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# Noise Estimation Using Filtering and SVD for Image Tampering Detection

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*Abstract— Digital images have an inherent amount of noise introduced either by the imaging process or digital compression. The amount of noise is typically uniform across the entire image. If two images with different noise levels are spliced together or if small amount of noise is added to conceal traces of tampering, then variations in the signal to noise ratio (SNR) across the image can be used as evidence of tampering. In this paper, we propose a method to estimate noise using filtering and block based singular value decomposition and then use the variations in Signal to noise ratio (SNR) for detecting image tampering.*

*Index Terms— Singular Value Decomposition, Image Tampering, Noise Inconsistencies.*

## I. INTRODUCTION

In recent years, the rapid expansion of the interconnected networks and development of digital technologies have facilitated instant multimedia transmission and creation of large scale image databases. Recent advances in communication infrastructure, signal processing and digital storage technologies have enabled pervasive digital media distribution. Digital distribution introduces a flexible and cost effective business model that is beneficial to multimedia commerce transaction. The digital nature also allows individuals to manipulate, duplicate or access media beyond the conditions agreed upon for a given transaction. With some powerful software one can remove/replace some features in a digital image without any detectable trace. These kinds of operations are regarded as *tampering*. For medical, military and judicial applications such operations are not allowed. Under these conditions authentication has become an important issue to ensure trustworthiness of digital images in sensitive application area such as government, finance, health care, and judiciary. Approaches of image authentication are mainly based on watermarking [1] or digital signatures. This direction is often referred as *active image authentication*, a class of authentication techniques that uses a known authentication code embedded into the image or sent with it for assessing the authenticity and integrity at the receiver. However, this category of approaches requires that a signature or watermark must be generated at precisely the time of recording or sending, which would limit these approaches to specially equipped digital devices. Therefore, in the absence of widespread adoption of digital watermark or signature, there is a strong need for developing techniques that can help us make statements about the integrity and authenticity of digital images. *Passive image authentication* is a class of authentication techniques that uses the received image itself only for assessing its authenticity or integrity, without any side information (signature or watermark) of the original image from the sender. It is an alternative solution for image authentication in the absence of any active digital watermark or signature. As a passive image authentication approach, digital image forensics is a class of techniques for detecting traces of digital tampering without any watermark or signature. It works on the assumption that although digital forgeries may leave no visual clues of having been tampered with, they may, nevertheless, disturb the underlying statistics property or quality consistency of a natural scene image. Most work on tampering detection literature identify tampering by studying properties of the manipulated image in terms of distortion it undergoes which might include resampling [2], jpeg compression [3], lens distortion, gamma correction and additive noise[4]. Each of these processing operations modifies the image statistics in a specific manner and thus can be identified by extracting certain salient features that would help to distinguish such tampering from authentic data or block.

## II. THE RELATED WORK

A.C.Popescu and H.Farid have proposed in [4] a noise inconsistencies detection method based on estimating the noise variances of overlapping blocks by which they tile the entire investigated image. The method uses second and fourth moments of analyzed block to estimate noise variance. The method assumes white Gaussian noise and non



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Gaussian uncorrupted image. The method also assumes that kurtosis of the original signal is known, which is mostly not true in practice. Hongmei Gou and etal. [5] Introduced a novel approach for tampering detection and steganalysis on digital images using three sets of noise features. They obtained the denoising algorithms to obtain the estimates of image noise. The second set of features was obtained by wavelet analysis and the third was obtained by utilizing prediction errors of neighborhood prediction. Using these features a classifier was built to distinguish direct camera output from their tampered or stego versions. Another method capable of detecting image noise inconsistencies is proposed in [6] by B.Mahdian and S.Saic. The method is based on tiling the high pass diagonal wavelet coefficients of the investigated image at the highest resolution with non overlapping blocks. The noise variance in each block is estimated using a widely used median based method and used as homogeneity condition to segment the investigated image into several homogenous sub regions. The shortcoming of the method is that the threshold must be carefully selected; otherwise it is difficult to separate the tampered region from rest of the image. Xunyu Pan et. al.[8] described a novel method for image forgery detection based on the clustering of image blocks with different noise variances. Again Xunyu Pan et. al. [9] described an effective method for exposing image splicing by detecting inconsistencies in local variances. Their method is based on the Kurtosis concentration property of natural image in the band pass filtered domains. The method has limitation as it assumes that splicing region and original image have different intrinsic noise variances.

