An Improved SIFT Image Tamper Forensics Method

Huifen Huang, Yonghui He, Qingmin Liu

***Abstract*—**In view of copy and paste, the most frequent operation in digital image tampering, an improved SIFT algorithm for forensics of image tampering was put forward. The algorithm sees to copy and paste forensics based on the SIFT circular descriptor operator, extracts the circular descriptor eigenvectors of the detected images, and conducts detection and location for the image copy and paste area by using eigenvector match-up. Experiments show that this method is robust to image processing operations, such as image rotation, zoom, blurring, noising and so on. It can detect the trace of copy and paste operation in digital image tampering quickly and effectively. Furthermore, it can accurately locate the area where copy and paste occurred.

***Keywords*—**tamper forensics; Copy-Move processing; SIFT matching.

I. INTRODUCTION

IMAGEfeature is very meaningful in image processing. At present, geometric features, color features, texture features and feature points are already somehow applied in the category of target recognition, motion estimation and stereo matching etc category. When realistic application, the image would change frequently, to extract image feature with strong robustness is obviously important. Feature points of invariant scale have strong adaptability to image transformations such as movement, rotation, noise, scaling, and occlusion. So, in recent years, feature points of invariant scale extraction algorithm and its application has been a hot research point in the image processing areas.

Harris corner detection algorithm[1] is a classic image feature point's extraction algorithm. Although Harris corner has strong robustness to image translation, image rotation and image noise,but it could not adapt to the image scale variance, which somehow restrict to its application. As the theatrical development of image scale space, some feature points of invariant scale extraction algorithm is raised in recent years. Among them including Harris-Laplacian algorithm[2], based on locally feature points extraction algorithm[3],Patch-Duplets algorithm[4], laplacian algorithm SIFT algorithm. The first three are based on Harris corner and expand to scale space for adapting to image scale variance. Such algorithm has strong robustness but the calculation is complex and real time characteristics are weak. Compared to them, the last two algorithms are weak in situation adaptability to big noise, but algorithm is comparatively simple, the real time characteristic is better.

SIFT algorithm[5]is a special feature points extraction algorithm, proposed by Lowe. It choose Gaussian residuals extreme value points in scale space as feature points,and calculate feature points, which is in locally neighboring area, the gradient direction histogram as operator. This algorithm introduce image Pyramid structure to scale space for less calculation,at the same time, against the eigenvector space, using BBF algorithm to speed up the searching process, and get a good result. SIFT algorithm has been successfully applied in the areas such as image matching, panorama splicing and visual navigation. In order to better adapt to the situations which has higher needs to real time requirements,an improved SIFT algorithm is raised,it could somehow less the calculation quantity, shorten calculation time**.**

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II. SIFT ALGORITHM'S BASIC THEORY

A. Feature Point's Extraction

SIFT feature points extraction algorithm procedure shown as below

1) Detect extreme value of image scale space. After the initial serial of Gaussian filter to original image and get the image Gaussian space.

$$L(x, y, \sigma) = G(x, y, \sigma) * I(x, y) \quad (1)$$

This process could be reviewed, as variablekernel function σ at different value, convolute the variableGaussian kernel function $G(x, y, \sigma)$ and the input image, get the image scale space. Among them

$$G(x, y, \sigma) = \frac{1}{2\pi\sigma^2} e^{-(x^2+y^2)/2\sigma^2} \quad (2).$$

Convolute the existing constant multiplicative scale operator k 's neighboringGaussian difference function and the original image, thus form the Gaussian difference scale space （Difference of Gaussian).

$$D(x,y,\sigma) = (G(x,y,k\sigma) - G(x,y,\sigma)) * I(x,y) = L(x,y,k\sigma) - L(x,y,k\sigma) \quad (3)$$

Take the Gaussian difference scale space locally extreme value, get scale space image feature points, Gaussian filter to image, ensure feature points not effected from the noise; After scale space difference processing, make the feature points with robustness to light variance; Extract extreme value points from Gaussian difference space ensure the scale invariance.

