Exposing Image Fuzzy Forgeries based on Dyadic Contrast Contourlet

Hui fan, Yongliang Wang, Jinjiang Li
School of Computer Science and Technology, Shandong Institute of Economic & Technology, Yantai, 264005, China
fanlinw@263.net, ljjinjiang@gmail.com

2. School of Information Science and Engineering Shandong Normal University, hzliang99@126.com
doi : 10.4156/jcit.vol6.issue7.5

Abstract

In this paper, we combined with efficient image signal processing algorithms, according to the manifestations of the blur of polish operation in the frequency domain, proposed a blind detection algorithm for image tampering evidence. First, the target image transformed into a new Nonsubsampled dyadic contourlet domain which based on contrast à trous wavelet, then homomorphic filtering on it in this domain to enhance the edge which was blurred, and then combined with morphological Filter to eroded the area of non-tampering, to complete the blurred image tampering detection. Through experiments, the algorithm in this paper have a excellent recognition for the blurred retouch images.

Keywords: Blurred Operation,Image Tampering,Dyadic Contourlet,Contrast à Trou Wavelet

1. Introduction

From the Photoshop to the light magic hand, the image tampering has increasingly become a popular entertainment, and its technical threshold has been lower, which led to the PS force is now overwhelming on the network, after some intentional or unintentional tampering, the only left the massive digital image information which real to the enemy, or even the deceptive. How to distinguish those images information has current as a problem to be solved.

Image authentication techniques can be divided into active and passive authentication according to the mode of certification [1]. Hany Farid distort the image into synthetic images, enhance image, variant images, retouching images, painting images and generated images [2]. The most common way is cut the target of an image synthesis to another image, as well as makes the fusion of synthesis of images look more natural, often through the blur operation to the edge portion to make fake flawless.

In the current study of passive image authentication, the image tampering operation of the copy - paste, variants and computer-generated have more mature theory. However, as blurred, graded, desalination and other polishing operations’s flexibility and its uniform change in the frequency domain, for the operation of these tampered, the academic community doesn’t have very accurate method of detection. H. Farid, Nachtegael, and Fridrich, who were proposed the image synthetic tamper detection methods [3-6], but these methods for the image after retouch have little effective detection, Tong, etc. detecte the blur operation in the wavelet transform domain[7], but can not guarantee synchronization of spatial and frequency domain and can not distinguish defocus blur and artificial blur. China's Zhou Linna detecte blur operator by edge characteristics of morphological filtering [8]. In this paper, we combined with efficient image signal processing method of dyadic contrast contourlet, according to the manifestations of the blur of polish operation in the frequency domain, proposed a blind detection algorithm for image tampering evidence. Experiments show that the algorithm have a excellent recognition rate of image blurring retouching operation, and have a effectively distinction between the artificial blurred and out of focus blur, accurate positioning of the splicing boundaries.
2. Dyadic contrast contourlet transform

The traditional Contourlet transform adopt double contrast filter bank structure, and use contrast pyramid (CP) to decompose input signal to capture the singular point.

CP decomposition in the first to generate a low-pass Gaussian pyramid of the target image, as the low-pass copies of the target image. In the process of build the pyramid, every gradual decomposition of image through the level an “REDUCE” operation to generate the after image, for each level of the pyramid \(1 < l < N\), \(N\) is the highest level of the pyramid), there are:

\[
G_l = \text{REDUCE}(G_{l-1})
\]

As each layer of low-pass pyramid image’s density and resolution are reduced, so, in the reconstruction of the prior level, through the “EXPAND” operation to interpolate. Defined the ratio low pass pyramid as follow:

\[
\begin{align*}
R_l &= \frac{G_l}{\text{EXPAND}(G_{l+1})} \quad 0 \leq l \leq N \\
R_N &= G_N
\end{align*}
\]  

\(R_l\) is the ratio between adjacent levels of low-pass pyramid, so the ratio low-pass pyramid is a complete representation of the original target image. Luminance contrast defined as:

\[
C = \frac{(L - L_b)}{L_b} = \frac{L}{L_b} - 1
\]

