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Robust First Quality Factor Estimation For Double Compressed and Resized Images

Vijayakumar Kadha
Dept. of ECE
NIT, Rourkela, Odisha
vijju.friend@gmail.com

Santos Kumar Das
Dept. of ECE
NIT, Rourkela, Odisha
dassk@nitrkl.ac.in

***Abstract*—The ability to identify tampering in JPEG images has become increasingly significant due to the high usage of JPEG as a compression technology. In doubly compressed and resized (DCR) images, this paper revisits the state-of-the-art resampling factor estimate and estimation of primary quality factor. As a result of the recent findings in the literature, the proposed technique improves existing approaches for analyzing double JPEG compression in the presence of resizing in between two compressions. By utilizing the period of Welch Power spectral density (PSD) of reverse resized image to estimate primary quality factor which is an important forensic clue of processing history of an image. Empirically find the nonlinear relationship between the first quality factor and location of the most prominent peak, which is the period of DC histogram of the first compression by utilizing Welch PSD analysis. Experimental validation of the proposed method is carried out on several JPEG images, and comparing with existing state-of-the-art methods reveals that the proposed method performs better.**

***Index Terms*—Digital image forensics, Double JPEG compression, Primary quality factor, Resizing factor**

I. Introduction

Today, high popularity of the digital era, one can easily manipulate digital data due to the easy availability of various editing software tools distributed on the internet. In turn, this situation creates a great demand for information forensics to determine the origin of digital image content and processing history. Many forensic approaches have been proposed during the last decade to determine the authenticity or integrity of images [1].

Among them, considerable attention has to be paid to analyzing JPEG traces since most image processing tools and digital cameras are widely used JPEG format as a lossy compression standard. Generally, it is difficult to analyze traces in image compression due to blocking artifacts left by this encoding operation. For the detection of image resampling in double JPEG compressed images, spectral analysis methods are used to estimate the resampling factor and first quantization matrix. Furthermore, these parameters are used to reconstruct the history of an image which will be helpful in detailed forensic analysis.

Several techniques are proposed to classify remote sensing images using the double feature extraction hybrid deep learning approach and image thinning technique [2], [3]. Moreover, some of the techniques has been proposed for detecting aligned and non-aligned [4], [5], estimating primary quantization matrix [6]–[8] in case of double JPEG compression scenario. Most of the spectral methods [9]–[12] are reported that the most prominent peak in spectrum location is considered to estimate resampling factor in uncompressed images. However, they may fail in compressed images since JPEG peaks will dominate resampling peaks for a high compression rate. A promising approach is the one introduced by Bianchi and Piva [13] to estimate resizing factor in between two compressions and the primary quality factor of the first compression. By exploiting integer periodicity maps (IPM) as a feature, a reverse engineering technique on double compression has been used to verify the near lattice distribution property (NLDP).

In [14], the resizing factor estimation is done by utilizing the most prominent peak obtained in Welch PSD analysis of DC coefficients histogram on reverse resized double compressed image. Further, with theoretical analysis, primary quality factor estimation is done in [15] by utilizing the estimated algorithm presented in [13]. In the previous approaches, the resizing and first quality factor estimation was done on DCR images without suppressing blocking artifacts obtained due to JPEG compression. These blocking artifacts interfere with resampling peaks, and this leads to incorrect estimation. However, these approaches have several limitations in real-world scenarios. Especially, primary quality factor estimation in the presence of resampling between two compressions erases the clues left by the previous compression. To mitigate this problem, one must determine an efficient primary quality factor estimator to find the processing history of the image.

Motivated from this shortcoming, an efficient deblocking technique by adding a suitable amount of Additive White Gaussian Noise (AWGN) to denoise the DCR image. Additionally, a modified estimation algorithm is proposed to estimate candidate resizing factors which are further utilized to estimate the first quality factor and better performance than state-of-art methods.