2) Locate exactly to feature points. First get the fitting function from the by-standing feature points

$$D(x) = D + \frac{\partial D^T}{\partial X} X + \frac{1}{2} X^T \frac{\partial^2 D}{\partial X^2} X \quad (4)$$

$$D(x) = D + \frac{\partial D^T}{\partial X} X + \frac{1}{2} X^T \frac{\partial^2 D}{\partial X^2} X \quad (5)$$

Derivative to the aboveformula and get the extreme value points $\hat{X} = -(\frac{\partial^2 D}{\partial X^2})^{-1} \frac{\partial D}{\partial X}$ and the corresponding extreme value $D(\hat{X}) = D + \frac{1}{2} \frac{\partial D^T}{\partial X}$. Constantly correct X in order to get the locally optimum point, get rid of $\left|D(\hat{X})\right| < 0.03$ weak feature points.At the same time, get the by-standing feature points' exact location, scale. Then get feature points Hessian Matrix, set the threshold γ detect whether the main curvature is less than the threshold value γ, which means to testify whether $\frac{tr(H)^2}{Det(H)} < \frac{(\gamma+1)^2}{\gamma}$ works. Among them $tr(H)$ and $Det(H)$ is respectively matrix's tracing and model; γ generally take 6 ~ 10.

B. SIFT feature description operator's structure

The feature description operator is constructed to determine the main direction of the feature points, and then rotate the image to main direction during the matching process, to ensure the image rotation's invariance. (x,y) Gradient value and direction read respectively

$$m(x,y) = \sqrt{(L(x+1,y) - L(x-1,y))^2 + (L(x,y+1) - L(x,y-1))^2} \quad (6)$$

$$\theta(x,y) = \tan^{-1}((L(x,y+1) - L(x,y-1)) / (L(x+1,y) - L(x-1,y))) \quad (7)$$

To take sample from the neighboring area window, which centered with feature points,at the same time, use gradient histogram to statistic neighboring area pixel HOG,the summit peak value point's corresponding direction is the main direction.

Take feature points as center, get 8×8 window, then calculate 8 direction DOG on 4×4 image blocks, draw the accumulate value to each gradient direction, form a seed point. Each feature point is described by 4×4 total 16 seed points, and each seed has 8 direction's vector information, so each feature point could yield $4\times4\times8=128$ data. Thus it could form 128 dimensional SIFT eigenvector or feature description operator.

III. Copy-Move forensics algorithm based on SIFT round shape operator

SIFT algorithm, keeps invariance to image scaling, rotation even affine transformation, is image locally feature description operator, which based on scale space. SIFT feature matching algorithm has scale invariant features variant characteristics, could process the matching problem under the situation of translation, rotation, affine transformation between two images, has strong matching ability, SIFT and its expand algorithm has the strongest robustness among the same type operator. At that time mainly used in target recognition, image detection, and image matching. SIFT algorithm is based on feature scale conception, compare among different scale feature points and find extreme value points, then get ride of low contrast point and edge response points, and extract rotation invariant features operator to match. The implementation of this algorithm has two phases: one is SIFT characteristics generation,the other is SIFT eigenvector's matching,which include 5 procedures:

1) scale space establishment;
2) feature points location;
3) eigenvector generation;
4) eigenvector dimension determination;
5) feature matching detection Copy-Move area.

A. Establishment of image scale space

Scale space theory came itself initially in computer vision, in order to simulate image data's multi-scale characteristics. One image's scale space comes from this image and Gaussian's convolution. In order to detect out stable feature points location,this algorithm use DOG Pyramid in the scale space, which is the neighboring scale space function difference.Simultaneously detect locally extreme value, in image two dimensional space and DOG scale space, as feature points,make the feature with good uniqueness and stability,DOG operator's calculation as formula 8:

$$D(x,y,\sigma)(G(x,y,k\sigma) - G(x,y,\sigma)) * L(x,y) - L(x,y,k\sigma) - L(x,y,\sigma) \quad (8)$$

B. Feature point's location

Feature point's location, also is scale space's extreme value detection, identify initially the key point's location and its scale. These feature points are generally local extreme value points of gray-scale variation, including significant structural information, and these points may not have actual visual sense, but with abundant and easy-matching information in some angle and scale.

