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Blind Detection of Digital Image Partial Saturation Manipulation

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ABSTRACT. *With the rapid development of the Internet and the popularization of digital image equipment, digital images have become our main source of information. At the same time, the detection technology of malicious tampering with the original content of the image came into being and developed rapidly. For the enhancement of digital images, the color saturation of the image will often be modified to some extent. In the current research, few related documents detect the image saturation tampering. This paper proposes a feature-based detection algorithm for image tampering with Photoshop. In this paper, the mean and variance of the Gaussian fitting saturation histogram in HSV space, the mean value of the angle between the brightness and saturation in HSI space and the estimated noise variance are extracted respectively. The K -means cluster is used to classify the image blocks, marking the tampering part. Experimental results show that the proposed method has better detection results for local saturation tampering.*

KEYWORDS: *Blind Detection; Digital Image; Saturation*

1. Introduction

The advent of the digital age will bring our lives into a more convenient and rapid development of a new era, digital technology for people's basic necessities of life and work and study has brought great convenience. The advantages of digital images are: easy to store, easy to transfer, can be directly displayed on the screen quickly, easy to modify. However, these advantages also pose some potential risks to digital images. The ease-of-modification of digital images allows people to optimize their images quickly and easily, but for digital images with evidence-based effects, this advantage can make some people take advantage of malicious tampering with the original contents of the image to distort facts or the purpose of cheating in photography contest. Therefore, the digital image tampering detection technology came into being and developed rapidly. Enhancements of digital images often modify the color saturation. Similarly, saturation modification is also applied to digital images as a means of image tampering. In the current study, few related documents detect the image tampering. Image tampering does not affect the edge, texture, histogram and other features of the image significantly, which brings some difficulties in detecting such tampering.

At present, the existing image enhancement algorithms mostly adjust the image saturation to different degrees. Saturation adjustment in the image enhancement algorithm can be roughly divided into the following categories: enhancement of the grayscale image of the color image and then back to the color image [1]; saturation of the color component of the RGB image is linearly changed based on the hue invariance; in HSV or HSL space, keep the hue unchanged, the algorithm directly adjust the saturation and brightness component [2-4]. The above methods can adjust the saturation component of the image, and the detection of the above adjustment method becomes the research focus. (The above adjustment method has in common that the hue value of the image remains unchanged when the saturation component is adjusted.)

When using the above method to linearly adjust the saturation, the phenomenon of over-saturation or stain appears [5]. Chen Jia-bin et al. [6] proposed a method of fixing gamut overflow by fixing the brightness constant in HSI space and changing the RGB component depending on the Hue value when the saturation equal to 1. Song Ruixia [7] and others put forward to enhance the subdivision index of saturation. Adjust the high-saturation region in a narrow range to reduce the saturation appropriately. Exponential tension stretching in the low-saturation region to increases the saturation under the premise of preventing the saturation overflow.

Now commonly used image editing software Photoshop use HSB color space to adjust the degree of saturation to avoid the case of over-saturation. Photoshop saturation adjustment differ from the method of directly adjust the saturation component, but to obtain a color saturation component S, the luminance component L as the upper and lower limit control, the original RGB value has the upper and lower limits of the local

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regulation. In this way, the image does not appear saturated stains or image color distortion, but also increased the scope of the saturation adjustment, but also gives the image tamper detection some challenges. We can not solely analyze the feature changes from the image's saturation component.

Fig.1 is a histogram of the S component directly adjusted in HSV space. It can be seen that the tampered image shows a color patch while the shape of the histogram does not change, but the distribution is entirely right Moved the size of the adjustment. Fig.2 shows the image tampered by Photoshop and their corresponding histogram of saturation, the shape of the histogram changes, not the simple translation before. This requires us to identify deeper changes in the histogram to identify saturation tampering.

