Detection of Copy-Rotate-Move Forgery Using Zernike Moments

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Contents

Introduction (1/2)

- Improvement of image processing softwares
  - People can easily alter digital images
  - Important to verify the authenticity of digital images
- Copy-Move forgery
  - Copies a part of the image
  - Pastes it into another part of the image
  - Example of Copy-move forgery

Introduction (2/2)

- Copy-Rotate-Move (CRM) forgery
  - Copies a region and rotates it before pasting
  - Example of CRM forgery

Related works

- Copy-move forgery
  - Structured features of small blocks
    - DCT coefficients by Fridrich *et al.*
    - PCA coefficients by Farid *et al.*
    - DWT-SVD coefficients by Luo *et al.*
    - Blur invariant moments by Mahdan *et al.*
- Copy-rotate-move forgery
  - Fourier-Mellin Transform
    - Bayram *et al.*
  - Summation of angle values of log-polar mapped block
    - Bravo-Solorio *et al.*
  - SIFT keypoints based method
    - Huang *et al.*, Amerini *et al.*, and Pan *et al.*

Zernike moments (1/2)

- Zernike moments
  - $A_{nm} = \frac{n+1}{\pi} \int\int_{x^2+y^2 \le 1} f(x,y) V_{nm}^*(\rho,\theta) dx dy$

$$\textit{Where } V_{nm}(\rho,\theta) = R_{nm}(\rho)\exp(jm\theta) \ ,$$

$$R_{nm}(\rho) = \sum_{s=0}^{(n-|m|)/2} \frac{(-1)^s[(n-s)!]\rho^{n-2s}}{s!\left(\frac{n+|m|}{2}-s\right)!\left(\frac{n-|m|}{2}-s\right)!}$$

- Properties
  - Insensitivity to image noise
  - Ability to provide faithful image representation
  - Rotational invariance
    - Magnitude of the Zernike moment

Zernike moments (2/2)

- Rotational invariance
  - Zernike moment in the polar coordinates

$$A_{nm} = \frac{n+1}{\pi} \int_0^{2\pi} \int_0^1 f(\rho,\theta) R_{nm}(\rho) \exp(-jm\theta) \rho \; d\rho \, d\theta$$

  - Zernike moment of the rotated Image

$$A'_{nm} = \frac{n+1}{\pi} \int_0^{2\pi} \int_0^1 f(\rho,\theta-\alpha) R_{nm}(\rho) \exp(-jm\theta) \rho \; d\rho \, d\theta$$

  - By change of variable $\theta_1 = \theta - \alpha$

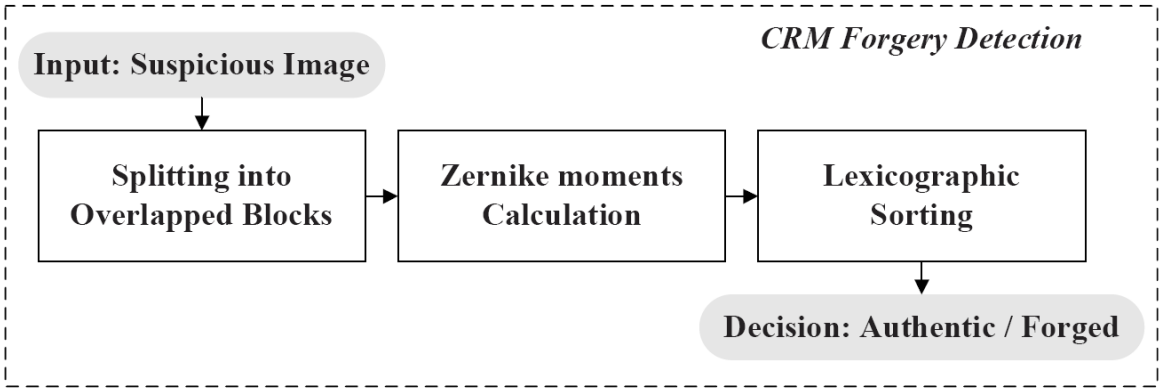
$$A'_{nm} = \frac{n+1}{\pi} \int_0^{2\pi} \int_0^1 f(\rho,\theta_1) R_{nm}(\rho) \exp(-jm(\theta_1+\alpha)) \rho \; d\rho \, d\theta_1$$

$$= \left[\frac{n+1}{\pi} \int_0^{2\pi} \int_0^1 f(\rho,\theta_1) R_{nm}(\rho) \exp(-jm\,\theta_1) \rho \; d\rho \, d\theta_1 \right] \exp(-jm\alpha)$$

