Journal of The Korea Institute of Information Security & Cryptology ISSN 1598-3986(Print)
VOL.31, NO.6, Dec. 2021 ISSN 2288-2715(Online)
https://doi.org/10.13089/JKIISC.2021.31.6.1171

저품질 이미지에서 확장된 마르코프 모델과 LBP 텍스처 연산자를 이용한 위조 검출 기법*

아가왈 사우랍,[1†] 정 기 현[2‡]
[1]아미티대학교 (교수), [2]경일대학교 (교수)

Forgery Detection Scheme Using Enhanced Markov Model and LBP Texture Operator in Low Quality Images*

Saurabh Agarwal,[1†] Ki-Hyun Jung[2‡]
[1]Amity University (Professor), [2]Kyungil University (Professor)

요 약

본 논문에서는 저품질 이미지에 적용된 미디언 필터링를 검출하는 기법을 제안하고자 한다. 이러한 미디언 필터링 검출은 이미지 포렌식 기법에 사용되고 있는 것으로 제안된 방법에서는 원본 이미지와 미디언 필터링된 이미지를 구분하기 위하여 공간 영역에서 통계적 특징 정보를 추출하고 확장시킨다. 확장된 특징 정보는 마르코프 모델을 사용하고 강인한 특징 집합을 생성하기 위하여 다중 방향 배열을 사용한다. 제안된 방법에서는 검출 정확도를 높이기 위하여 텍스처 연산자를 사용하고 SVM 분류기를 통하여 분류 모델을 훈련시킨다. 실험 결과에서는 JPEG 압축을 사용한 저품질 이미지에서 제안한 방법의 우수함을 보인다.

ABSTRACT

Image forensic is performed to check image limpidness. In this paper, a robust scheme is discussed to detect median filtering in low quality images. Detection of median filtering assists in overall image forensic. Improved spatial statistical features are extracted from the image to classify pristine and median filtered images. Image array data is rescaled to enhance the spatial statistical information. Features are extracted using Markov model on enhanced spatial statistics. Multiple difference arrays are considered in different directions for robust feature set. Further, texture operator features are combined to increase the detection accuracy and SVM binary classifier is applied to train the classification model. Experimental results are promising for images of low quality JPEG compression.

Keywords: Forgery detection, Texture operator, Median filtering.

I. Introduction

Digital images are very popular on social media platforms such as WhatsApp, Facebook, Instagram and Twitter. Image is more informative and requires less memory in comparison with other information representation alternatives. In

Received(09. 24. 2021), Accepted(11. 05. 2021)
* 본 논문은 2021년도 한국정보보호학회 영남지부 학술대회에 발표한 우수논문을 개선 및 확장한 것임
* 본 연구는 한국연구재단을 통해 과학기술정보통신부의 「해외우수과학자유치사업」의 지원을 받아 수행되었음(2019H1D3A1A01101687). 이 논문은 2021년도 정부(교육부)의 재원으로 한국연구재단의 지원을 받아 수행된 기초연구사업임(2021R1I1A3049788).
† 주저자, saurabhnsit2510@gmail.com
‡ 교신저자, kingjung@kiu.kr(Corresponding author)

many countries, images can be shared easily in contrast to video files, where speed of the internet is slow. The wide availability of digital images makes it vulnerable. Images can be manipulated and shared by anyone using mobile applications and software. The main motive of fake images is to spread some wrong information to gain political, social, business advantages. Sometimes, fake images are also created for fun. As shown in Fig. 1, the left photo is a fake image. White eyebrows are created to show that cat is angry in the fake photo. The right photo is real in which no changes are done. If the purpose of the fake photo is fun, it is not a bad thing. In general, the purpose is not good that makes the situation grim and needs a proper attention.