### III. NOISE ESTIMATION

In this section, we discuss the methodologies to extract image noise for tampering detection. Firstly we estimate the noise by applying denoising algorithms. Secondly we estimate the noise by Singular value decomposition.

**Noise estimation from denoising Algorithms:** To estimate the noise we utilize image denoising algorithms. As shown in Fig 1 (a), given an image  $I$ , is first divided into blocks and then denoising operation is applied to obtain its denoised version  $I_D$ . In order to capture different aspect of noise four different denoising algorithms are used. In our experiment we use an averaging filter of size  $3 \times 3$ , a Gaussian low pass filter of the same size and with a standard deviation  $\sigma = 0.5$ , a median filter of size  $3 \times 3$  and an adaptive Weiner filter of same size. Using these denoising filters, we obtain noise for the image under test. Then the Signal to noise ratio (SNR) and Peak Signal to noise ratio (PSNR) are computed as follows

$$\sum_{i=1}^M \sum_{j=1}^N I(i, j)^2 \quad (1)$$

$$N_0 = \sum_{i=1}^M \sum_{j=1}^N [I(i, j) - I_D(i, j)]^2 \quad (2)$$

$$SNR = 10 \log_{10} \left( \frac{S}{N_0} \right) \quad (3)$$

$$PSNR = 10 \log_{10} \left( \frac{peak * peak}{MSE} \right) \quad (4)$$

Where  $peak = \max \{I(i, j)\}$  and

$$MSE = \frac{1}{MN} \sum_{i=1}^M \sum_{j=1}^N [I(i, j) - I_D(i, j)]^2 \quad (5)$$

**Noise estimation from Singular value Decomposition:**



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In the theory of SVD, any  $m \times n$  real valued matrix A can be decomposed uniquely as

$$A = U \sum \sum V^T = \sum_{i=0}^n \alpha_i u_i v_i \quad (6)$$

Here U and V are orthogonal matrices with column vectors  $u_i$  and  $v_i$  and  $\sum = \text{diag}(\alpha_1, \alpha_2, \dots, \alpha_n)$  is a diagonal matrix. The diagonal elements of  $\sum$  can be arranged in a descending order and are called singular values of A. The rank of A is the number of its nonzero singular values. If rank of A is r, where  $r \leq \min(m, n)$ , then

$$\alpha_1 \geq \alpha_2 \geq \dots \geq \alpha_r > \alpha_{r+1} = \dots = \alpha_n = 0 \quad (7)$$

In practice, under an additive noise model, we observe a matrix  $B=A+E$ , where E is a random noise perturbation matrix of full rank. In that case, the last n-r singular values of B can be small, but not necessarily zero.

Let  $\beta_1 \geq \beta_2 \geq \dots \geq \beta_{n-1} \geq \beta_n$  be the singular values of B listed in non-increasing order. We define the effective rank of B as r if

$$\beta_1 \geq \delta_1 \geq \beta_{r+1} \quad (8)$$

Here  $1 \leq r \leq \min(m, n)$  and  $\delta_1 = \|E\|_2$  is the 2-norm of E. If the elements of E are identically distributed random variables with Gaussian distribution of zero mean and variance  $\sigma^2$ , then the upper bound on  $\delta_1$  can be found as follows;

$$\delta_1 \leq \sqrt{mn}\sigma \quad (9)$$

Image decomposition into non overlapping blocks is quite useful to reduce computation. Let B be an  $M \times N$  image divided into  $k \times k$  image sub blocks  $B_s$ . Using singular value decomposition each block can be decomposed as

$$B_s = U_B \sum_B V_B^T = \sum_{i=1}^n \beta_i u_{Bi} v_{Bi}^T \quad (10)$$

Given a threshold  $\epsilon$ , let  $\sum'_B = \text{diag}(\beta'_1, \beta'_2, \dots, \beta'_n)$ , where  $\beta'_i = \beta_i$  if  $\beta_i > \epsilon$  and  $\beta'_i = 0$  if  $\beta_i \leq \epsilon$ . Then, the reconstructed matrix  $B'_s = U_B \sum'_B V_B^T$ .

From (10), each sub block can be expressed as a weighted sum of basis images  $u_{Bi}, v_{Bi}^T$  where the weights are the singular values. By setting to zero the “non significant” singular values in effect we perform a *lossy compression* on each sub block  $B_s$ . Then the noise estimated is equal to the subtraction of original block and reconstructed block [7]. The main steps for noise estimation using SVD are shown in Fig 1(b). The main steps are as follows.

