with. Pixel domain techniques are based on properties of second difference. A binary sequence \( p[k] \) is constructed from the sequence of second difference \( x''[k] \) to detect resampling as given below,

\[ p[k] = 1 \quad \text{if} \quad x''[k] = 0 \]
\[ = \quad 0 \quad \text{otherwise} \]  

(3)

DFT of eq. (3) will display distinct peaks showing the presence of periodic zeros in the second difference. Another method is based on zero crossings of the second difference of a resampled sequence which exhibits periodicity. The second difference is constructed and zero crossings of the obtained sequence is computed. A binary sequence is constructed using the equation below,

\[ p[k] = 1 \quad \text{if} \quad x''[k] > 0 \quad \text{and} \quad x''[k+1] \leq 0 \]
\[ = 1 \quad \text{if} \quad x''[k] < 0 \quad \text{and} \quad x''[k+1] > 0 \]
\[ = 0 \quad \text{otherwise} \]  

(4)

However authors have not paid attention to rescale factor estimation issue. We propose a method based on equation 4 which estimates rescale factor of the resampled image.

A method is proposed to detect resampled imagery which is based on examining the normalized energy density present within windows of varying size in the second derivative of the image in the frequency domain and exploiting this characteristic to derive a 19-D feature vector that is used to train a support vector machine (SVM) classifier [7]. Another method is presented for detecting interpolation by using the periodicity characteristics hidden among the row (or columns) of the image [8]. The core of the algorithm is use of correlation coefficients based on the observation that the correlation coefficients of the row (or column) vectors vary periodically in resampled image. A blind and efficient method which is capable of finding traces of resampling and interpolation based on singular value decomposition (SVD) is proposed in [9] - [10]. The specific statistical changes brought into the linear dependencies among image pixels and image rows/columns due to tampering are analyzed using SVD.

In [11], a technique is developed to detect doctored and manipulated images using three features, the binary similarity measures between the bit planes, the image quality metrics applied to denoised image residuals and the statistical features obtained from the wavelet decomposition of an image. Image rescaling and rotation angle detection and parameter estimation to detect fake object into images is developed in [12]. In addition to this, forged areas are detected in an image that have been rescaled and/or rotated by dividing image into blocks. Multiple geometrical operations repeated zooming, repeated rotation, rotation-zooming, or zooming-rotation, were also determined from different behaviours of the peaks due to rescaling and rotation. Resampling detection in re-compressed JPEG images is investigated in [13]. Authors demonstrated how blocking artifacts in re-compressed images can actually help to increase detection performance.

III. PROPOSED ALGORITHM FOR RESCALE DETECTION AND ESTIMATION

In this section, a method capable of detecting the traces of resampling and scaling factor estimation using properties of the zero-crossings of the second difference is proposed. Suppose the image size is \( M \times N \). The algorithm is described below:

1) Pre-processing: The input RGB image is converted into the grayscale image and Y component is also extracted after YCbCr conversion.

2) Second difference computation: Obtain the second difference of Y component. The second difference of the input test image \( f(i,j) \) is computed with the following difference equation.

\[ S_n(i,j) = 2f(i,j) - f(i,j+1)f(i,j-1) \]  

(5)

3) Computing zero-crossings of the second difference: Find the zero crossings of the obtained sequence using step (2). A binary sequence is constructed using eq. (4). Compute average over columns.

4) Computing the DFT: Calculate DFT \( F(u) \) using FFT of the binary sequence obtained in step (3).

5) Search for the periodicity and peak detection: To detect the periodicity, the magnitudes of FFT \( |FFT f(x)| \) are all combined and plotted together to obtain the output. To automatically detect the resampling peaks \( f_x \), a simple threshold-based peak detector searching for the local maximum (peaks \( n \) times greater than a local average magnitude) is used.