II. Problem Formulation

Let 'I' be the uncompressed image undergoes through first JPEG compression with quality factor QF_1 and decompressed denoted by 'I_{SC}'.

$$I_{SC} = IDCT(DQ(Q(DCT(I)))) \qquad (1)$$

where DCT is 8×8 block DCT and $Q(.)$ and $DQ(.)$ are quantization and dequantization process and IDCT is 8×8 block inverse DCT. Now the image I_{SC} resized with resizing factor λ is expressed in practice in rational form $\lambda = \frac{p}{q}$ with transformation matrix A_λ forms single compressed and resized (SCR) image.

$$I_{SCR} = A_\lambda * I_{SC} \tag{2}$$

Further, the resized image is compressed again with with second quality factor QF_2 and decompressed denoted by I_{DCR} is referred as double compressed and resized (DCR) images.

$$I_{DCR} = IDCT(DQ(Q(DCT(I_{SCR})))) \tag{3}$$

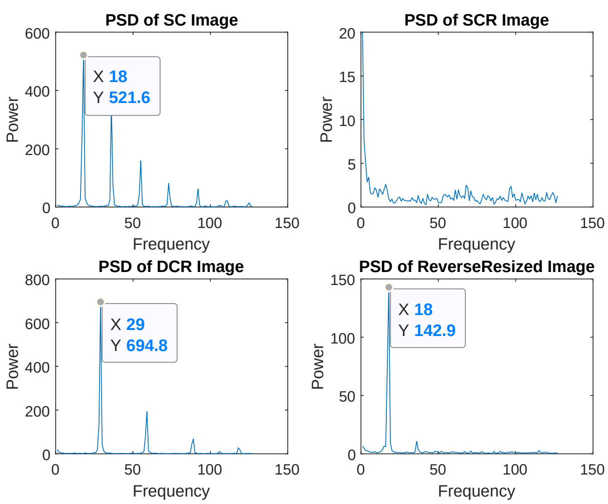

Fig. 1. Welch PSD of DC Coefficients of Single Compressed, Single Compressed and Resized, Double Compressed and Resized, Reverse Resized Image. (Image r5d3acff9t.TIF from RAISE Dataset is taken and double compressed with $QF_1 = 50$, $QF_2 = 70$ and $\lambda = 1.5$
)

As our study shows in Fig. 1 that Welch PSD of histogram of DC coefficients has monotonically decreased and follows Gaussian distribution [21] with periodic nature where the fundamental period depends upon Quality factor used for compressing the image. By evaluating Discrete Fourier Transform (DFT) we can obtain period of DC histogram.

$$F(Q) = \sum_n d(n)\, e^{\frac{-j2\pi n}{Q}}, Q \in \mathbb{N} \tag{4}$$

Where $F(Q)$ is DFT of DC coefficients histogram $d(n)$ The same analysis carry forward for single compressed and resized (SCR) images where the previous compression clues are erased due to resizing so the spectrum doesn't have any prominent peaks. Further, if the SCR image is compressed with QF_2 again the spectrum consists peaks monotonically decreasing and periodic which depends on QF_2 which erases the clues left by resizing and first compression. Furthermore, if DCR image is resized with reverse resizing factor then we can able to get the clues left by first compression by prominent peak location which give the period of singly compressed image. However,

TABLE I
THEORETICAL RESAMPLING PEAK ON NORMALIZED FREQUENCY SPECTRUM

Resampling factor(λ)	**Resampling peak**$(f_n \in (0, 0.5])$
$\frac{1}{2} < \lambda < \frac{2}{3}$	$f_n = 2 - \frac{1}{\lambda}$
$\frac{2}{3} < \lambda < 1$	$f_n = \frac{1}{\lambda} - 1$
$1 < \lambda < 2$	$f_n = 1 - \frac{1}{\lambda}$
$\lambda > 2$	$f_n = \frac{1}{\lambda}$

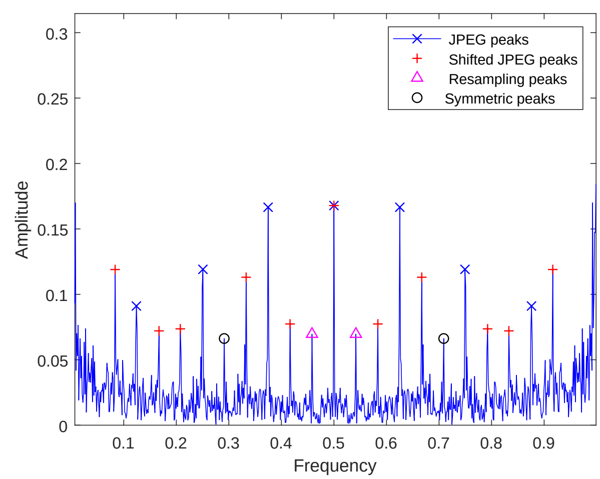

Fig. 2. Spectrum calculated by the classical method in [10] on double compressed and resized image consists different peaks (image r5d3acff9t.TIF taken from RAISE database doubly compressed with $QF_1 = 50$, $QF_2 = 70$ and resized by $\lambda = 1.5$.

