Detection of Image Region Duplication Using Spin Image

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SUMMARY  Passive-blind image forensics is a technique that judges whether an image is forged in the absence of watermarking. In image forgery, region duplication is a simple and widely used method. In this paper, we proposed a novel method to detect image region duplication using the spin image which is an intensity-based and rotation invariant descriptor. The method can detect region duplication exactly and is robust to geometric transformations. Furthermore, it is superior to the popular SIFT-based detection method when the copied patch is from smooth background. The experiments have proved the method’s effectiveness.

key words: image forensics, region duplication, spin image

1. Introduction

The rapidly developing Internet and multimedia editing tools made image tamper more easy and hard to be visually distinguished, which made image forensics be necessary especially when an image is taken as proof in the court of law.

The most common manipulation of image forgery is region duplication, that is, the copy of one region is pasted on another position in the same image. In Fig. 1, we demonstrate two major forgery intentions, one is emphasizing particular image content and the other is concealing unwanted object. For the aim of convincing results, the cloned region is often pasted after affine transformation and illumination adjustment.

Detection of image region duplication is one kind of passive blind forensics. The existed methods can mainly be divided into two categories. One is block-matching-based and the other is pixel-matching-based. The basic detection method of duplication is based on DCT (discrete cosine transform) coefficients feature of the image block [1]. In [2], PCA (principal component analysis) is used to represent an image block, and it has been robust to minor variations due to additive noise or lossy compression. FMT (Fourier Mellin Transform) of the image block is also exploited as a clue for region duplication [3], which is robust to limited JPEG compression and affine transformation.

The main shortcoming of the block-matching methods is its poor robustness to geometric transformations. The pixel-based methods like SIFT can’t be extracted in the smooth region which lacks textures and has few details, thus, this kind of method is invalid when the cloned region is from the smooth background. In this paper, we propose a novel image duplication detection method using intensity-based spin image, which is robust to geometric transformations, and furthermore, this block-based method is efficient for smooth region.

2. Spin Image

Spin image [8] is a surface representation technique which was initially introduced for surface matching and object recognition in 3D scenes. It has been applied to the registration of range images and object recognition successfully because it is rotation, scale and position invariant. In [9], the authors described a novel intensity-based descriptor inspired by the idea of spin image. An intensity domain spin image is a 2-dimensional histogram encoding the distribution of brightness values in an affine-normalized patch. The two dimensions of the histogram are \( d \), the distance between the pixel and the center of the patch, and \( i \), the intensity value. The spin image is implemented as a “soft histogram” where each pixel within the support region contributes to more than one bin. For the pixel having distance \( d \) from the center and intensity value \( i \), its contribution to the bin...
indexed by \((d_0, i_0)\) is proportional to
\[
\exp\left( -\frac{(d - d_0)^2}{2\alpha^2} - \frac{|i - i_0|^2}{2\beta^2} \right)
\]
(1)

where, \(\alpha, \beta\) are “soft width” parameters to represent 2-dimensional histogram bins. Figure 2 developed in [9] illustrates the construction rules of spin image, three sample points in the normalized image patch are mapped to three different positions in the spin image. An example about spin image is shown in Fig. 3.

3. Proposed Method

At first, spin image feature extraction and matching is implemented on the input image, and then the false matching is deleted by some refinements we defined. The feature is an intensity domain spin image vector. According to the matching image patches, the tamper region can be exactly located. Figure 4 depicts the proposed method, which is composed of the three stages detailed below.

3.1 Feature Extraction

Suppose the input image \(I\) is gray with the resolution \(M \times N\). For color image, we can implement the method in the three channels respectively or transform it to gray. At first, the image illumination is normalized and divided into overlapping image patches. Let the size of each patch is \(B \times B\), the square window slides one pixel along the image from the upper left corner right and down to the lower right corner. Therefore, \(n = (M - B + 1)(N - B + 1)\) patches can be obtained from the input image. For each patch, the corresponding spin image \(s_i\) is computed, where the distance \(d\) from the center \(x_i\) of every patch is also normalized. Suppose that the bin sizes of the normalized distance and the normalized gray value are \(r\) and \(t\) separately, then every patch can generate a \(r \times t\) dimension feature descriptor \(s_i\). The exactness of the detection is closely related to the size of the parameters \(B, r\) and \(t\).