As it is shown in Fig.1, the three neighboring scale in DOG scale space pyramid, in order to detect the maximum and minimum values in DOG space, each pixel (the pixel marked with a cross in Fig.1)of the middle layer (except the bottom and top layers) in the DOG scale space, need to compare with the neighboring 8 pixel points in the same scale and 9 neighboring pixels points in the neighboring scales, total $8+9\times2=26$ neighboring pixels points, to ensure that the local extreme value could be detected in both the scale space and the two-dimensional image space. treat the above terms-satisfied points as a locally extreme value points,and write down its position and corresponding scale.

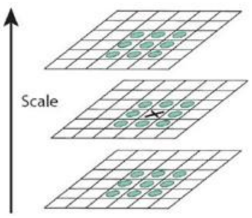

Fig.1.DOG scale space

C. Generation of feature vector

Utilize feature points' place gradient's modulus and direction, point out direction parameter for each feature points, make the operator with rotation invariance, rotate the axis to the feature points direction, take 8×8 window centered with key point, like Fig.2 left, calculate each pixel's gradient modulus and gradient direction by using formula 9, carry out weighted operation by Gaussian window, calculate 8 direction's gradient histogram in each 4×4 smaller window, each feature point characterized by a 128-dimensional vector.

$$m(x,y)=\sqrt{(L(x+1,y)-L(x-1,y))^2+(L(x,y+1)-L(x,y-1))^2}$$

$$\theta(x,y)=a\tan2((L(x,y+1)-L(x,y-1))/(L(x+1,y)-L(x-1,y))) \quad (9)$$

In order to ensure the operator rotation invariance, distribute to the key point a main direction and several secondary direction, thus generate 128 dimensional feature points description operator, calculation resource has 60% ~ 80%'s time spent in this 128-bit eigenvector matching, in this thesis, we raise an improved SIFT algorithm, by using circular itself with very good anti-rotation characteristics' operator, and serialize to each eigenvector, to ensure objects' rotation invariance, use 24 dimensional vector to replace the 128 dimensional vector, increase algorithm efficiency.

Because the round has very good rotation invariance, after the image's rotation, the feature points' neighboring areas won't change, so this thesis use round to construct feature description operator, centre with the feature points, divide the 4σ radius round window into 2 concentric circle, and then statistic the 12 eigenvector generated from the 12 gradient direction in each circle, the Fig. 2 (right) shows the outer circle generated 12 directions' eigenvector.

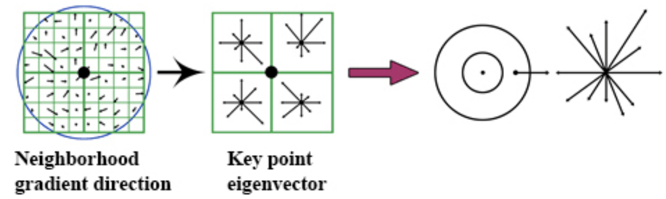

Fig.2. Feature vector generated from key point neighboring area gradient information (left)and improved SIFT feature operator (right)

D. Determinations to eigenvector dimensions

To construct circle operator's key parameter is to determine circle statistics window inner vector dimension n, which is decided by the matching efficiency. We define: matching efficiency=correct matching rate/ matching time, after the experiments to 25 different types of image, it is found out in the chosen circle, as the growth of matching vector dimension N, the correct matching rate's growth increase exponentially, after n=14, the growth index reduce, the curve is obviously smooth and steady; at the same time, the calculation time increases greatly, also find when n>12, the matching rate does not increase obviously. When n=12, the matching rate is highest, choose n=12, when at the maximum matching rate, as eigenvector dimension.