the periodicity of DCR images may effect the estimation of resizing factor, which is more crucial step to obtain reverse resize DCR image by utilizing estimated resizing factor. In [10], spectral method is utilized and the frequency is mapped to the range [0, 1] and search for the prominent peak location in the range [0, 0.5] based on the location resampling factor is estimated in uncompressed images.The Eq. 5 represents the spectral method to estimate resampling factor reported in [10].

$$S(u) = \left| F \left\{ Var_y \left\{ \nabla_x^2 \left\{ I(x, y) \right\} \right\} \right\} \right| \tag{5}$$

Input image denoted as $I(x, y)$, where $\nabla_x^2 \{.\}$ second order difference along row direction , $Var_y\{.\}$ variance along column direction. The resampling peaks are theoretically analyzed in the spectrum of uncompressed images as shown in the Table. I

However, The peaks considered in [13] which satisfies $5.\frac{N_d}{64} < k < \frac{N_d}{4}$ in the frequency spectrum where N_d is the length of the DFT sequence, however some of the resampling peaks lies outside this interval which makes false estimation in resampling factor. So, search interval has to be changed and find all the theoretical resampling peaks by omitting JPEG peaks.

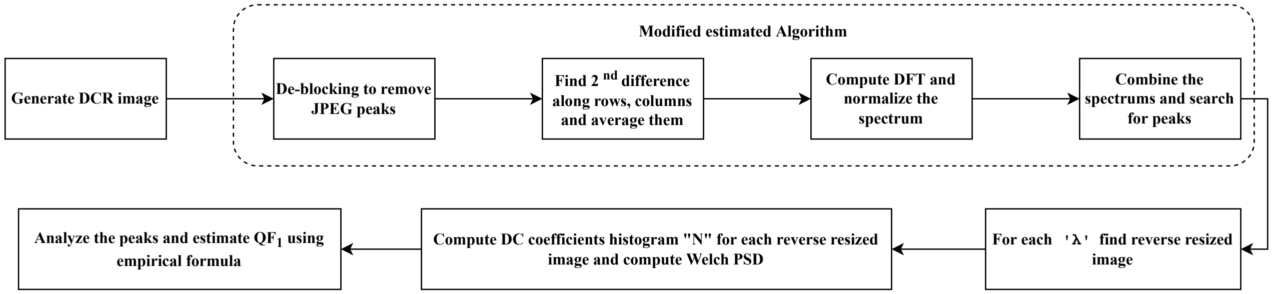

Fig. 3. Block diagram of proposed method to estimate primary quality factor by utilizing modified estimated algorithm to estimate resizing factor of DCR images.

Observations from Fig. 2 show the most of the JPEG peaks dominate the resampling peaks this makes the false resampling factor estimation. So efficient deblocking technique has to be proposed to suppress blocking arifacts in DCR images before estimating resizing factor using spectral method. Natraj *et al.* [18] proposed that by adding suitable amount of gaussion noise to resized and compressed images can suppress blocking arifacts and retain resampling peaks.

Furthermore, less AWGN may not impact on JPEG peaks and excessive may suppress both resampling and JPEG peaks. So the key idea is that we have to add suitable amount AWGN which depends on quality factor on DCR images to mask JPEG peaks and retain resampling peaks. Deblocking is utilized to estimate resampling factor in case of double compression.

The next section describes the proposed method to estimate first quality factor (QF_1) of DCR images by using robust estimated algorithm.

III. Proposed Method

A simple and effective method is proposed to estimate the first quality factor. In this approach, the resizing factor is estimated using the modified estimated algorithm to find the counter-resized image. Further, PSD analyses are utilized to estimate the first quality factor by finding the most significant peak location in the spectrum. The block diagram of proposed method presented in Fig. 3.