Several image processing operations are applied in the process of fake image. Some common operations are resampling, rotation, blurring, denoising, contrast enhancement, and filtering and so on. The detection of these operations helps in fake image detection. In this paper, the detection of median filtering operation is focused. Median filter operation is a nonlinear operator and it serves two purposes. It is used for denoising and diminishing the artifacts of other operations like resampling, contrast enhancement, etc. Median filter detection

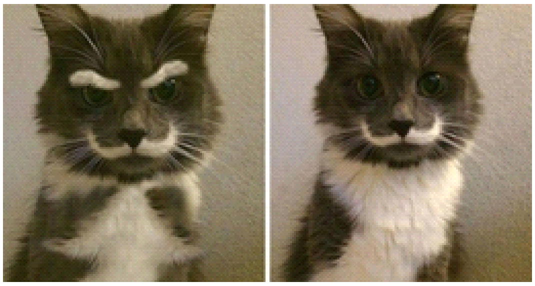

Fig. 1. Fake and real photo of cat

is tough in comparison to Gaussian blurring, and mean filtering. Median filter changes the image statistics in nonlinear way. Several attempts have been made to detect median filtering. As JPEG compression is quite popular that make the problem more challenging, JPEG compression suppresses the median filter artifacts. Existing techniques can be improved further to give better accuracy in compressed images. In this paper, one attempt is made to detect median filtering in a low quality JPEG compression and small size image blocks. The proposed technique is based on manual feature extraction process. In manual methods, a computational requirement is very less in contrast to deep learning methods without sacrificing the effectiveness. In the first phase of manual methods, features need to be extracted from the image. The extracted features provide the internal statistical information. In median filtering operation, image statistics gets modified. The statistical gap between non-filtered and median filtered images can be noticed by extracting the relevant features. In the second phase, a relevant classifier is applied to train the model and testing is performed using trained model.

Several techniques [1]-[9] based on manual feature extraction process are discussed in literature. Kirchner and Fridrich [1] introduced the median filtering detection technique in the first time. Markov model is applied on difference arrays in multiple directions and popularly known as SPAM. Chen et al. [2] proposed global and local feature set (GLF) technique. Markov features and normalized cross correlation features are combined to improve the performance. Agarwal et al. [3] applied the Markov model on the first, second and third order difference arrays in multiple directions to get better results. Peng et al. [4] considered the autoregressive model and Markov model to detect median filtering. Model is applied on median residual and other differences. In similar approach, Gao et al. [5] applied autoregressive model in frequency domain and Markov model in spatial domain. In Gao et al.'s method [6], Markov model and texture features are combined to get better detection accuracy. A local configuration pattern is used as a texture operator. Wang and Gao [7] applied the local quadruple pattern for extracting statistical information in discrete cosine transform (DCT) domain. Peng et al. [8] considered autoregressive model and the local binary pattern texture operator. Gupta and Singhal [9] extracted the features in DCT domain after calculating median filter residual, where a value of mean, variance, skewness and kurtosis features are fetched in DCT domain. After analyzing previous papers, two outcomes are considered for improving the existing techniques. First, Markov model provides the better statistical information then autoregressive model. Second, there is a lot of scope for considering more robust texture operator. As a result, modified difference arrays are considered for extracting improved Markov features and more robust texture operators are utilized for performance boost in this paper.

The proposed scheme is discussed in next section. Effectiveness of the proposed scheme is verified in section III using experimental analysis. The conclusion of this paper is discussed in section IV.

II. The Proposed Scheme

A widespread popularity of digital images has increased its importance in people's life. In this paper, a robust forensic technique for detection of median filtering is proposed to preserve the integrity of images. Markov features are extracted in enhanced rescaled domain and combined with robust texture operator features. The general block diagram of feature extraction techniques is shown in Fig. 2. Initially, training and test set are prepared from pristine and median filtered images. Features are extracted using the proposed scheme. SVM classifier is used to create the trained model using training set features. The trained model is used for test set images and images are classified into pristine and median filtered images. The results are represented using accuracy, sensitivity and specificity.