To calculate each pixel gradient's model and direction in each circle by using formula 9, then refer to SIFT algorithm, use gradient histogram to statistic inner circle gradient's accumulative value as 1~12 dimension's vector $(d_1,d_2...,d_{12})$, outer circle gradient's accumulative value as 13~24 dimension's vector $(d_{13},d_{14}...,d_{24})$. Normalize to each eigenvector generated from each circle, could further reduce the light affection to feature description. Suppose D is the inner circle eigenvector, $D=(d_1,d_2...,d_{12})$ after normalization, there is

$$\overline{D}=\frac{D}{\sqrt{\sum_{i=1}^{12} d^2}}=(\overline{d_1},\overline{d_2}...,\overline{d_{12}}) \qquad (10)$$

Serialize to each feature vector, to ensure the object's rotation invariance, find out the biggest vector after the normalization d_1 in each circle, and put it front, in order to comparably keep the rotation invariance when matching. For example in the innercircle $\overline{d_5}=\max\{\overline{d_1},\overline{d_2},...,\overline{d_{12}}\}$, then the last generated vector is $(\overline{d_5},\overline{d_6},...,\overline{d_{12}},\overline{d_1},...,\overline{d_4})$.

E. Detect Copy-Move area by utilizing SIFT eigenvector matching

Adopt the most neighboring distance algorithm to match, means take certain feature point, search the nearest and second nearest point to this feature point by the traversal search algorithm. Between these two feature points, if the nearest distance divide by second nearest distance's value less than an set threshold value, then judge them as a pair of matching point. Lower the proportional threshold, SIFT matching point number would reduce, but more stable.

Detect to a given image possible with matching block by Copy-Move, the method of dividing eigenvector sets could be adopted during the matching, need to calculate all the eigenvector of the pending-detected images. Then divide and match the feature vector according to some rule, the process of using the SIFT feature vector matching to detect Copy-Move areas as below:

1) Select eigenvectors sets, which contains N feature points
2) If N=1then stop the matching,if N>1 go on with step3;
3) Select randomly N eigenvector's half as sub-collectionS1,the other half as sub-collection S2;
4) Compare and match S1 and S2,and record down the matching feature points pairs;
5) Execute steps2,3,4 to these two sub-collections,till the vector concentration N=1stop the matching;
6) Get all the matching point pairs, and mark white to the areas where matching points pairs lie.

IV. Simulation and Experimental Results

This thesis chooses international standard detect image Lena picture (256×256) , detect the improved SIFT algorithm under the situations of light variance, scale variance, rotation variance. The speed comparison between the improved SIFT algorithm and the initial SIFT forensics algorithm as Table 1, when the same 320x240 image is taken as forensics. The matching rate and mis-matching rate results as Table 2

Table1 Improved algorithm and SIFT algorithm's image speed

	U-SURF	SURF	SURF-128	SIFT
time(ms):	255	354	391	1036

Table 2Matching rate and mismatch rate of improved SIFT

Terms	Feature points NO.	Feature points pair	Matching time/ms	Matching rate/%	Mis-matching rate/%
Light down50%	236	190	265	83.5	1.2
Light up 50%	420	124	329	93.5	1.1
Image reversal	371	341	323	86.5	4.6
Image rotation45°	382	246	389	72.2	6.8
Scale increase 2 times	506	158	341	80.1	6.6

Matching rate and mismatch rate of improved SIFT algorithm

The experiment shows, this method has robustness to image processing such as image's rotation, scaling, fuzzy, noise etc, it could detect quickly and efficiently out the trace of Copy-Move operation in digital image tamper, and locate accurately to the Copy-Move area.

V. Summary and Outlook

This thesis starts from the most popular used Copy-Move mean's characteristics in the digital image tamper operation, raise an algorithm based on SIFT round shape operator's image forensics, this algorithm extract the pending-detected image's round shape operator eigenvector, to detect and locate against the image's copy-Move area by utilizing eigenvector matching.

There are various methods in digital image tamper and forge, and its effects to image feature are also of multi aspects. The detect forensics accuracy, which based on digital image's single feature forensics technology, is becoming obviously weak in strength as the improvement of the forgery technology. Meanwhile, the above raised SIFT round shape operator only use till gray scale property algorithm, ignore color information, and this shuttlecock's robustness is still weak against the objects with non-linear corresponding relationship. Think multi-angle, full-range, into the effects of digital image tamper and forge against image feature, and to increase the digital image forensics accuracy, fight against the higher level, more complicated digital image tamper and forge, is the coming research direction for blind digital image forensics technology.

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