A. Modified estimated algorithm

To estimate the candidate resizing factors using modified estimation algorithm steps shown below

(a) Add sutiable AWGN (η) with variance σ^2 to double compressed and resized image (I_{DCR}) to reduce blocking arifacts introduced due to second compression.

$$I^{'}(x_1, y_1) = I_{DCR} + \eta \tag{6}$$

where $\sigma^2 = 0.00568 \sum_{i,j=1}^{25} q_{i,j}$, $q_{i,j}$ is the first 25 coefficients of quantization matrix in zigzag order and $I^{'}(x_1, y_1)$ is deblocked image.

(b) Compute second derivatives of deblocked image along rows and columns

$$\begin{aligned} I_x^{''}(n_1, n_2) &= D_x^2(I^{'}(x_1, y_1)) \\ I_y^{''}(n_1, n_2) &= D_y^2(I^{'}(x_1, y_1)) \end{aligned} \tag{7}$$

where, D_x^2 and D_y^2 represents second derivative along x and y directions respectively. n_1 and n_2 are the length and width of the difference image.

(c) Evaluate the mean absolute difference along horizontal and vertical direction.

$$\begin{aligned} v_h(n_2) &= \frac{1}{M} \sum_{n_1}^{M} \left| I_x^{''}(n_1, n_2) \right|, n_2 = 1, 2, 3....N-2 \\ v_v(n_1) &= \frac{1}{N} \sum_{n_2}^{N} \left| I_y^{''}(n_1, n_2) \right|, n_1 = 1, 2, 3....M-2 \end{aligned} \tag{8}$$

where, $v_h(n_2)$ and $v_v(n_1)$ are mean absolute difference along horizontal and vertical direction.

(d) Compute DFT and normalize the above vectors to obtain horizontal and vertical spectrums with half of total length and find the sum of both spectrums.

$$V(k) = |DFT(v_h)| + |DFT(v_v)| \tag{9}$$

To improve this, we analyzed the peaks locations in the interval $5.\frac{l_d}{128} < k < \frac{l_d}{2}$ where l_d is length of the DFT sequence.

(e) With in the above search interval estimate all available peak locations having higher magnitude in the spectrum and considered as candidate peak locations f_p^i . The estimated resizing factors λ^i are calculated using

$$\begin{aligned} \lambda_1^i &= \frac{1}{2 - f_p^i} \\ \lambda_2^i &= \frac{1}{1 + f_p^i} \\ \lambda_3^i &= \frac{1}{1 - f_p^i} \\ \lambda^i &= [\lambda_1^i, \lambda_2^i, \lambda_3^i] \end{aligned} \tag{10}$$

B. Empirical relationship between QF_1 and prominent peak location of all candidate resizing factors

We empirically find the nonlinear relationship between first quality factor (QF_1) and location of the most prominent peak (l_p) which is period of DC histogram of first compression by utilizing Welch PSD analysis. We have empirical formula as

$$QF_1 = 77.34 * \sin(0.03888 * l_p + 0.005861) \tag{11}$$

Fig. 4 shows the agreement between experimental data and

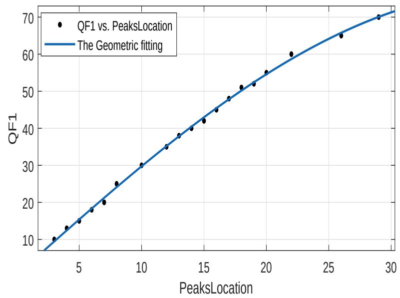

Fig. 4. Agreement between the values estimation of QF_1 by Eq. 11 and the experiment data.

empirical data which is represented in Eq. 11.

C. Proposed method

1) Estimate the candidate resizing factors using modified estimation algorithm.
2) Find reverse resized JPEG compressed images by utilizing each estimated resizing factor λ^i with bicubic interpolation
3) Evaluate DC coefficients histogram of each reverse resized image and find its PSD as like [14]
4) By analyzing the peaks of all candidate resizing factors chose the most prominent peak location and calculate QF_1 using Eq. 11 .

