Factor Histogram based Forgery Localization in Double Compressed JPEG Images

Archana V. Mire\textsuperscript{a,∗}, S. B. Dhok\textsuperscript{b}, N. J. Mistry\textsuperscript{a} and P. D. Porey\textsuperscript{a}

\textsuperscript{a}Sardar Vallabhbhai National Institute of Technology, Surat, India
\textsuperscript{b}Visvesvaraya National Institute of Technology, Nagpur, India

Abstract

Today convincing digital forgery can be created without master learning of image editing software. These fake pictures over exceptionally quick media may cause extreme results in the public arena. Passive digital image forensic is an area which uncovers these problems. Since JPEG compression deals with 8 × 8 DCT matrix it makes its own fingerprint which can be utilized to distinguish further forgeries in the picture. In this paper, we have proposed a technique which automatically locates forgery in the image based on histogram of DCT coefficient factors, called as factor histogram. When image undergoes aligned double compression this factor histogram shows peak at current quantization step as well as primary quantization step. Our algorithm searches for absence of such double maxima in block-wise factor histogram to identify tampered region. This method can find copy-move, copy-paste as well as pre-processed forgeries such as rotation and scaling.

© 2015 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Keywords: Passive digital image forensic; DCT; Double compression artefact, JPEG; Forgery detect.

1. Introduction

As the majority of the pictures disseminated in the computerized world is in JPEG form, forgery localization algorithms focused around JPEG unique fingerprint impression can restrict a large portion of the forgeries. A large portion of these techniques dissects inconsistencies in frequency of quantized coefficient or blocking antiquity to find altering. As stated earlier Fig. 1 shows one of the scenarios of forgeries in JPEG images\textsuperscript{1}.

Here gray segment positioned at \(x_1, y_1\) from source-image Fig. 1(a) which is compressed with primary compression quality \(Q_1\) (or uncompressed) is pasted on destination-image Fig. 1(b) with primary compression quality \(Q_2\) at position \(x_2, y_2\) to form tampered-image Fig. 1(c) which is recompressed at secondary compression quality \(Q_3\) where \(Q_3 > Q_1, Q_2\).

Square blocks present in Fig. 1 represent the 8 × 8 JPEG block grid for DCT quantization and \((x_1, y_1), (x_2, y_2)\) represents the original position of copied segment and destination position of pasted segment. Equation 1 and

\*Corresponding author. Tel.: +918141555185.
\E-mail address: archam2002@yahoo.co.in

1877-0509 © 2015 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of organizing committee of the Eleventh International Multi-Conference on Information Processing-2015 (IMCIP-2015)
doi:10.1016/j.procs.2015.06.081
Equation 2 represents the shifting with respect to $8 \times 8$ JPEG block grid

$$c_x = (x_1 \mod 8) - (x_2 \mod 8) \quad (1)$$

$$c_y = (y_1 \mod 8) - (y_2 \mod 8) \quad (2)$$

If $c_x = c_y = 0$ pasted region as well as the background region undergoes Aligned Double JPEG Compression (ADJPEG) otherwise Non aligned Double JPEG compression (NADJPEG). Hence double compression artifacts will be present in background region, but not in pasted region. Whenever region is pasted in image it is very difficult to align this $8 \times 8$ DCT grid hence and double compression artefacts will be always missing in pasted region. Even in preprocessed forgeries this alignment is not possible and can be detected by applying our proposed algorithm. As a experimental proof we have tested algorithm only against scaled and rotated forgeries since these preprocessing are very necessary to make forgeries realistic.

