Gaussian Filtering Detection of Digital Image Forensic

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Abstract: For a design of the Gaussian filtering (GF) detection (GFD) in the altered digital images, this paper presents a new feature vector that is formed from the autoregressive (AR) coefficients by AR model of the gradients of the horizontal and vertical lines in an image. In the proposed algorithm, AR coefficients are computed from the gradients of the lines. Subsequently, the defined 20-dim. feature vector is trained in a SVM (Support Vector Machine) for the GFD of the forged images.

In the experiment, four kinds test items are the area under curve (AUC), the true positive rate at the false positive rate is 0.01, the minimal average decision error, and the classification ratio. The performance is excellent both at GF (3×3) and GF (5×5) vs. ORI (Unaltered) and JPEG (Quality Factor=90) on the proposed DFD scheme.

However, the measured performances of the AUC is above 0.9. Thus, it is confirmed that the grade evaluation of the proposed algorithm is rated as "*Excellent* (*A*)."

Keywords-- **Gaussian filtering detection, Line gradients, Autoregressive model, SVM.**

1. Introduction

In the image alterations or the content-preserving manipulation are using a filtering operation. In the forgery methods [1,11,12,13], the Gaussian filtered image is mainly preferred among some forgers because that the Gaussian low-pass filter has a very smooth transition band and achieves the smoothing in the frequency domain by high-frequency attenuation [2].

Furthermore, the GFD could classify to the altered images. Consequently, the GFD becomes a significant forensic tool for the recovery of the processing history of a forgery image [9].

In this paper, a newly Gaussian filtering detection algorithm is proposed, in which the feature vector is formed from AR coefficients by AR model of the gradients of the horizontal and vertical lines in an image.

The rest of the paper is organized as follows. In Section 2, it briefly presents the theoretical background of the autoregressive (AR) modeling [3] and an image line's gradients. In Section 3, it describes the construction of the new feature vector, and the proposed method is presented to classify the Gaussian filtering of the proposed GFD algorithm. The experimental results of the proposed algorithm are shown in Section 4. The performance evaluation is followed by some discussions. Finally, the conclusion is drawn, and the future work is presented in Section 5.

2. Theoretical Background

2. 1 Autoregressive Modeling

In this section, an image pixel's gradients are shortly introduced.

AR coefficients [10] computed as

$$a_k^{(r)} = AR(mean(d^{(r)})) \tag{1}$$

$$a_k^{(c)} = AR(mean(d^{(c)})) \tag{2}$$

$$a_k = (a_k^{(r)} + a_k^{(c)})/2 \tag{3}$$

where r and c mean that row and column directions respectively in an image and k is AR order number, $1 \le k \le p$, p is maximum order number. Again AR coefficients are to be the difference image by following

$$d(i,j) = -\sum_{q=1}^{p} a_k^{(r)} d(i, j-q) + \varepsilon^{(r)}(i,j) \tag{4}$$

$$d(i,j) = -\sum_{q=1}^{p} a_k^{(c)} d(i-q, j) + \varepsilon^{(c)}(i,j) \tag{5}$$

where $\varepsilon^{(r)}(i,j)$ and $\varepsilon^{(c)}(i,j)$ are the prediction errors [4] in the row direction and column direction respectively, and q is a surrounding range of (i,j), $q<3$.

2. 2 Line's Gradients of Image

The gradients G of the horizontal and vertical line [5] in an image x are defined as G_r and G_c respectively as follows:

$$G_r(i,j) = x(i, j+1) - x(i,j) \tag{6}$$

$$G_c(i,j) = x(i+1, j) - x(i,j) \tag{7}$$

where r and c mean that row and column directions respectively in an image.