IV. Results and Discussions

MATLAB 2018b is utilized for experimentation. To evaluate the performance of the proposed method, 500 uncompressed images (in TIFF format) are taken from RAISE [20] dataset. Each image is compressed (using imwrite) with five different quality factors QF_1= $\{50, 60, 70, 80, 90\}$ to obtain single compressed images. The resulting 2500 images are resized (using imresize) with lemda of set λ = $\{0.6, 0.7, 0.8, 0.9, 0.95, 1.05, 1.1, 1.2, 1.3, 1.4\}$ with bicubic interpolation. The resulting singly compressed resized images are again compressed with six quality factors QF_2 = $\{50, 60, 70, 80, 90, 99\}$ to form the final 150000 (i.e., $500\times5\times10\times6$) double compressed and resized images. The central part of size 128×128 and 256×256 luma component is utilized for experimentation. Each double compressed and resized image is reverse resized with 'λ^{-1}' with bicubic interpolation to obtain reverse resized image. The estimated algorithm presented in Section III, is utilized to estimate candidate resizing factors and this is considered as 'estimated' scenario.

A. Performance analysis of Proposed method

The efficiency of the proposed method is assessed by calculating percentage of correct quality factor estimation of first compression is considered. We have not done 'fixed' resizing factor scenario because most of the forensics problems may not have priori knowledge about possible resizing factors. Fig. 5 shows the analysis carried out to estimate correct quality factor of first compression by considering resizing factor fixed at 0.8 and averaged overall primary quality factors QF_1 with a image patch size of 128×128 and 256×256. The comparative analysis carried and compared with Niu. *et al.* [15] and the results shows that estimated case has better results than fixed case. Furthermore, correct primary quality factor estimation is less for high second compression due to high compression the clues left by the resampling may lost.

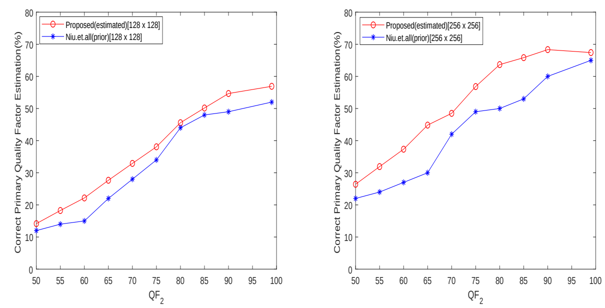

Fig. 5. Correct primary quality factor estimation(%) for different QF_2, considering λ = 0.8 for image size is 128×128 and 256×256

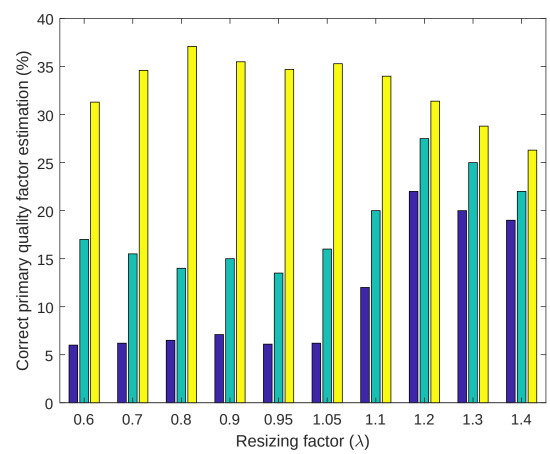

Fig. 6. The comparison of the correct primary quality factor estimation(%) for different resizing factors (λ), considering $QF_2 = 80$ and averaged over all QF_1(proposed (yellow), Niu.*et al.* (cyan) and Bianchi & Piva's (blue) methods) on image size 256×256

B. Performance of the proposed method evaluated on early reported techniques

Additionally, Fig. 6 shows the performance achieved by the proposed method outperforms the state-of-the-art methods such as Niu. *et al.* method and IPM method for different resizing factors for image size 256×256 . Moreover, the performance of quality factor estimation in case of downscaling scenario has improved due to modified estimated algorithm present in section III. However, the proposed method has some limitations that $QF_1 > 75$ primary quality factor estimation is very difficult due to higher QF_2 erases clues left by resizing that makes the estimation of resizing factor more difficult that inturn efficiency of QF_1 estimation is reduced.

V. Conclusions

This paper investigates the specific periodic traces hidden in the presence of resizing in double compressed and resized images by utilizing Welch PSD. The nonlinear relationship of the Welch PSD spectrum of DC coefficients of reverse resized double compressed image, and quality factor of the first compression is empirically found. Further, an improvement of the existing estimation algorithm is proposed to estimate candidate resizing factors utilized to estimate the quality factor of the first compression. As part of future work, the post attacks such as noise addition, gamma correction, and median filtering have to be analyzed. Estimation of the resizing factor and quality factor of the first compression in double JPEG images in the presence of resizing is also a significant challenging problem.

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