Next, the enhanced Markov features

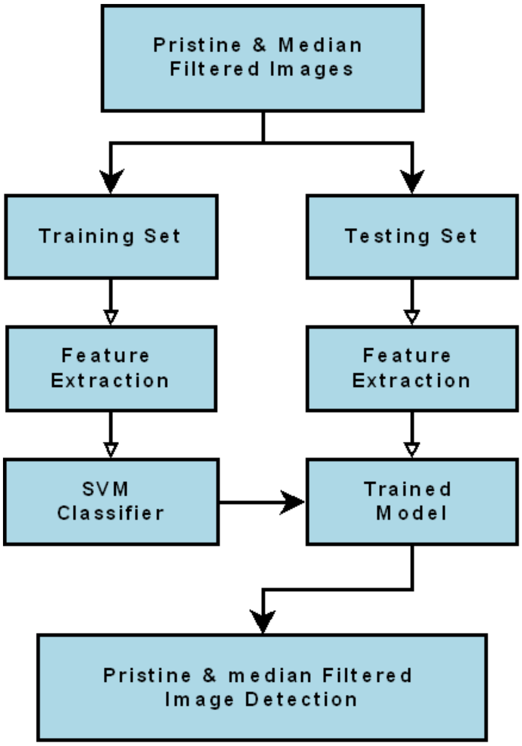

Fig. 2. Block diagram of feature extraction techniques

extraction process is discussed. Markov features are popular due to their low computational cost and robustness in many classification applications. The second order Markov features is proved its worth in comparison with the first, third and higher order Markov features. In this paper, the second order Markov model is considered. Conventionally, the second order Markov features can be extracted using following equation.

$$K_{(a,b,c)} = \Pr(E_{(m,n+2)} = a | E_{(m,n+1)} = b, E_{(m,n)} = c) \quad (1)$$

E is the thresholded difference array in a particular direction and $a,b,c \in \{-H,\cdots,H\}$ and H is the threshold value. $\Pr(E_{(m,n+2)} = a|E_{(m,n+1)} = b, E_{(m,n)} = c) = 0$ if $\Pr(E_{(m,n+1)} = b, E_{(m,n)} = c) = 0$. The difference array can be defined of a gray level image $G_{(m,n)}$ as follows.

$$D_{(m,n)} = G_{(m,n+1)} - G_{(m,n)} \quad (2)$$

,where $G_{(m,n)} \in \{0,1,...,L-2,L-1\}$ and $D_{(m,n)} \in \{-L+1,-L+2,...,0,...,L-2,L-1\}$. Then the thresholded difference array $E_{(m,n)}$ is calculated.

$$E_{(m,n)} = \begin{cases} -H & \text{if } D_{(m,n)} < -H \\ D_{(m,n)} & \text{if } -H \le D_{(m,n)} \le H \\ H & \text{if } D_{(m,n)} > H \end{cases} \quad (3)$$

However, the thresholding process replaces the $D_{(m,n)}$ elements with threshold value without considering its weight. To overcome the gap, $G_{(m,n)}$ elements are rescaled first in smaller domain and generated a new array named as $GS_{(m,n)}$, where $GS_{(m,n)} \in \{-S,-S+1,...,0,...,S-1,S\}$. The value of S is decided by experimental analysis. The optimal value is obtained 10 for S. Further, difference array is obtained as follows.

$$DS_{(m,n)} = GS_{(m,n+1)} - GS_{(m,n)} \quad (4)$$

,where $GS_{(m,n)} \in \{-10,...,10\}$ and $DS_{(m,n)} \in \{-20,...,20\}$. The enhanced thresholded difference array $ES_{(m,n)}$ is calculated.

$$ES_{(m,n)} = \begin{cases} -H & \text{if } DS_{(m,n)} < -H \\ DS_{(m,n)} & \text{if } -H \le DS_{(m,n)} \le H \\ H & \text{if } DS_{(m,n)} > H \end{cases} \quad (5)$$

Further, the second order Markov model is applied to extract features as follows.

$$KS_{(a,b,c)} = \Pr(ES_{(m,n+2)} = a | ES_{(m,n+1)} = b, ES_{(m,n)} = c) \quad (6)$$