Farid\(^2\) proposed that difference of the suspected double compressed image and its ADJPEG recompressed image at various qualities will demonstrate minima at the quality of primary compression as well as quality of double compression. Archana \textit{et al.}\(^3\) showed that pasted region never undergoes ADJPEG compression, thus as opposed to demonstrating minima at the primary compression quality of source image it will show a maxima at the primary compression quality of the destination image and will overlap with one of the visible segment of image. Lin\(^4\) computed posterior probability map of each $8 \times 8$ block of being tampered based on the bin of histogram to which it contributes. Binachi \textit{et al.}\(^5\) considered DCT coefficient and plotted the histogram of DCT coefficient by moving the grid at a distinctive position to find clustering around the first compression DCT grid. D. Fu\(^6\) demonstrated the probability of the first digits of the uncompressed and single compressed images follows the Generalized Benford law. Xiang Hua\(^7\) computed the divergence in the current probability distribution and probability distribution utilizing the Generalized Benford law to discover Double JPEG compression. Bo Liu\(^8\) introduced noise features to identify regions having different source of noise in a picture. J Yang\(^9\) used the concept of the factor histogram to find a primary quantization table of ADJPEG compressed image.

The remaining portion of the paper is organized as below. Theoretical justification of the proposed algorithm is explained in section 2 and it’s experimental evaluation is given in section 3. Finally paper is concluded in section 4 with future work.

2. Proposed Approach

2.1 Factor histogram estimation

As suggested by Yang\(^9\) when picture experiences double compression, the first unquantized DCT coefficient $c_0$ gets quantized by the step size $q_1$ to produce $c_1$, and after that, this quantized DCT coefficient $c_1$ experiences dequantization, inverse discrete cosine transform (IDCT), DCT, quantization with step $q_2$. Hence quantized coefficient $c_1, c_2$ can be represented as Equation 3 and Equation 4 respectively

$$c_1 = [c_0/q_1] \quad (3)$$

$$c_2 = [c_1q_1 + e]/q_2 \quad (4)$$
Table 1. Third row of each $8 \times 8$ grid of $32 \times 32$ blocks.

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>3</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

where $\lbrack \cdot \rbrack$ signifies the round operator, and e is the error introduced during first quantization. Due to quantization and rounding operation, set of dequantized primary quantized coefficients $(c_1 \times q_1)$ will map to the same value of the secondary quantized coefficient $c_2$. Yang $^9$ called this set as $D(c_2, q_2)$ which can be calculated using Equation 5.

$$D(c_2, q_2) = \lfloor [(c_2 - 0.5)q_2] + x \rfloor \mid x = 0, 1, 2, \ldots, q_2 - 1$$

Eg. $c_0 = 16$, $q_1 = 6$, $c_1 = 3$, $q_2 = 4$, $c_2 = 5$, $D(5, 4) = 18, 19, 20, 21$.

Because of rounding operation error term ‘e’ cannot be greater than 1 and $(c_2, q_2)$ i.e. $c_1q_1 \in D(c_2, q_2)$. All the positive factors of all coefficients in set $D(c_2, q_2)$ are collected to form the factor set $F(c_2, q_2)$. Since $c_1q_1 \in D(c_2, q_2)$, $q_1$ will be always one of the factors of set $D(c_2, q_2)$ and will be always present in set $F(c_2, q_2)$. Factor set is calculated by using Equation 6

$$F(c_2, q_2) = \{ x \mid \text{mod}(y, x) = 0, y \in D(c_2, q_2), x > 0 \}$$

Thus, for $c_2 = 5, q_2 = 4, D(5, 4) = \{18, 19, 20, 21\}$ and corresponding factor set becomes $F(5, 4) = \{1, 2, 3, 4, 5, 6, 7, 9, 10, 18, 19, 20, 21\}$.

In above equation $q_2$ was used as a constraint on set $D$ hence $q_2$ consecutive coefficients will always be present in set $D(c_2, q_2)$ and hence numbers 1 to $q_2$ are always factors of set $D(c_2, q_2)$ and will be present in set $F(c_2, q_2)$. As factors 1 to $q_2$ and $q_1$ are always factor of set $D(c_2, q_2)$, if we plot histogram of all factor present in each set $D(c_2, q_2)$ for different values of secondary quantized coefficient $c_2$, frequency of factors 1 to $q_2$ and $q_1$ will be always maximized. If $q_1 > q_2$, then the histogram will show maxima at bin 1 to $q_2$ and $q_1$ and in this way we can check primary quantization step $q_1$ if $q_1 > q_2$.