3. Proposed Gaussian Filtering Detection Algorithm

For the proposed Gaussian filtering detection (GFD) algorithm, AR coefficients are computed by AR model with (6) and (7) then to be as follows:

$$a_k^{(r)} = AR(mean(G_r)) \quad (8)$$

$$a_k^{(c)} = AR(mean(G_c)) \quad (9)$$

$$a_k = (a_k^{(r)} + a_k^{(c)})/2 \quad (10)$$

As like (10), a_k [1^{st} : 20^{th}] is formed to be 20-dim. feature vector in this paper. The flow diagram of the proposed algorithm for the GF detection is shown in Fig. 1.

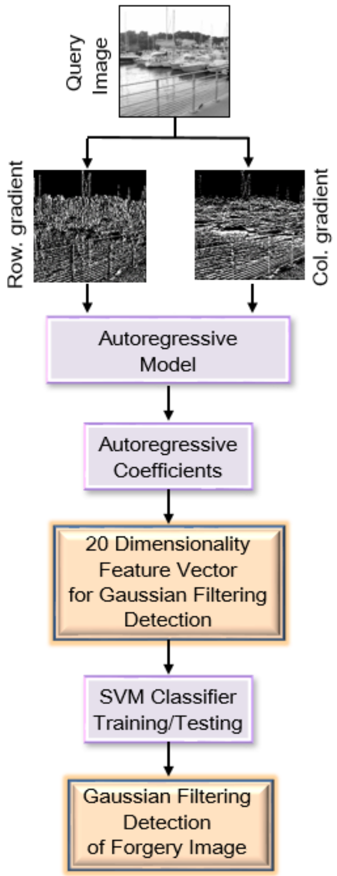

Fig. 1. The flow diagram of the proposed GF detection algorithm.

The GFD scheme is described as following steps.

[Step 1] Computing line's gradients of an image.

[Step 2] Built AR model of Step 1's gradients.

[Step 3] Step 2's AR coefficients [1^{st} : 20^{th}] are formed to be 20-dim. feature vector.

[Step 4] 20-dim. feature vector is trained on a SVM classifier.

[Step 5] The GFD implemented by the trained SVM.

4. Performance Evaluation

The employed method uses a SVM classifier [6] with 20-dim. feature vector for the training of the GF classification. *C*-SVM with Gaussian kernel is employed as the classifier:

$$K(x_i, x_j) = \exp(-\gamma \| x_i - x_j \|^2) \quad (\gamma > 0). \quad (11)$$

Moreover, the formed 20-dim. feature vectors to a SVM classifier with trained four-fold cross-validation in conjunction with a grid search for the best parameters of C and γ in the multiplicative grid:

$$(C, \gamma) \in \{(2^i, 2^j) | 4 \times i, 4 \times j \in Z\}. \quad (12)$$

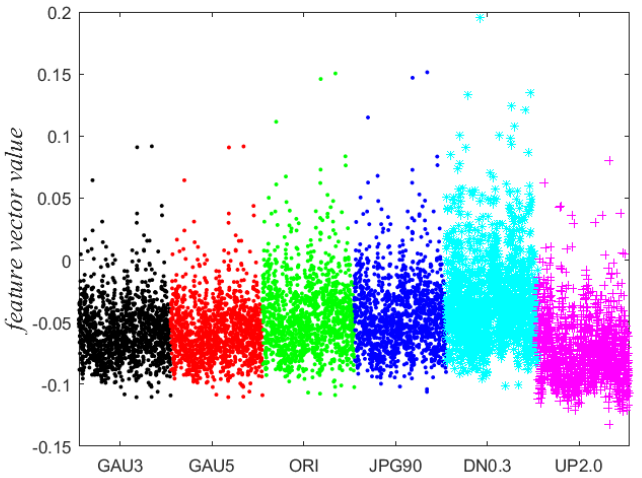

Fig. 2. Feature vectors distribution of each image types.