Where \(L\) is the brightness of the image in a specific location, \(L_b\) is the background brightness of the point. For any \((i, j)\), let \(I(i, j) = 1\). Contrast pyramid defined as:

\[
\begin{align*}
C_l &= \frac{G_l}{\text{EXPAND}(G_{l+1})} - 1 \quad 0 \leq l \leq N \\
C_N &= G_N
\end{align*}
\]

\(C\) sequence is a multi-scale decomposition of the target image get by the contrast pyramid, which decomposed the target image into several band-pass sub-band. Subsequently, the high frequency sub-band obtained by CP decomposition using the direction filter banks (DFB) for the direction analysis[9].

In order to change the traditional contrast Contourlet transform’s problems of lost translation invariance and spectral leakage and aliasing due to subsampling, we adopt à trous wavelet algorithm to deal with dyadic wavelet which has non-subsampling characteristics of [10], to replace ratio low-pass pyramid of Contrast contourlet transform. For the target image of evidence, can use à trous wavelet to...
Exposing Image Fuzzy Forgeries based on Dyadic Contrast Contourlet
Hui fan, Yongliang Wang, Jinjiang Li
Journal of Convergence Information Technology, Volume6, Number 7, July 2011

generate approximate image sequence \( p(l = 1,2,\ldots N) \), where \( N \) is the number of layers of wavelet decomposition. Can define dyadic contrast à trous wavelet transform as follow:

\[
\begin{align*}
    p_0 &= p \\
    w_l &= (p_{l-1} / p_l) - 1 & 0 \leq l \leq N \\
    w_N &= p_N
\end{align*}
\]  (8)

With (7) Similarly, for any \((i, j)\), let \( I(i, j) = 1 \). Accordingly, it’s inverse is the images reconstruction process. The directional analysis implementate through Non-Subsampled Directional Filter Banks (NSDFB) [11]. NSDFB adopted a set of two-channel nonsampled filter banks, decomposed in the direction of each layer, and then use all the filters of quincunx matrix \( Q = \begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix} \) top-sampled directional filter banks, as the directional filter of next layer’s directional decomposition. NSDFB decomposition schematic shown as Figure 3, \( U(z) \) is filter.

![NSDFB decomposition](image)

**Figure 3.** NSDFB decomposition

**Figure 4.** The pre-process of the evidence target image
So far, this paper on the basis of original Contourlet structure, construct a new non-subsampled dyadic contrast Contourlet transform, the overall process shown in Figure 4.

After the processing of the original evidence image signal, it have the multi-directional and frequency shift invariance, so the frequency domain information can be more fully utilized in the blur operation detection, with the use of the à trous dyadic wavelet, which is the “weapon” of signal amplification, so we are able to trace any trace of the evidence target image, greatly enhanced the subsequent evidence operation’s hit rate and accuracy. Decomposition as shown below, where Figure 5 is a sample image, and Figure 6 is a dyadic contrast Contourlet transform’s third level decomposition, Figure 7 is dyadic contrast Contourlet transform’s decomposition of the fourth level.

**Figure 5.** Sample image

**Figure 6.** Transform’s third level decomposition
3. Amplification and locating of the blur tampering

3.1. Homomorphic filtering in dyadic contrast contourlet transform

The essence of image blur is low-pass filter, the performance in the frequency domain is the high frequency components which represent a drastic change filtered out, leaving only the low frequency part which is the slow change. So after polishing operation the polished part of blur image’s gray-scale range will shrink significantly. And, with the imaging defocus blurred different, artificial blurred part’s radius are quite obviously, within the radius of the blurred, gray-scale of the image is limited to a specific small area. Using this feature, we can use the targeted Homomorphic filtering algorithm to locate the region of the polishing. Homomorphic filter function is very conducive for enhance artificial blur region edge, strengthening the distinction of the regional blurred and not blurred [12], and then using mathematical morphology for accurate positioning.