Given below is the example of such double quantized $32 \times 32$ image consisting of such 16, $8 \times 8$ DCT double quantized block. Table 1 represents coefficients in third row of each $8 \times 8$ DCT block. Table 2 represents primary and a secondary quantization table used for compression. In Table 2 secondary quantization step at mode 4 (in zigzag order) is 3 while the primary quantization step is 11. Table 3 represents the DCT coefficients present in the image block at mode 4 in zigzag order. Table 4 represents a histogram of DCT coefficients from Table 3 starting with first non zero coefficient. Table 5 represents a computed factor histogram. Here $q_2 = 3$ and if we check factor histogram all the initial bins up to $q_2 = 3$ show maximum count, also bin 11 shows the maximum count which is nothing but primary quantization step $q_1$. As we are able to find two maxima at the different locations, image has undergone ADJPEG compression.

Here $q_2 = 3$ so for $c_2 = 4$, $D(4, 3) = \{11, 12, 13\}$ and for $c_2 = 7$, $D(7, 3) = \{20, 21, 22\}$.

2.2 Localization algorithm

In this proposed algorithm we computed factor histogram for each $32 \times 32$ block moving window at first 20 modes where not all DCT quantized coefficients are zero and quantization step is more noteworthy than 2. As discussed earlier
Table 2. Quantization table.

<table>
<thead>
<tr>
<th></th>
<th>a. $Q_1 = 65$</th>
<th></th>
<th>b. $Q_2 = 95$</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>9  8  13  19  32  41  49  3</td>
<td>2  2  3  5  8  10  12</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>10 11 15 21 46 48 44 2  2  3  4  5  12 12 11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>10 13 19 32 46 55 45 3  3  3  5  8  11 14 11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>14 18 23 41 70 64 50 3  3  4  6  10 17 16 12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>18 30 45 54 87 82 62 4  4  7  11 14 22 21 15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>28 44 51 65 83 90 74 5  7  11 13 16 21 23 18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>57 62 70 82 97 96 81 10 13 16 17 21 24 24 20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>58</td>
<td>74 76 78 90 80 82 79 14 18 19 20 22 20 21 20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Coefficients of $32 \times 32$ blocks at mode 4.

|   | 0  0  4  4  0  7  0  4  0  0  4  0  4  0  0  0 |

Table 4. Histogram of DQ DCT Coefficient of $32 \times 32$ block at mode 4.

| hist $Y = 5$ | 0 | 0 | 1 |

Table 5. Factor histogram of $32 \times 32$ blocks at mode 4.

| histFac = 6 | 6  | 6  | 6  | 1  | 5  | 1  | 0  | 0  | 1  | 6  | 5  | 5  | 0  | 0  | 0  |

Initial bins up to $q_2$ demonstrates the same highest count in the histogram. An area which has experienced ADJPEG compression demonstrates one more neighborhood maxima at bin $q_1 > q_2$ which is a primary quantization step. However, as stuck region experiences NADJPEG compression no such second maxima occurs in the factor histogram of tampered region and is distinguished as altered block. Because of frequency distribution, such local peak beyond bin $q_2$ may exists in blocks of tampered region and may get delegated as untampered. Also peculiar intensity combination and quantization steps may not show second maxima in the background blocks, so some morphological processing such as closing and opening is also performed on resultant image and finally declared largest component as a tampered region. An algorithm for forgery localization is as shown below.