1. Divide an  $M \times N$  image B into sub blocks  $B_s$  as given in equation (10).
2. Perform SVD on each sub block and set to zero the singular values that are smaller than threshold  $\epsilon$ .
3. Replace  $B_s$  with  $B'_s$  defined before.
4. Estimate the noise, SNR and PSNR for each sub block using equation (3) and (4) and observe the variations in SNR and PSNR for detecting tampering.

IV. EXPERIMENTAL RESULTS

In this section, we present experimental results on applying the proposed noise estimation algorithms for image tampering detection using Matlab. A testing set of 12 images (6 authentic and 6 tampered) was used for the experiments. The images were obtained from various sources including the CASIA Tampered Image detection Evaluation Database (CASIA TIDEv2.0)<sup>1</sup>. The images are shown in fig 2. Table I shows the average PSNR obtained using the denoising filters and SVD.

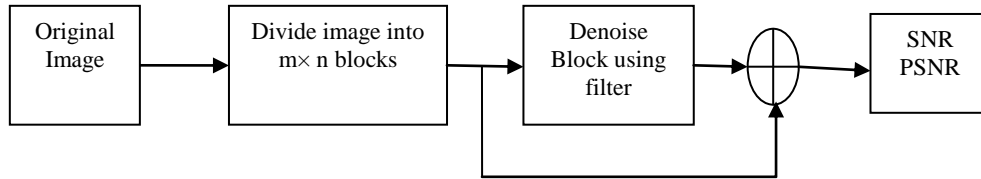


Fig. 1 Noise Estimation via denoising

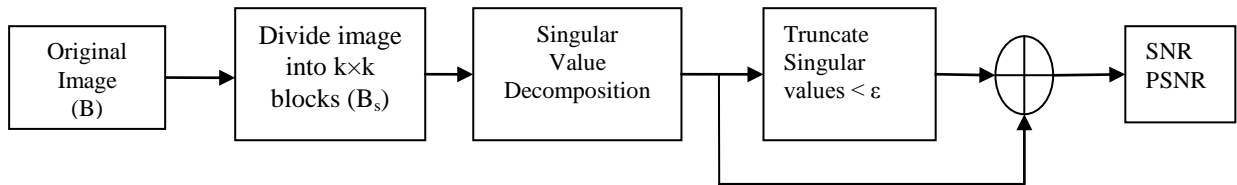
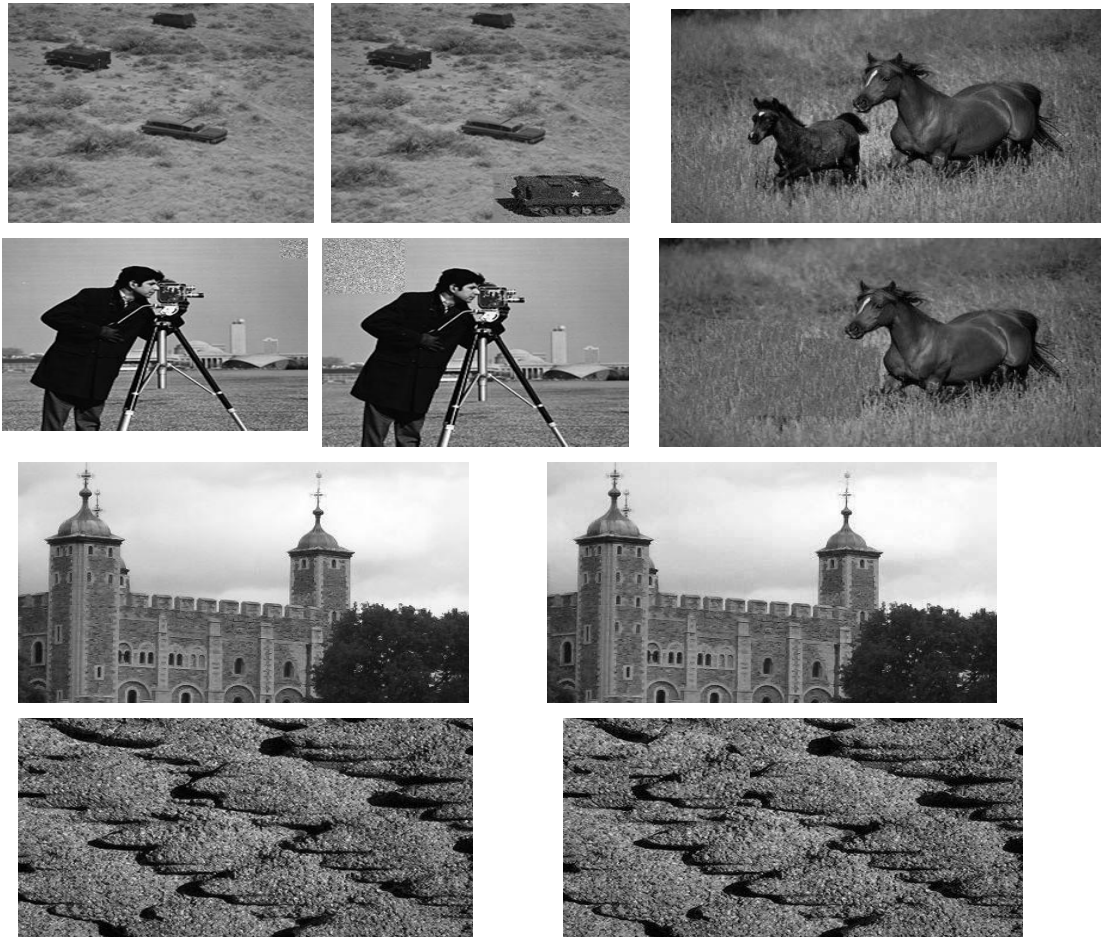