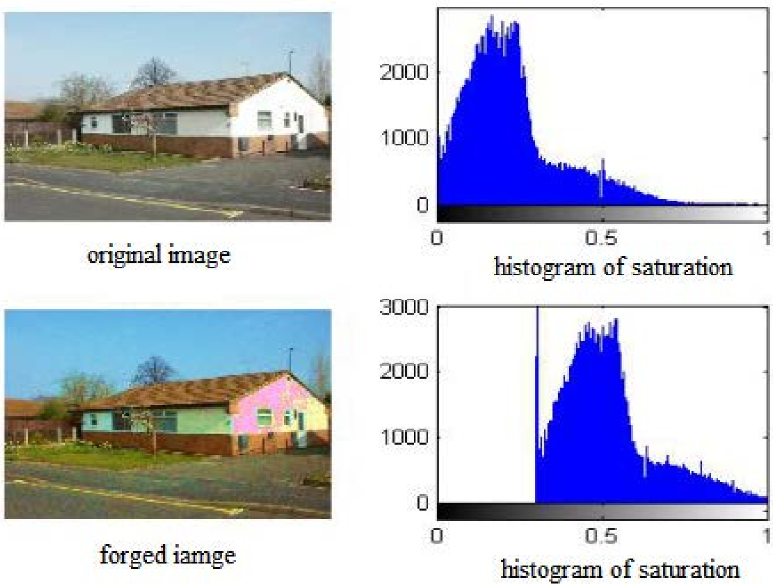

Figure.1 Saturation adjustment by HSV

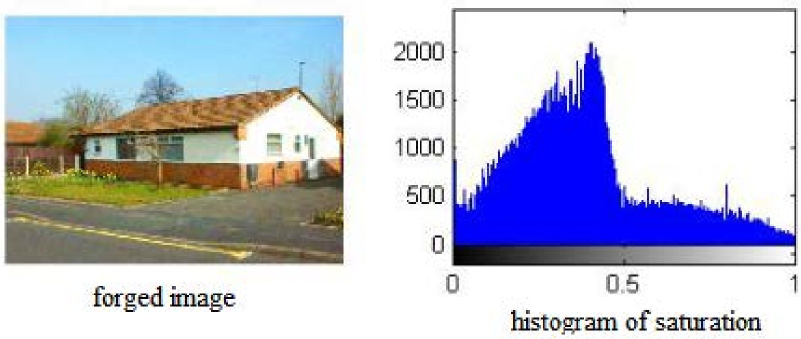

Figure.2 Saturation adjustment by Photoshop

2. Method

2.1 Analysis of blind detection algorithm for image local saturation adjustment

(1) Effect of Image Saturation Adjustment on Image Saturation Histogram

In order to find out the influence of saturation adjustment on the histogram of image saturation component, we design the following experiments: we extract the saturation component from the original image and the tampered image and do the histogram analysis. Due to the influence of the image content, in the histogram, the minimum frequency is always in the direction of 0 and 1, there also will be the distribution of the maximum value of the particularity, that is, a single maximum appears at a certain value, as shown in Fig.3, which bring us

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distraction of our analysis. Therefore, we perform Gaussian fitting on the histogram of the image saturation and then extract the fitted mean and variance for feature analysis.

$$f(x) = \frac{1}{\sqrt{2\pi\delta}} \exp(-\frac{(x-\mu)^2}{2\sigma^2}) \tag{1}$$

μ is the average, σ is the standard deviation. $f(x)$ is the normal distribution function and used to fit the histogram distribution. According to the fitted histogram, the single maximum of saturation can be excluded. And also, we can find that the maximum value of the original image appears at the position of saturation of 0.27 and the tampering image appears at the position of 0.44 with variance of 0.15 and 0.22.