Expressed in the form of homomorphic filtering, the decomposition of an image \( f(x, y) \) is the lighting components \( i(x, y) \) and reflection component \( r(x, y) \), which is:

\[
f(x, y) = i(x, y) \cdot r(x, y)
\]  

Among them, the lighting component \( i(x, y) \) determines the range of images gray-scale, the function of the content reflective properties’s changes of reflecting component \( r(x, y) \), determines the contrast of the image. Since \( i(x, y) \) and \( r(x, y) \) in the homomorphic filter is nonlinear multiplied relations, it is usually exponented before process images to be transformed into two linear components, logarithmic after process completed for image reconstruction. Gaussian homomorphic filter function is:

\[
H(u, v) = (\gamma_1 - \gamma_2)[1 - e^{-e^{\frac{1}{(d(u, v)/D)}^2}}] + \gamma_2
\]
In the above formula, \( D_0 \) is the high-pass cutoff frequency. \( D(u,v) \) is the distance from Point \((u,v)\) which is in the frequency domain to the frequency domain origin, is \( D(u,v) = \sqrt{u^2 + v^2} \). \( c \) constant is filter function’s index of the cannot sharpening, the range between the \( \gamma_l \) and \( \gamma_h \), in which \( \gamma_l < 1, \gamma_h > 1 \), is high and low frequency gain. As the traditional homomorphic filter is not fully deal with local features of image’s airspace domain, so the enhancement of high frequency components very poor, and artificial tampering in the high-frequency reflection components after neighborhood gray average, so traditional homomorphic filter positioning enhanced blur edges very unfavorable for evidence. In order to homomorphic filter function can be optimize applied in our dyadic contrast Contourlet field, we can make the following improvements to its:

\[
H(i, \omega_h, \omega_v) = \left( \frac{\gamma_l - \gamma_h}{\gamma_h - \gamma_l} \right) \left[ 1 - e^{-\left( \frac{\omega_h + \omega_v}{c} \right)^2} \right] + \gamma_l
\]

Where, \( i \) is the decomposition level of dyadic contrast Contourlet, \( s \) is the cut-off coefficient, \( 2^i \) reflects the resolution of the corresponding level, \( \omega_h \) and \( \omega_v \), respectively, is horizontal and vertical weights index. In the \( LL \) sub-band, \( \omega_h = 0, \omega_v = 1 \); in the \( HL \) sub-band, \( \omega_h = 1, \omega_v = 0 \); in the \( LH \) sub-band, \( \omega_h = 0 \), \( \omega_v = 0 \). After these optimizations, homomorphic filtering function already has a very good time and frequency synchronization and local relevance, and because the filter in the dyadic contrast Contourlet domain, obtained the underlying support of the fine treatment of the image from root.

Image after homomorphic filtered in the dyadic contrast Contourlet domain, polished region of the artificial blurred edge was enhancemented, increase the blurred regions and not blurred regions’s discriminative, enlarged traces of artificial tampering, this provides a good support for our follow-up using mathematical morphology Methodology to mark the blurred region.

3.2. Localization of the tampered region by mathematical morphology

Mathematical morphology take the shape as the basic unit of image processing, use a certain shape of structural elements (SE) to deal with the corresponding shape in the image, basic operations are divided into erosion and dilation[13]. Image erosion operation is a contraction processing of the image, operations form is put the structural elements SE shift in the image I, the point of the SE which can fill in I composite the new image results, can be expressed as:

\[
I \ominus SE = \{ Y \mid SE + Y \in I \}
\]

The results on the above equation is get the external connection boundary of the image inward in the narrow layer, the image expansion operation is the inverse operation of the corrosion, will expand the image’s connection boundary to a out layer, with the structure element SE’s all points as a reference point shift the image I, the intersection of shift result as the result of the expansion operation, the expression is as follows:

\[
I \oplus SE = \bigcup \{ I + Y : Y \in SE \}
\]

Artificial blur operation polished on the edge of the mosaic image is an average of gray within a blurred radius of neighborhood pixels, in the morphological can be seen as the expansion operations of images’ local edge. Evidence target image after homomorphic filtering, amplified the artificial blur-polished splicing edge, while the natural edge relative to the stitching edge becomes weak edge, then we can select the appropriate threshold for erosion operation, contraction the natural edge without enhancement of homomorphic filtering the, reserve the blurred edge which after the splicing tampering.