Fig. 1(b): Noise Estimation via Singular Value Decomposition

Fig2 Authentic and Tampered Images





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Image	Size	No. of Blocks	Average PSNR in dB				
			Weiner	Averging	Gaussian	Median	SVD
Lena (Au)	256×256	16	32.35	29.28	37.44	28.56	50.68
Lena (Tp)	256×256	16	31.37	28.28	36.40	27.90	49.77
Cameraman(Au)	256×256	16	33.12	29.00	37.78	27.27	58.22
Cameraman(Tp)	256×256	16	31.25	27.48	36.13	26.29	56.71
Tank (Au)	256×256	16	28.57	28.08	36.64	26.82	49.30
Tank(Tp)	256×256	16	27.89	27.20	35.68	26.21	48.21
Texture (Au)	256×384	24	20.89	19.30	27.24	19.00	36.39
Texture(Tp)	256×384	24	20.12	18.49	26.06	18.17	34.75
Animal(Au)	256×384	24	29.57	28.13	36.94	28.99	54.75
Animal (Tp)	256×384	24	30.04	28.96	38.00	27.50	62.02
Architecture(Au)	256×384	24	33.10	31.65	40.33	27/01	64.16
Architecture(Tp)	256×384	24	32.78	31.16	40.02	26.94	65.11

Table I Average PSNR for images

Table II Average SNR for images

Image	Size	No. of Blocks	Average SNR in dB				
			Weiner	Averging	Gaussian	Median	SVD
Lena (Au)	256×256	16	27.56	24.49	32.65	23.77	45.89
Lena (Tp)	256×256	16	26.53	23.45	31.56	23.07	44.93
Cameraman(Au)	256×256	16	27.95	23.82	32.61	22.09	53.05
Cameraman(Tp)	256×256	16	25.85	22.08	30.73	20.89	51.31
Tank (Au)	256×256	16	25.69	25.20	33.76	23.94	46.42
Tank(Tp)	256×256	16	24.52	23.84	32.31	22.84	44.84
Texture (Au)	256×384	24	13.87	12.28	20.22	11.98	29.37
Texture(Tp)	256×384	24	12.81	11.18	18.75	10.86	27.44
Animal(Au)	256×384	24	24.49	23.06	31.88	21.92	49.68
Animal (Tp)	256×384	24	25.63	24.56	33.60	23.10	57.61
Architecture(Au)	256×384	24	29.28	27.83	36.51	23.19	60.34
Architecture(Tp)	256×384	24	33.10	31.65	40.33	27.01	64.16



Table II shows the average SNR for the images. The results show that the average PSNR and SNR are higher for the Authentic images and lower for the Tampered images. The values of PSNR and SNR are higher using SVD.

Table III SNR values using SVD for different blocks for Lena Image

B.N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Au	49.6	46.8	49.5	45.8	49.4	37.0	43.0	49.2	46.0	35.1	44.6	54.1	45.3	38.9	51.1	48.2
Tp	34.3	46.8	49.5	45.8	49.4	37.0	43.0	49.2	46.0	35.1	44.6	54.1	45.3	38.9	51.1	48.2

Table III shows SNR values for the authentic (Au) and tampered (Tp) Lena image shown in fig 2. The bar graph of the SNR and block number is shown in fig4. The tampered image has noise in the first block which is seen from the table III value and is clearly visible in fig. 3 and fig 4. It is possible to localize tampering using blocks.