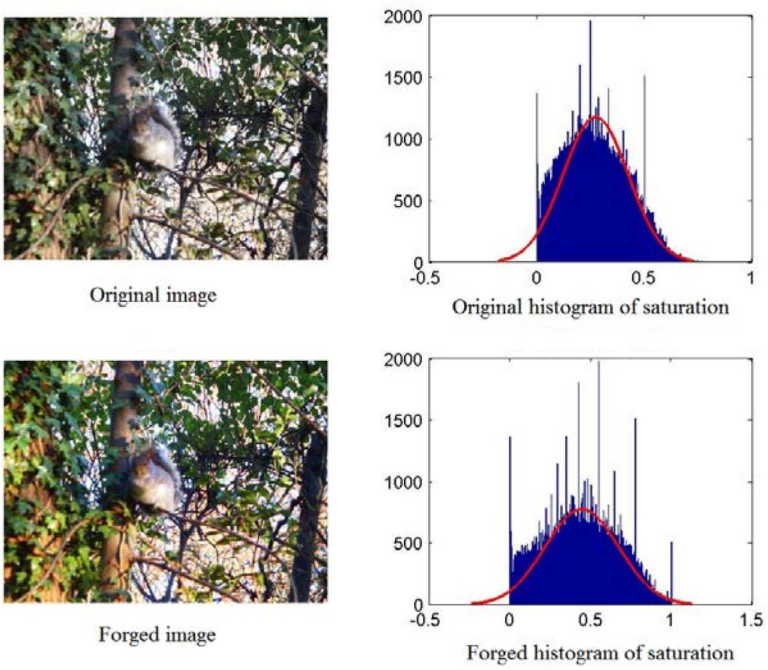

Figure.3 Histogram of the saturation component after Gaussian fitting

Based on the above findings, in order to further verify the universality of this law, we randomly selected 50 images in the UCID image database, and used Photoshop to adjust the image saturation randomly, histograms of the saturation component extracted from original image and the tampered image were further analyzed.

According to the fitted histogram distribution, we extracted the mean and variance to compare the original image with the tampered image. As shown in fig.4, the mean and variance of the tampered image saturation components are larger than the original image and there are significant differences. Due to the difference of each image content, saturation reference value is different, but in the local detection of single image, the camera type, shooting scenes, light intensity are basically the same, this shortcoming will be reduced.

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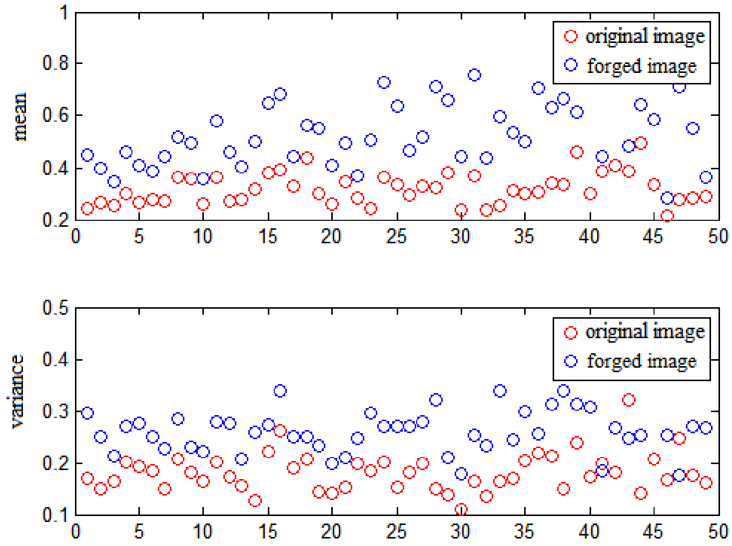

Figure.4 Comparison of mean and variance for 50 images

(2) Effect of Image Saturation Adjustment on the Angle of Image Intensity and Saturation

When the saturation is tampered, the brightness value will change while keeping hue unchanged. So, in order to verify whether the change in the ratio of saturation and brightness can be used as a judge to judge the saturation tampering, we designed a comparative experiment. For the original image and tampered image with random percent saturation manipulation, we extract the S and I components separately in HSI space and use their ratio to find the angle between saturation and brightness. In the HSI space cylinder representation, the hue value is the angle of the bottom circle, the brightness is the height of the cylinder, and the saturation is the bottom diameter, as shown in fig.5, then we can see that the value of Hue does not affect the ratio between saturation and brightness, so the hue value can be ignored in calculating the ratio between saturation and brightness.