The proposed process can improve significantly without increasing feature vector size. The features are extracted for horizontal, vertical, diagonal and minor diagonal difference arrays in forward and backward directions. Further, texture operator based features are extracted. Texture operators are effective in many applications like as face recognition, object classification, medical imaging and so on. Some of robust texture operators like LBP [10], LBPRIU [11], COALBP [12], RICLBP [13] are also analyzed in median filtering detection. Simple LBP operator [10] provides local statistical information. LBPRIU [11] considers rotation invariant uniform LBP and gives local statistical information. Co-occurrence between LBP's are calculated in COALBP [12] to get global information. RICLBP [13] gives global structural statistical and local statistical details among similar type of LBP. The LBP is treated similarly with other LBP if it produces a similar pattern after rotation from one of the rotation angel, 0^0, 45^0, 90^0, 135^0 and 180^0. Further, co-occurrence of the rotation invariant LBPs gives global statistical details. The LBP is derived using Fig. 3. The center pixel is compared either by horizontal and vertical neighbors or diagonal neighbors. The center pixel is compared with neighbors and then replaced with 0, otherwise by 1 if neighbor pixel value is less than center pixel value. Four neighbors and anti-clock wise direction is considered for calculating the LBP.

There is a noticeable improvement after combining enhanced Markov features and RICLBP texture operator in the proposed scheme. Experimental results are discussed in next section. Median filters of size 3x3 and 5x5 are considered for experimental analysis. The proposed technique is compared with different texture operators and some median filtering detection techniques.

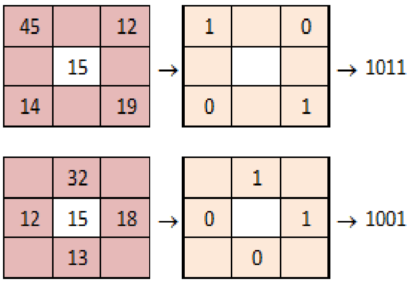

Fig. 3. LBP formation

III. Experimental Results

Median filtering is a nonlinear operation and its detection is challenging in comparison with averaging and Gaussian filtering. The proposed scheme is applied on UCID database [14] as many existing techniques are used. The UCID database has miscellaneous categories containing

Fig. 4. Example of UCID database images

1,338 images of natural scenes, objects, peoples, etc. Some images of UCID database are shown in Fig. 4.

It is concluded from previous literature and experimental analysis that detection of median filtering is challenging on low quality and small size images. Therefore, experimental results are displayed only for low JPEG quality factors 30, 50 and 70. The small size image blocks with 32x32 and 64x64 pixels are considered. Non-filtered images are created by cropping center block of required size after applying JPEG compression. Median filtered images are created by using following steps: apply median filter on the UCID database images in the first step, compress images using required quality factor in the second step and crop the center block of the compressed median filtered image in the last step. Padding artifacts of median filter will not arise by following these steps. In experiments, 3x3 and 5x5 window size are considered for median filtering. Training set contains sixty percent images of both the classes and testing set contains remaining forty percent images. Around fifty training and testing pairs are formed for unbiased performance evaluation. The results are shown in terms of detection accuracy, sensitivity, and specificity in percentage.

$$
\begin{aligned}
Accuracy &= \left(\frac{TP+TN}{TP+TN+FP+FN}\right)*100 \\
Sensitivity &= \left(\frac{TP}{TP+FN}\right)*100 \\
Specificity &= \left(\frac{TN}{TN+FP}\right)*100
\end{aligned}
\qquad (7)
$$

where true positive, true negative, false positive and false negative are abbreviated as *TP*, *TN*, *FP* and *FN*, respectively.

The proposed technique is compared with COALBP, RICLBP, GDCTF, LBP, LBPRIU, and SPAM. In Fig. 5, an average detection accuracy is shown to detect median filter of size 3x3 on block size 64x64. The proposed technique achieves 86.36%, 91.04%, and 93.69% detection accuracy for JPEG compression quality factors 30, 50 and 70 respectively. Even for low quality factor Q=30, the accuracy of the proposed method is 86.36%.

Sensitivity (SE) and specificity (SP) can be seen in Fig. 6. The sensitivity of each method is higher than its corresponding specificity. It means that a number of median filtered images are incorrectly

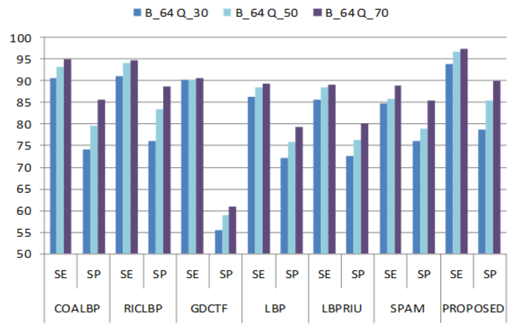

Fig. 6. Sensitivity and specificity for median filter of size 3x3 and image size 64x64

classified as non-filtered images. The difference between sensitivity and specificity values are the highest in GDCTF technique.