Fig. 3 a) Authentic Lena image b) Tampered Lena image

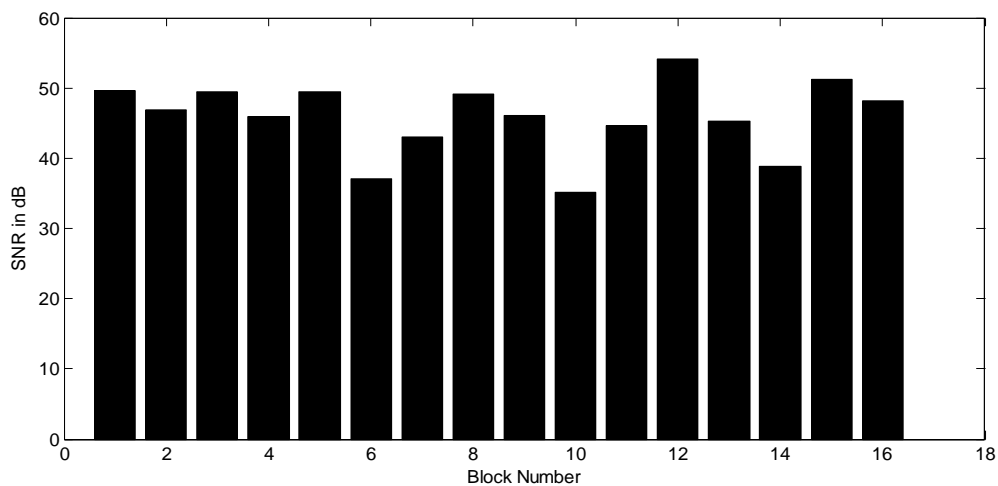


Fig. 4 a) Bar graph of SNR and Block number for Original Lena Image using SVD



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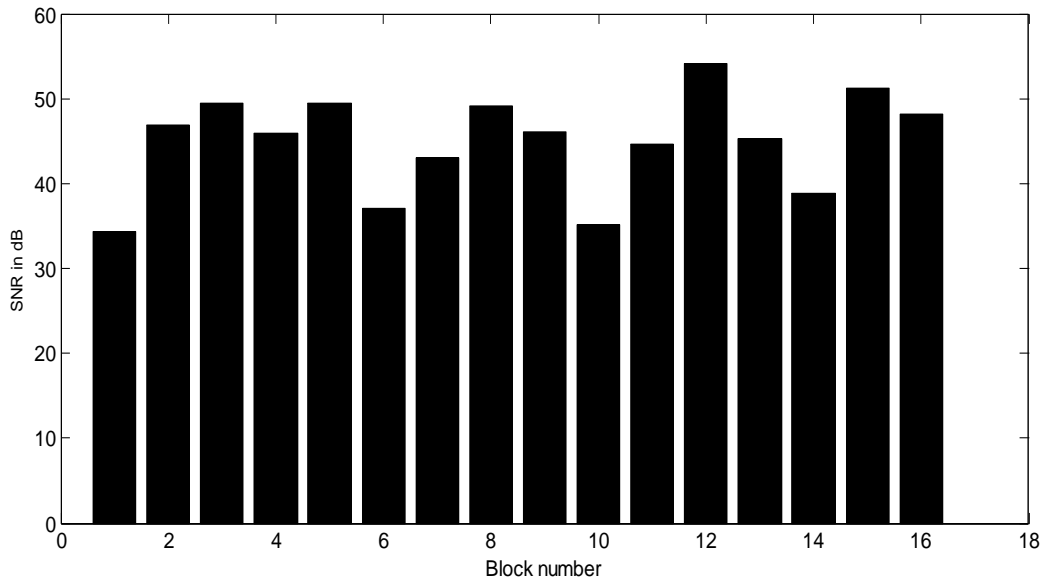


Fig. 4b) Bar graph of SNR and Block number for Tampered Lena Image using SVD

#### V. CONCLUSION

The proposed algorithm is passive or blind technique for the tampering detection as it does not require a priori information or rely on predistribution watermarking or digital signature which is the case with active approaches. The tampering can be detected by comparing the PSNR and SNR of the authentic and tampered image. The region of tampering is localized using the blocks. The method identifies a tampered region when noise has been added locally. Random noise could be added across the entire image to conceal image tampering, and this would not be detected by this method. Sometimes the splicing of two images may change the PSNR and SNR randomly which may not be detected by this method.

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