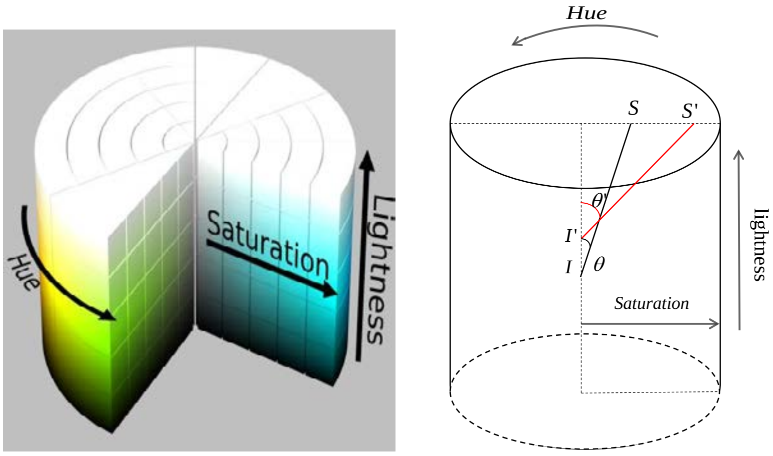

Figure.5 Color space component diagram

$$\theta = \arctan\frac{S}{1-I} \tag{2}$$

$$\theta' = \arctan\frac{S'}{1-I'} \tag{3}$$

Where θ is the angle between the original image saturation and the brightness value, S is the original

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image saturation component, I is the original brightness component, θ' is the angle between the tampering image saturation and the brightness value, S' is the tampering image saturation component, I is the tampering brightness component . In the HSI space cylinder representation, the bottom center of the circle is black with lowest brightness, the top center of the white circle with the highest brightness, so in our calculation, the denominator brightness value is $1-I$.

Similar to the previous experiment, we randomly selected 50 images from the UCID image database and randomly tampered the saturation for each of them. We calculated the angle values for each pixel of the original image and the tampered image, the values of all corners are summed and averaged, and tampering images do the same. The result is shown in Fig.6.

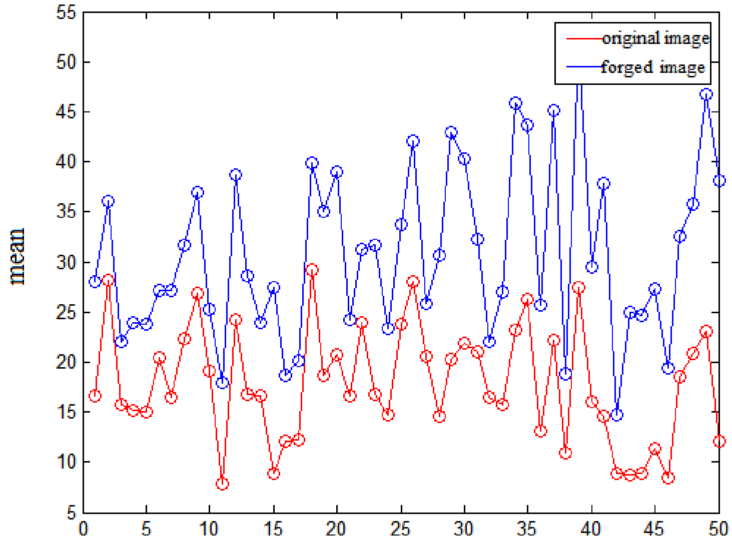

Figure.6 Comparison of saturation and brightness angle for 50 images

From the result graph, it shows that when the saturation increases, the brightness value also increases, but the degree is much less than the increase of the saturation, which leads to the angle θ' of tampering graph is obviously larger than the original image. So it can also be used as a feature to indicate the saturation tampering.