Now, results are shown in Fig. 7 for median filtering detection of filter size 3x3 on 32x32 pixel blocks. The proposed technique gives 79.38%, 83.34%, and 88.34% detection accuracy for quality factors 30, 50 and 70 respectively. For block size 32x32, the performance gain of the proposed method is comparatively better than block size 64x64. It can be concluded that the proposed scheme gives better results in tough scenario.

The sensitivity and specificity results are presented in Fig. 8. The similar

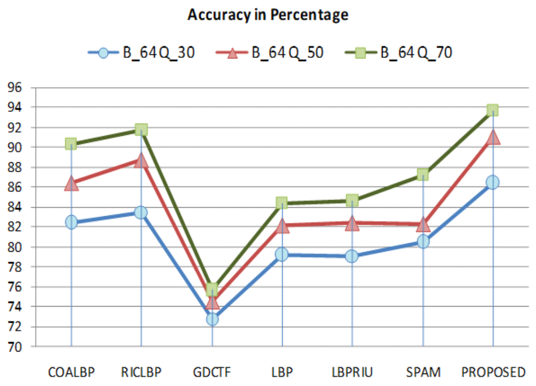

Fig. 5. Detection accuracy for median filter of size 3x3 and image size 64x64

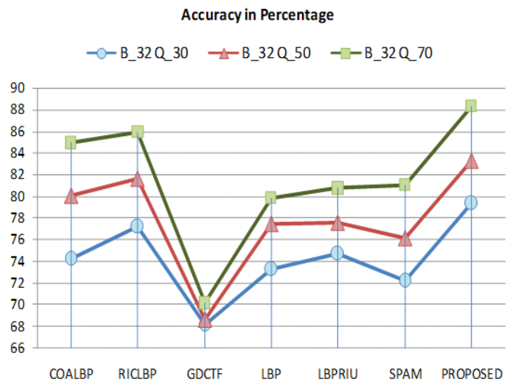

Fig. 7. Detection accuracy for median filter of size 3x3 and image size 32x32

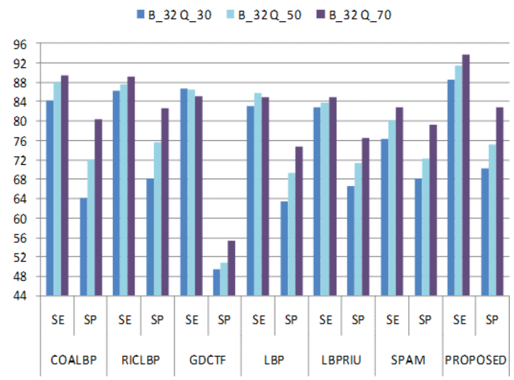

Fig. 8. Sensitivity and specificity for median filter of size 3x3 and image size 32x32

behavior is followed by sensitivity and specificity for block size 64x64 in Fig. 6. However, sensitivity and specificity of the proposed scheme are the highest in comparison with other techniques.

In Table 1, detection accuracy is displayed for image size 32x32 (B_32) and 64x64 (B_64) for 5x5 median filter. JPEG compression $Q=\{30,50,70\}$ is considered. RICLBP performance is comparable with proposed method, where the proposed scheme achieves better results. The performance gain of proposed scheme is better in low quality compression. There is additional gain of 2% in detection accuracy for JPEG $Q=30$.