3.2 Feature Matching

For the centers of the patches \(X = \{x_1, \ldots, x_n\}\), the corresponding spin image descriptors are \(S = \{s_1, \ldots, s_n\}\). Two spin images \(s_i\) and \(s_j, i \neq j\) are considered to be duplicated when their SSD (sum of squared differences) smaller than the threshold \(T\). Finally, a list of matches \(L\) is formed.

3.3 Refinements

The list of matches \(L\) typically contains a significant number of false matches because of similar gray distribution. For instance, Fig. 5 (c) shows the whole set of unrefined matches detected in an example forgery. Note that the false matches clearly render the results useless. Therefore, in this section, some rules are defined to identify the copy-move region from the mismatched pairs, which is important to produce reasonable results.

**Rule 1.** Avoid matching the blocks close to each other, which could produce a false match especially in the smooth region e.g. sky and sea.

**Rule 2.** Delete the isolated matched blocks. Because the copy-move region often includes many neighboring matched blocks, the isolated matched blocks can be
considered as noise.

**Rule 3.** Just leave the matched regions having similar offsets, that is, the points in the matched patches should have consistent offset decided by the transform in Eq. (2),

\[
\begin{pmatrix}
\tilde{x} \\
\tilde{y}
\end{pmatrix} = \begin{pmatrix}
t_{11} & t_{12} \\ t_{21} & t_{22}
\end{pmatrix} \begin{pmatrix}
x \\
y
\end{pmatrix} + \begin{pmatrix}
x_0 \\
y_0
\end{pmatrix}
\]

\[p(x, y) = s \ast p(\tilde{x}, \tilde{y})\]  \hspace{1cm} (2)

where \((x, y)\) and \((\tilde{x}, \tilde{y})\) are the pixel coordinates, \(p(x, y)\) and \(p(\tilde{x}, \tilde{y})\) represent the illumination values, \((x_0, y_0)^T\) is a position shift vector. \(t_{ij}, i, j = 1, 2, 3, 4\) decide the pixel rearrangement and \(s\) represents the illumination scaling.

### 4. Experimental Results

When image blocks matched, the threshold \(T\) is mainly decided by block size \(B\). To find suitable value for the block size \(B\) and the threshold \(T\), the experiments were formulated with 300 images from the Caltech-256 dataset [12]. The test images depicted diverse contents, from objects to landscapes. It was empirically found that block size \(B = 31\), the bin sizes of the normalized distance \(r\) and the normalized gray value \(t\) are both 10, and the threshold \(T = 5\) provide a fair balance between false detections and the correct detections of duplicates.

To evaluate the robustness of the proposed method, a square region was selected from a random location in every test image. Before being pasted to another random location, within the same image, a post-processing operation was applied to the selected region. The following operations were independently tested: (1) no further distortion (simple copy-move); (2) rotation: 30°, 45°, 90°, 135° and 180°; (3) smooth background. Each of which was analyzed by the proposed detector in non-compressed. Hence, a total of 2000 (300 simple copy-move, 1500 rotation and 200 smooth backgrounds) forgeries were analyzed. Figure 5 shows a result of the test (1): Fig. 5 (a) is an original car image sized 512×512, we copied a rectangular region and then pasted on same image using image editing tool, the tampered image is shown in Fig. 5 (b) and the detection results with refinements and without refinements are shown in Fig. 5 (c) and (d), respectively. An experiment of multi copied block tamper detection about rotation is demonstrated in Fig. 6, Fig. 6 (a) is the original Lena image, a patch is copy-pasted on one place and copy-pasted after rotation on another place, the detection and location results are shown in Fig. 6 (c).

Finally, a comparison between SIFT-based method and proposed method is introduced. Just like Fig. 7 (a) shows, large area of the image is smooth, if we copy one block from it to hide a target region as Fig. 7 (b) shows, the SIFT features can’t be extracted in this region, see Fig. 7 (c) and (d). Therefore, when using the method based on SIFT [7], the detection result in Fig. 7 (e) demonstrates that just 25 irregular and isolated mismatches are found like red circles labeled in the lower left corner. The detection result using the method in this paper is displayed in Fig. 7 (f). Certainly, there are also many mismatched blocks, but they are removed by the refinement rules proposed in the study.
5. Conclusion and Future Work

In this paper, we introduce a novel detection method for image region duplication using an intensity-based spin image. This method can detect and locate the cloned region exactly and is robust to geometric transform. Moreover, it is more effective than SIFT-based method when the duplicated regions are smooth. In the future, we plan to combine the spin image feature descriptor with other features such as SIFT to strengthen the exactness and efficiency.

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