(3) Effect of Image Saturation Adjustment on Image Noise Variance

KRIS HENRY analyzed the effect of saturation on PRNU in the paper[6]. He classifies the images according to the camera types, and at the same time divides the images of the same camera type into two according to the image contents. One is something like sky with low saturation or single-color walls, the other is a natural image of high saturation. The authors extracted the noise from these two types of images for each camera and analyzed the correlation with the reference model noise of the camera model. The analysis showed that the correlation between low-saturation images and camera reference mode noise was higher, So the reverse can be explained, the saturation of the image noise has a certain impact.

The noise of the image is significantly related to the sensor used by the camera, as well as the texture and brightness of the shot scene[7]. In order to ensure the stability of these factors, we choose to use the same image and break it into many non-overlapping blocks, extract noise for these small blocks, and then estimate the noise variance of each local block.

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(a)Original image (b) Forged image

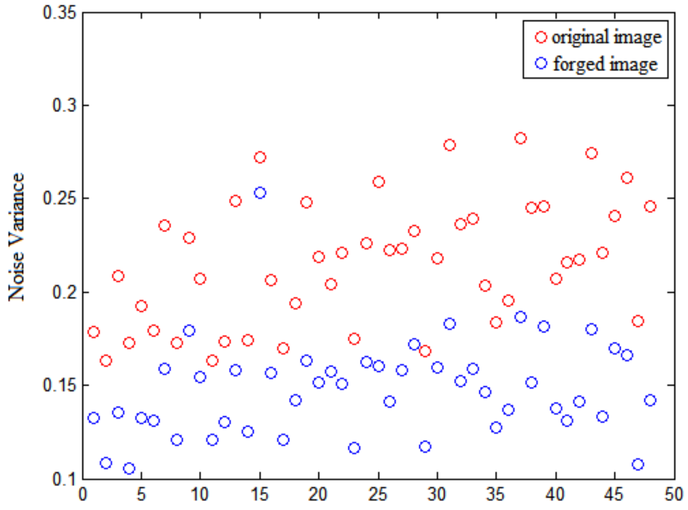

Figure.7 Comparison of Mean Noise Variance between single original Image and Tamper image

Fig.8 is the comparison of the noise variance between original image and tampered image, the red shows the noise variance distribution of the tampered image, and the blue shows the noise variance distribution of the original image. It can be seen that there is a significant difference in the noise variance between the original image and the tampered image, so the k-means method can be used to classify the image blocks according to the similarity of the noise variance.

At the same time we randomly manipulate the saturation of 40 images which selected from Dresden image database to degree of -90 to 90. Then we estimated the average noise variance for all original and tampered images. We divide each image into 20 blocks, extract the noise for each block and calculate the noise variance, and use the average result as the average noise variance of this image. Fig.9 shows the comparison of the mean variance of the original image and the tampered image of 40 images. The result shows that for the noise variance, there is an obvious difference between the original image and the tampered image.