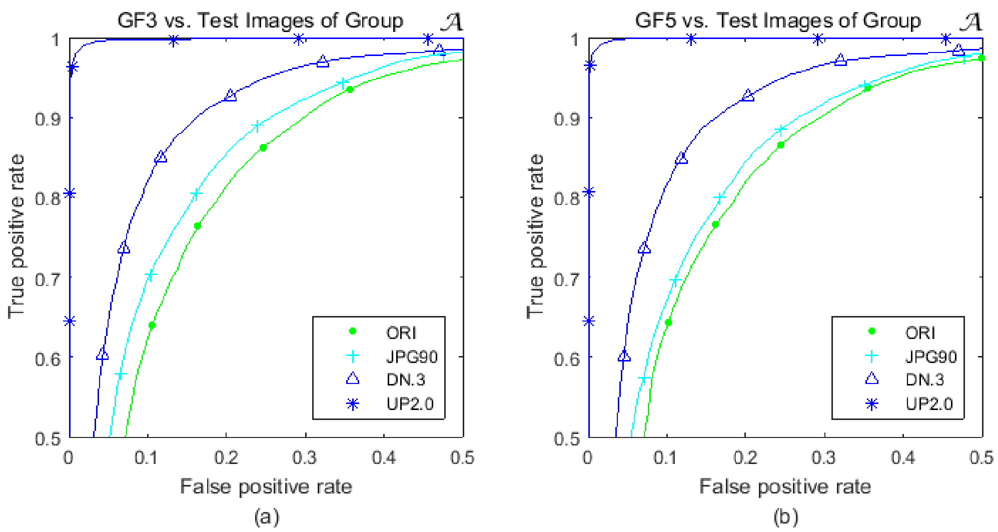

Fig. 3. ROC curves of the proposed GF detection.

For the proposed method, the experiments were conducted using the MATLAB (R2016a) tools on PC environment (the 64-bit ver. of Windows 7, Intel® core™ i7-6700 CPU @ 3.40GHz and DDR4 16GB memory).

The UCID image database [7] consists of 1,338 uncompressed color images of size 512×384 or 384×512.

The database images are used for the GFD, and test image types are prepared GF3 (window size: 3 × 3), GF5 (window size: 5 × 5) for the positive, and Group $\mathcal{A}$ for the negative as follows:

- ORI (Unaltered)
- JPG90 (QF=90)
- DN.3 (Downscaling 30%)
- UP2.0 (Upscaling 200%)

respectively.

Subsequently, the trained classifier model is used to perform the classification on the testing set. Among UCID 1,388 images DB, randomly 1,000 images are selected in training, and the rest 388 images are testing.

The extracted feature set distribution of six kinds of images from the proposed GF detector is shown in Fig. 2.

In Fig. 3, ROC curves show each performance on (a) GF3 vs. Test images Group $\mathcal{A}$ and, (b) GF5 vs. Test images Group $\mathcal{A}$ respectively.

However, in the measured performances of AUC (Area Under Curve) by the sensitivity (TP: True Positive rate) and 1-specificity (FP: False Positive rate) is above 0.9. Thus, it is confirmed that the grade evaluation of the proposed algorithm is rated as '*Excellent* (*A*)' according to an evaluation method in [8] for the training–testing pair.

TABLE 1 shows that the experiment results of GF*w* and the Test image types Group $\mathcal{A}$ on AUC, the true positive rate (P_{TP}) at the false positive rate (P_{FP}) is 0.01, P_e (Minimal Average Decision Error) and the classification ratio respectively.

$$P_e = \min\left(\frac{P_{FP}+1=P_{TP}}{2}\right) \qquad (11)$$

From TABLE 1, it can be seen that the performance of the proposed method is excellent at UP2.0 and DN0.9 on the GF3 and GF5 detection both. Besides, the performances of ORI (Unaltered) and JPG90 are second-drawer on the GF3 and GF5 detection both. The performance of all test items is excellent except ORI and JPG90.

In all the above experiments, the proposed GFD considered only AR coefficients of the image line's gradients to form the feature vector.

5. Conclusion

In this paper, we have proposed a new robust Gaussian filtering detection (GFD) method. We built AR model of an image pixel's gradients, and the AR coefficients used as the GFD feature vectors.

AR model of the employed method will serve as the further research content to the GFD.