IV. SIMULATION RESULTS AND DISCUSSION

In the experiment, we took 20 uncompressed color images of size \( 384 \times 512 \) from the UCID database [14]. After extracting Y component these images were rescaled using linear and bicubic interpolation methods with resize factors ranging from 1.2 to 5 with step size of 0.2. Database consists of total 800
test images with various sizes. All of our experiments are carried out in Matlab environment. Calculating DFT of the zero crossing of the second difference of an interpolated signal to get a spectral representation, the frequency \( f_n \) at which a scaling factor-related peak occurs can be found.

\[
f_n = \begin{cases} 
1 - \frac{1}{r} & 1 < r \leq 2 \\
\frac{1}{r} & r > 2
\end{cases}
\]

(6)

Where \( r \) is rescale factor.

The original image is rescaled by 1.6 resulting in a bigger image of \( 615 \times 812 \) using bilinear and bicubic interpolation. The averaged horizontal spectrum of the zero crossing of the second difference of the rescaled image is shown in the Fig. 1. It is evident that peaks signifying rescaling are strong and clearly detectable. Peaks appeared at \( f_n = 0.376 \), giving an estimated rescaling factor of 1.602 from eq. (6), which is very close to the actual value. Another example shows spectrum of rescaled image with rescale factor of 4.8 using bicubic interpolation scheme in Fig. 2. Here peak appears at 0.208 which results in rescale factor 4.8. The detection and estimation process was based on the global rescale operation. Table I-VI show the detection accuracy (%) as a function of different scaling factors using bilinear and bicubic interpolation for grayscale, G component and Y component image respectively. The detection accuracy is close to 100%. G component is extracted from RGB image and Y component is extracted by converting input RGB into YCbCr image. The algorithm performs better in case of G and grayscale images as compared to Y image.

In this experiment, it is observed that the detection and estimation is nearly perfect for scaling factors within the specified range compared to algorithm given in [9]. Fig. 4 and 5 show DFT magnitude corresponding rescale factor 4.8 in case of bilinear and bicubic interpolation methods. Bilinear interpolation generates stronger peaks as compared to bicubic interpolation. Bicubic interpolation generates less spikes compared to bilinear. It is also observed that, algorithm presented is better when detecting images resized using bilinear method. A. Gallagher’s algorithm [5] cannot detect images resized by factor 2 where phase is preserved because of the second order derivative. Our algorithm is better when detecting images resized by ratio 2 as shown in Fig. 3. When rescale factor =1.8, bilinear method produces multiple peaks with one prominent peak which is used to estimate rescale factor where in bicubic produces a single peak.

V. CONCLUSION

Blind method for global rescale operation detection based on zero crossings of the second difference of the tampered image and estimation is presented in this paper. In comparison with active approaches, blind approaches do not need any explicit prior information about the image. Resampled signal exhibits a periodicity which is used to detect the presence of resampling operation. The method presented in this paper detects rescale operation and correctly determines most of the rescale factors in presence of linear and bicubic interpolation schemes. It works for a variety of rescale factors. The method does not need complex computing process and the simulation results over a large set of images indicate the validity of the proposed scheme. Our future work aims to analyze the effect of JPEG compression on the detection of rescale operation.

REFERENCES

TABLE I. DETECTION ACCURACY (%) AS A FUNCTION OF DIFFERENT SCALING FACTORS USING BILINEAR INTERPOLATION FOR GRAYSCALE IMAGE

<table>
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TABLE II. DETECTION ACCURACY (%) AS A FUNCTION OF DIFFERENT SCALING FACTORS USING BICUBIC INTERPOLATION FOR GRAYSCALE IMAGE

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TABLE III. DETECTION ACCURACY (%) AS A FUNCTION OF DIFFERENT SCALING FACTORS USING BILINEAR INTERPOLATION FOR G COMPONENT IMAGE

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Fig. 3. Pronounced spike occur at normalized frequency of 1/2, with the estimated rescale factor 2

Fig. 4. Magnitude spectrum for rescale factor = 4.8 using bilinear interpolation


TABLE V. Detection accuracy (%) as a function of different scaling factors using bilinear interpolation for Y component image

<table>
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TABLE VI. Detection accuracy (%) as a function of different scaling factors using bicubic interpolation for Y component image

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Fig. 5. Magnitude spectrum for rescale factor = 4.8 using bicubic interpolation