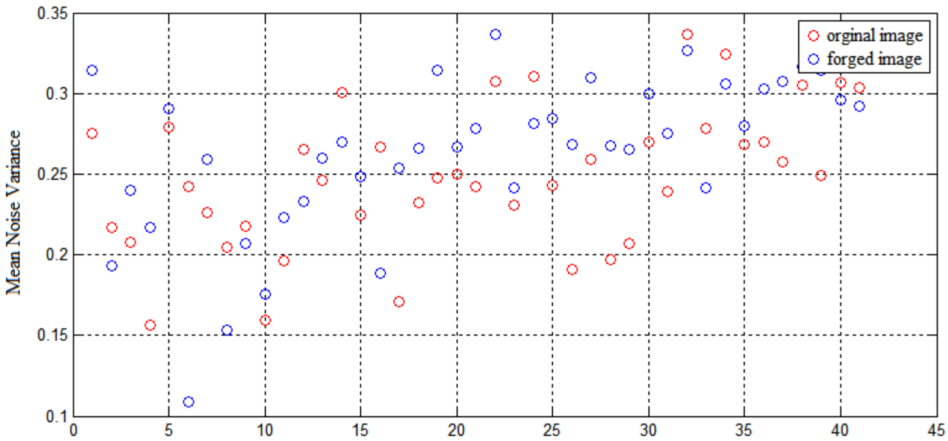

Figure.8 Comparison of Mean Noise Variance between Multiple original Images and Tamper images

Part of the experimental data shown in Table 1, it shows that no matter the noise variance increases or decreases, the saturation changes will cause the common inconformity of noise variance, which can be used as a feature to detect tampering.

Table1. Comparison result of noise variance

	1	2	3	4	5	6	7	8	9	10
Original image	0.275	0.217	0.207	0.156	0.279	0.267	0.226	0.205	0.218	0.160

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Forged image	0.314	0.193	0.240	0.217	0.291	0.189	0.259	0.153	0.207	0.176
Difference	0.039	-0.024	0.033	0.061	0.012	-0.078	0.033	-0.052	-0.011	0.016

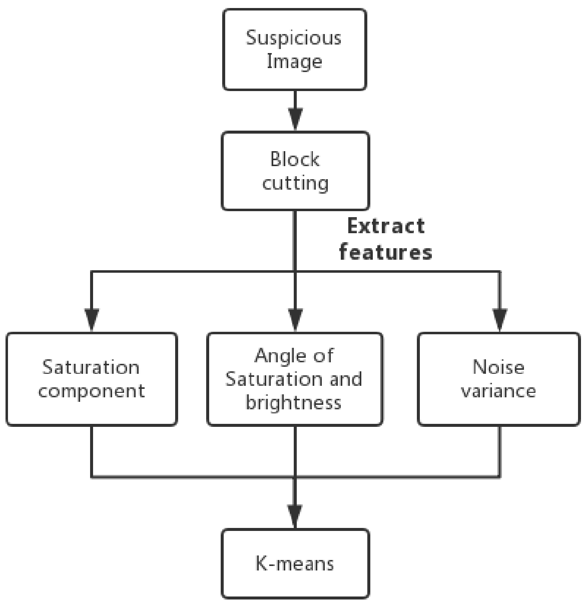
2.2 Detection of Local saturation tampering

In the previous section, we analyzed three features of saturation tampering. In the local saturation tampering detection algorithm, the first step is segmenting the suspicious image, and then weighting each feature according to the degree of influence as the final unsupervised classification algorithm K-means clustering features. KRIS HENRY mentioned in the article that although color saturation affects the image noise, the factors that affect the noise are texture, lighting, camera sensor model, etc. Therefore, the color saturation of the image can not be used as a criterion [9]. The first two features clearly distinguish between the original image and the image that has been tampered with, thus assigning a higher weight.

We use Eq.(4) to assign weights to the three features:

$$\overline{x} = f_1 w_1 + f_2 w_2 + f_3 w_3 \tag{4}$$

Where, $f_1 + f_2 + f_3 = 1$, w_1 is the mean and variance characteristic of the saturation component of the image, w_2 is the angle characteristic of image saturation and brightness in HSI space, and w_3 is the noise variance characteristic of the image. Algorithm flowchart as shown in Fig.9:



Figuer.9 The flowchart of proposed method

The final test results divide all the image blocks into two categories. In this paper, the default image tampering premise is that the tampered area should be smaller than the real image area. In the final test results, we consider the smaller part of the cluster as tampered area.