To the best of our knowledge, this is the complete solution of AR model of the variations of the horizontal and vertical lines in an image.

TABLE 1 PERFORMANCE OF GF DETECTION EXPERIMENTAL RESULTS.
GF*w*: GAUSSIAN FILTERING WINDOW SIZE
TI: TEST ITEM
1: AUC, ***2***: P_{TP} AT P_{FP}=0.01
3: P_e ***4***: CLASSIFICATION RATIO

GF*w*	TI	Test Image Types			
		ORI	JPG90	DN.3	UP2.0
GF3	*1*	0.8797	0.9015	0.9343	0.9986
	2	0.1378	0.1904	0.3703	0.9805
	3	0.1837	0.1657	0.1227	0.0109
	4	0.7741	0.7962	0.8587	0.9851
GF5	*1*	0.8823	0.8956	0.9327	0.9992
	2	0.1359	0.1478	0.3428	0.9849
	3	0.1820	0.1704	0.1227	0.0089
	4	0.7667	0.7840	0.8624	0.9876

However, the proposed GFD in spite of a short length of the feature vector, the performance results are excellent at UP2.0 and DN0.9 on the GF3 and GF5 detection both due to the AUC and the classification ratio are above 0.9.

Finally, the proposed approach can also be applied to solve different forensic problems, like the previous GFD methods.

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References

[1] Kang Hyeon RHEE, "Median filtering detection using variation of neighboring line pairs for image forensic," *Consumer Electronics -Berlin (ICCE-Berlin), 2015 IEEE 5th International Conference on*, pp. 103-107, Sept. 2015.

[2] Junyu Xu, Yun Ling and Xuan Zheng, "Forensic Detection of Gaussian Low-pass Filtering in Digital Images," *2015 8th International Congress on Image and Signal Processing (CISP 2015),* pp. 819-823, 2015

[3] https://en.wikipedia.org/wiki/Autoregressive_model (March 2016)

[4] S. M. Kay, *Modern Spectral Estimation: Theory and Application*. Englewood Cliffs, NJ, USA: Prentice-Hall, 1998.

[5] Kang Hyeon RHEE, "Median Filtering Detection of Digital Image using the Pixel's Gradients," *ITC-CSCC 2015 Seoul*, July 2015.

[6] C. C. Chang and C. J. Lin, "*LIBSVM: A library for support vector machines*," [Online]. Available: http://www.csie.ntu.edu.tw/cjlin/libsvm

[7] G. Schaefer and M Stich, "UCID - an uncompressed color image database," *Proc. SPIE, Storage and*

Retrieval Methods and Applications for Multimedia 2004, pp. 472–480, 2004.

[8] http://gim.unmc.edu/dxtests/roc3.htmhttp://gim.unmc.edu/dxtests/roc3.htm (March 2016)

[9] Junyu Xu, Yun Ling and Xuan Zheng, “Forensic detection of Gaussian low-pass filtering in digital images,”, *2015 8th International Congress on Image and Signal Processing (CISP)*, pp. 819-823, 2015

[10] Xiangui Kang, Matthew C. Stamm, Anjie Peng, and K. J. Ray Liu, “Robust Median Filtering Forensics Using an Autoregressive Model,” *IEEE Trans. on Information Forensics and Security*, vol. 8, no. 9, pp. 1456-1468, Sept. 2013.

[11] Kang Hyeon RHEE, “Framework of multimedia forensic system,” *Computing and Convergence Technology (ICCCT), 2012 7th International Conference on, IEEE Conf. Pub.*, pp. 1084-1087, 2012

[12] Kang Hyeon RHEE, “Median Filtering Detection using Latent Growth Modeling,” *IEIE, Journal of IEIE*, Vol. 52, No. 1, pp. 61-68, 2015.1.

[13] Kang Hyeon RHEE, “Forensic Decision of Median Filtering by Pixel Value's Gradients of Digital Image,” *IEIE, Journal of IEIE*, Vol. 52, 2015.