Sensitivity and specificity is given in

Table 1. Detection accuracy for median filter of size 5x5

Techniques	B_32			B_64		
	Q_30	Q_50	Q_70	Q_30	Q_50	Q_70
COALBP	84.41	86.37	89.24	88.50	90.77	92.64
RICLBP	85.61	87.31	90.39	89.42	91.30	93.73
GDCTF	73.49	75.15	76.07	81.78	83.34	84.20
LBP	82.04	84.91	86.78	87.46	88.96	91.07
LBPRIU	82.90	84.41	86.54	86.86	88.34	89.26
SPAM	82.28	85.65	89.38	88.05	89.44	93.46
PROP.	**87.49**	**88.96**	**91.54**	**91.51**	**92.46**	**94.70**

Table 2. Sensitivity and specificity for 5x5 median filter and 32x32 image

Techniques	Q_30		Q_50		Q_70	
	SE	SP	SE	SP	SE	SP
COALBP	92.07	76.75	92.90	81.83	93.62	85.86
RICLBP	92.25	80.54	92.72	83.12	93.31	87.89
GDCTF	86.21	60.77	87.63	62.66	87.63	64.50
LBP	89.41	74.67	89.94	79.88	90.77	82.78
LBPRIU	88.70	77.10	89.05	79.76	89.53	83.55
SPAM	87.69	76.86	88.40	82.90	90.53	88.22
PROP.	**93.49**	**81.48**	**93.96**	**83.96**	**94.44**	**88.64**

Table 2 for detection of median filtering 5x5 on 32x32 size images with JPEG $Q=\{30,50,70\}$. Sensitivity is higher than specificity in each scenario. However, there is a wide gap in sensitivity and specificity of GDCTF technique.

The difference between sensitivity and specificity values is affected by the compression. As the compression increases, difference between sensitivity and specificity values also increases.

The sensitivity and specificity are higher for 64x64 images in comparison with 32x32 images as shown in Table 3.

The sensitivity is higher than specificity similar with the results of Table 2. However, the difference between sensitivity and specificity values is less in 64x64 images in comparison with 32x32

Table 3. Sensitivity and specificity for 5x5 median filter and 64x64 image

Techniques	Q_30		Q_50		Q_70	
	SE	SP	SE	SP	SE	SP
COALBP	94.09	83.91	94.44	86.09	95.21	91.07
RICLBP	94.26	85.39	94.74	87.70	95.27	92.08
GDCTF	93.02	70.53	93.79	72.90	94.33	73.73
LBP	93.37	81.54	93.56	84.56	94.67	87.46
LBPRIU	92.19	81.54	92.45	84.50	92.43	86.09
SPAM	91.01	85.09	91.24	87.63	94.44	91.49
PROP.	**95.86**	**87.16**	**95.74**	**89.17**	**96.39**	**93.02**

images. It is due to the fact that large size images contain more statistical information than small size images. Similar pattern is also followed by JPEG compression. As the compression increases (Q decreases), the statistical information gets limited. There is little difference between sensitivity and specificity for JPEG Q=70.

IV. Conclusion

As image forensics assured the integrity of the images, multiple operations have been identified in image forensics. In this paper, a new scheme for detection of median filtering has been proposed. Detection of median filtering has been significant due to its nonlinear behavior. In the proposed scheme, image array was rescaled in optimum domain. The enhanced statistical information has been derived using Markov model. Further, the rotational invariant LBP operator has been applied for additional features. The proposed scheme has given the satisfactory results in experimental analysis, where the experiments were performed on small blocks with low quality compression.

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〈저자소개〉

아가왈 사우랍 (Saurabh Agarwal) 정회원
2003년 7월: Barkatullah Univerity 컴퓨터공학과 졸업
2010년 6월: Abdul Kalam Technical University 소프트웨어공학과 석사
2004년 9월~2018년 5월: SRMSCET 컴퓨터공학과 교수
2017년 6월: University of Delhi 컴퓨터공학과 박사
2018년 5월~현재: Amity University 컴퓨터공학과 교수
〈관심분야〉 이미지포렌식, 컴퓨터비전, 자료은닉

정 기 현 (Ki-Hyun Jung) 정회원
1995년 2월: 경북대학교 컴퓨터공학과 졸업
1997년 2월: 경북대학교 컴퓨터공학과 석사
1997년 2월~2003년 2월: 국방과학연구소 선임연구원
2003년 9월~2015년 2월: 영진전문대학 컴퓨터정보계열 교수
2007년 8월: 경북대학교 컴퓨터공학과 박사
2015년 3월~현재: 경일대학교 사이버보안학과 교수
〈관심분야〉 멀티미디어보안, 스테가노그래피, 스테거날리시스, 블록체인, 게임프로그래밍