4. Experimental results and analysis
To verify the effectiveness of the algorithm, we will make the simulation of the algorithm. In summary, the tamper detection process is as follows:

![Diagram of tamper detection process]

**Figure 8.** The tamper detection process

Algorithm execution environment is Matlab R2010a, the source of evidence target image from the digital camera and altered images posted on the network, which original image from camera retouched by Photoshop CS4 for artificial tampering operation. The parameters of the experiment set:

\[ \gamma_1 = 0.85, \gamma_2 = 2.1, s = 0.125 \]

structural elements SE is set to:

\[
SE = \begin{bmatrix}
1 & 1 & 1 \\
1 & 1 & 1 \\
1 & 1 & 1
\end{bmatrix}
\]

The results shown in Figure 9 and Figure 10, we can see from the experimental results, after homomorphic filtered the tampering region of the original image has been enhanced, make the gray-scale range of it’s edge enhanced significantly, and the range of whole image’s gray level is compressed, expanded contrast of tampered regions and non-tampered, provide a favorable orientation material for follow-up morphological.

![Experimental results images]

**Figure 9.** The experimental results
To verify the algorithm's adaptability and robustness, as well as the distinction between defocus blurred and artificial blurred, we collected from the digital camera, PS, and network spoof etc. a large number of blurred images repeated the experiment, the results shown below:

<table>
<thead>
<tr>
<th>source</th>
<th>quantity</th>
<th>correct quantity</th>
<th>error quantity</th>
<th>correct rate(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cannon A720 original images</td>
<td>44</td>
<td>42</td>
<td>2</td>
<td>95.5</td>
</tr>
<tr>
<td>Cannon A720 tampered images</td>
<td>43</td>
<td>40</td>
<td>3</td>
<td>93</td>
</tr>
<tr>
<td>Non-tempered images from network</td>
<td>30</td>
<td>28</td>
<td>2</td>
<td>93</td>
</tr>
<tr>
<td>Tempered images from network</td>
<td>34</td>
<td>31</td>
<td>3</td>
<td>91.2</td>
</tr>
<tr>
<td>Kodak DC290 original images</td>
<td>37</td>
<td>34</td>
<td>3</td>
<td>91.8</td>
</tr>
<tr>
<td>Kodak DC290 tampered images</td>
<td>41</td>
<td>39</td>
<td>2</td>
<td>95.2</td>
</tr>
</tbody>
</table>

As can be seen from the table, the algorithm can accurately identify and locate the image of artificial blurred tampering, image recognition for high-pixel camera is best, be able to accomplish relatively accurate tampered evidence, for the network image, due to its altered approach more complex, the recognition rate dropped to a certain extent, so in the follow-up studies need to combine a variety of evidence means to improve the algorithm.

5. Summary

In this paper, we use the features of artificial blurred tampering image, combined with the signal processing methods in dyadic contrast Contourlet domain, provide a targeted evidence methods of the blurred tampering image. The target evidence image first transform to a new domain of dyadic nonsampled contourlet based on the contrast a trous wavelet, then put it homomorphic filtering in contourlet domain to enhance the edge was blurred, and combined Corrosion operation of morphology filtering to eliminate its non-tampered areas, to complete the locating of blurred tampering area. Experimental results show that this algorithm has better ability to identify artificial tampering image, and because the use of perfect signal processing methods in dyadic contrast Contourlet domain, image processing with more accurate positioning and refinement of the scale. For tampering image with the comprehensive means, the algorithm still have some shortcomings, in future studies should pay attention to evidence with a variety of means to improve the algorithm.
6. Acknowledgment

This work is supported by the National Natural Science Foundation of China under Grant No. 60970105, the Provincial Natural Science Foundation of Shandong under Grant No. ZR2009GGQ005, 2009ZRB01620 and ZR2010FM044; Shandong Outstanding Young Scientist Research Award Fund No. 2008BS01026; Science and technology projects of Shandong Province Education Department No. J08LJ06.

7. References