2.3 Saturation Tamper Detection Algorithm

For the local saturation tampering, the use of these three features K-means classification can be better detection results. In order to test the universality of our algorithm for tamper detection of the overall image saturation, we conducted experiments using SVM (Support Vector Machine) based on the above characteristics. The experimental steps are as follows:

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1) Firstly, we randomly select 200 images from the UCID database and randomly select 100 images to randomly tamper the overall image saturation. Among them, the cross-validation test set occupies 20% of the sample size, that is, 160 training images, 40 test images.

2) Input the above features of the training set image into the SVM classifier with RBF kernel, conduct cross-validation and training to be SVM model;

3) Input the above characteristics of the test group image into the SVM classifier, and classify the images of the test group using the model obtained by the above training to obtain the classification result.

3. Expriments result

3.1 Local saturation tampering detection result

At present, researchers have not paid much attention to the detection of saturation modification. Therefore, it is very important for the detection of this type of tampering. In this chapter, we verify the proposed algorithm for local saturation tampering detection and analyze the experimental results. We randomly selected 100 images from the RAISE image database and used Photoshop to increase or decrease the degree of randomness of the image locally to produce 100 tampered images. Figure 4-10 shows the detection result of our algorithm for this tampering strategy. As can be seen from the experimental results, our algorithm is also suitable for tamper detection with reduced saturation.

(a) Original image (b) Forged image (c) Detection result

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Figure.10 Experimental results of local Saturation tampering

In order to locate a suspected tamper area, the suspicious image is divided into non-overlapping image blocks for feature extraction. In general, the size of the image block can have an impact on noise extraction and estimation of noise variance. Large image block size can be extracted to more accurate noise variance, but will affect the accuracy of the test results. In order to select a suitable block size, we compare the results of the image size of 32 * 32,64 * 64,128 * 128 images, the final results show that the block size of 64 * 64 can have the best test results.

At present, our algorithm tampered by default is smaller than the real image area. For the tampered area larger than the original image area, we think the area of the original reference image is too small, and our algorithm test result is not very good for such tampering solution. In the future research and improvement, we will address this flaw to improve.

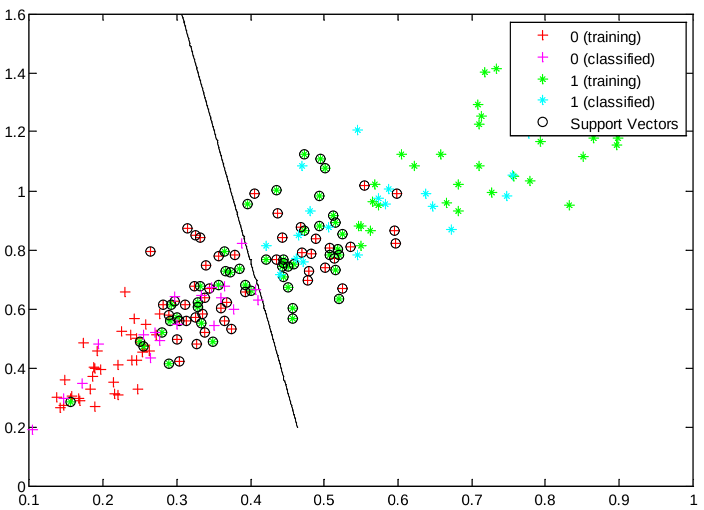
3.2 Saturation tampering detection result using SVM

For this experiment, we divided the three groups for classification testing. The first group has 40 samples, of which the original images and the tampered images of increased saturation each occupy 50%. The second group also has 40 samples, of which the original images and the tampered images of decreased saturation each occupy 50%. The third group consists of 40 samples, including the original images, the tampered images with increased saturation and the tampered images with decreased saturation, each of which has the same proportion (three type s of images are guaranteed to be basically the same because they can not be completely and accurately allocated here).

The experimental results are shown in Figure 4-11. The red crosses and green asterisks respectively represent the original images and the tampered images in the training set, and the circled samples are the support vectors o f the SVM classifier. The purple crosses and blue asterisks indicate the samples in the test set. The test classificat ion accuracy in the test set as shown in Table 4-2.