**Locate Forgery (I)**

```plaintext
// Input image I in JPEG format
Read Available quantization table Q encoded in JPEG header
// Identify the mode corresponding to first quantization step coefficient q2 greater than 2
For each B×B block of Image I
DCT_C = DCT coefficient
// DCT coefficient at mode corresponding to position of q2 in DCT block
hf = factor_histogram(DCT_C, q2) // Calculate factor histogram
max_count = hf(1)
For i = q2+2 : Max_R // Check maximum count after range
// q2+1 h
hf
   if ( hf(i) == max_count )
      block = valid // untampered
      break;
   else
      block = invalid // tampered
   end
end
```
3. Experimental Results

In our experiments, we have used Matlab(7.12.0), 64 bit image processing toolbox to implement JPEG compression, and used P. Sallee, JPEG toolbox\(^\text{10}\) to extract the quantized DCT coefficients and the quantization matrix for calculating factor histogram. For simplicity, standard QMS, which is recommended by JPEG compression standard, is adopted in our analysis and experiments. For each region identified as tampered region, following metrics were computed

\[
T_p = \text{Number of pixels which were pasted and identified as pasted}
\]

\[
F_p = \text{Number of pixels which were not pasted and identified as pasted}
\]

\[
A_p = \text{Total number of detected pixels (all positive, } T_p + F_p)
\]

Image is correctly categorized only if \( T_p / A_p > = 60\% \).

UCID database\(^\text{11}\) consists of large number of uncompressed colour images. Though it is easy to evaluate an algorithm against complete database using above performance metrics, it is difficult to visualize the performance. Hence, for visualizing the results, we have experimented with different sets of 50 random source and destination images. Here we have discussed one such experiment where randomly selected 50 images from UCID database\(^\text{11}\) were primarily compressed at quality level \( Q_1 \). Block of size \( 200 \times 200 \) randomly selected from each one of the pictures and glued at random positions on all the pictures. Resultant pictures were JPEG compressed at quality \( Q_2 \). Consequently, total 2500 doubly compressed tampered images were created for each test case such as copy paste, resampling and rotated forgery. Figure 2 demonstrates examples where forgery localized properly for copy paste (a) (b), (c) (d), rotated before pasting (e, f) and scaled before pasting(g,h) where pasted region effectively turns out. In Fig. 2(e), (f) though forgery is detected by algorithm correctly, since \( T_p / A_p \) is not grater than 0.6, counted as a wrong localization.

Figure 3(a), (b) shows performance of our proposed scheme at various qualities of primary and secondary compression without preprocessing of forgery. In Fig. 3(a) qualities of the first compressions \( Q_1 \) varied from 60 to 95 in steps of 5 and qualities of the second compression maintained fixed at \( Q_2 = 95 \). In Fig. 3(b) qualities of the second compressions \( Q_2 \) varied from 65 to 95 in steps of 5 and qualities of the first compression maintained fixed at \( Q_1 = 65 \). Figure 4 (a), (b) shows the accuracy of our proposed algorithm against rotated and scaled forgery. In Fig. 4(a) the region is pasted after rotating by angle 25° to 360° degrees in steps of 25°. In Fig. 4(b) region is pasted after scaling by scale factor 0.5 to 1.5 in steps of 1. Primary and secondary compression qualities were maintained at 60 and 85 respectively. We likewise tried our proposed scheme against CASIA tampered image database\(^\text{12}\) but since compression qualities of destination and source images was not accessible precision of the strategy couldn’t be identified. Some of the results correctly localizing pasted region are shown in Fig. 5.
4. Conclusion

The experimental results shows that, the proposed scheme has performed satisfactorily in copy-move, copy-paste and preprocessed forgeries such as scaling and rotation. Other preprocessed forgeries will also create non aligned double compression in pasted region and since proposed algorithm searches for absence of aligned double compression artefacts, though we have not practically tested this algorithm against other preprocessed forgeries such as contrast and lightning adjustment, we can predict to have satisfactory performance. Since images are analyzed with respect to 32 × 32 block size, the algorithm is able to detect small as well as large size forgeries. The major advantage of proposed algorithm is that as soon as the primary quantization step is greater than the secondary quantization step we can detect all forgeries done with any custom quantization table. Like major DCT based techniques drawback of the algorithm is able to detect only if primary quality is greater than second. In future work we will improve and evaluate the algorithm for actual convincing forgeries as available in the CASIA tampered image database.
References