Table2. Detection rate of SVM

Tamper strategy	Saturation increases	Saturation decreases	Mixture
Detection rate	72.5%	87.5%	60%



(a) saturation increase

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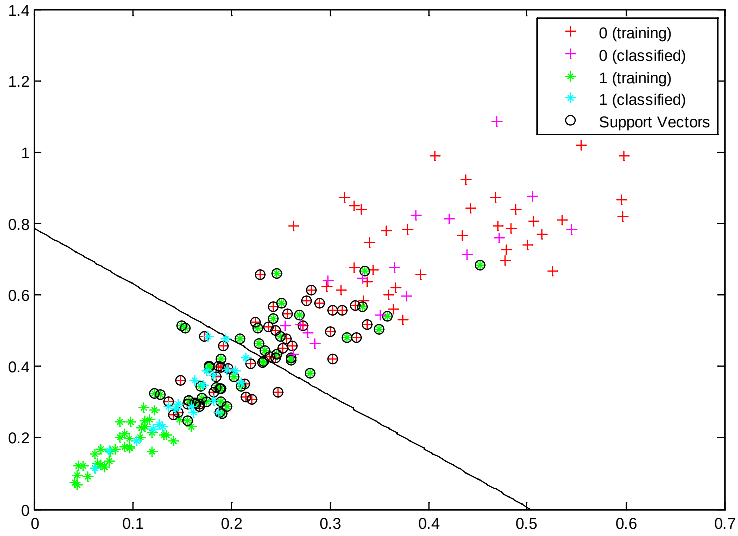
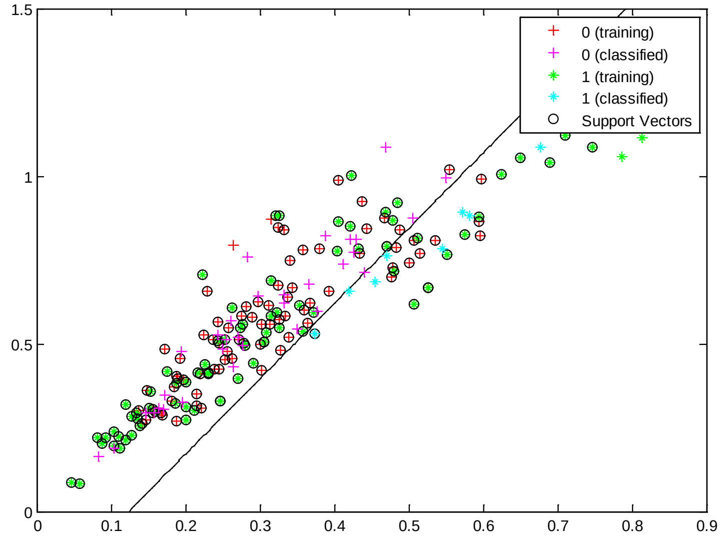


(b) saturation decrease



(c) mixture modification

Figure.11 SVM classification results

Based on the above results, our feature has a higher detection rate for the classification of the whole image after saturation and saturation reduction. However, when the test set has both the saturation increase and the saturation reduction as well as the unmodified images, the detection rate of distinguishing whether the image is modified is lower than that of a single adjustment method. Based on the shortcomings of the current research, the detection of mixed tampering with saturation in the follow-up study will be further improved.

4. Conclution

In this paper, we introduce the detection method of local image saturation tampering. The method is based on the features of the three components of the HSV color space and the noise variance features of the image, which are classified using k-means for the above features. At the same time, we also use SVM to verify that our method has better detection results for tampering detection of saturation in a single direction of the entire image, and the classification results of hybrid adjustment still need to be improved. At present, there is no detection method for this type of tampering. The experimental results show that our method can detect the local saturation tampering. However, tampering detection with tampered area greater than non-tampered area and multi-color tampering methods has not been very effective.

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