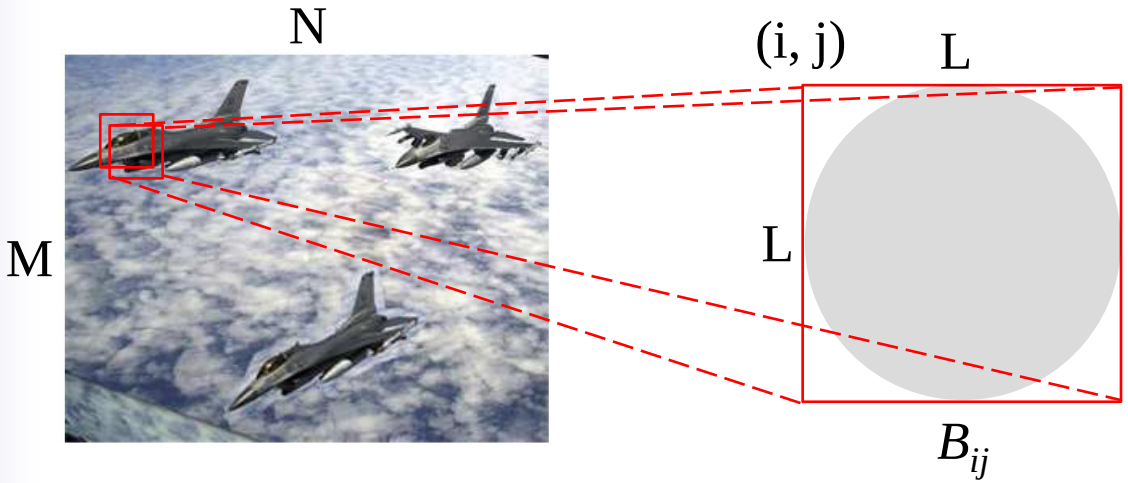
$$= \boxed{A_{nm} \exp(-jm\alpha)}$$

Copy-Rotate-Move Forgery Detection (1/3)

Procedure



Feature Extraction



$$\mathbf{V}_{ij} = getZernikeMoments(B_{ij}, n)$$

$$N_{blocks} = (M - L + 1) \times (N - L + 1)$$

$$N_{moments} = \sum_{i=0}^{n} \left(\left\lfloor \frac{i}{2} \right\rfloor + 1 \right)$$

$$\mathbf{Z} = \begin{bmatrix} \mathbf{V}_{00} \\ \dots \\ \mathbf{V}_{(M-L)(N-L)} \end{bmatrix}$$

Copy-Rotate-Move Forgery Detection (2/3)

- Detection Criteria
  - Euclidean distance between two adjacent pair of feature vector

$$\hat{\mathbf{Z}}_p = \left(\hat{z}_1^p, \hat{z}_2^p, ..., \hat{z}_{N_{moments}-1}^p, \hat{z}_{N_{moments}}^p\right) \ ,$$

$$\hat{\mathbf{Z}}_{p+1} = \left(\hat{z}_1^{p+1}, \hat{z}_2^{p+1}, ..., \hat{z}_{N_{moments}-1}^{p+1}, \hat{z}_{N_{moments}}^{p+1}\right) \ ,$$

$$\sqrt{\sum_{q=1}^{N_{moments}} \left(z_q^p - z_q^{p+1}\right)^2} < D_1$$

  - Actual distance of two image blocks

$$\sqrt{(i-k)^2 + (j-l)^2} > D_2 \ ,$$

$$\text{where } \hat{\mathbf{Z}}_p = \ V_{ij} \text{ and } \hat{\mathbf{Z}}_{p+1} = \ V_{kl}$$

Copy-Rotate-Move Forgery Detection (3/3)

- Complexity Analysis
  - Calculation of Zernike polynomials
    - $O(N_{moments})$
  - Computing Zernike moments from each overlapped block
    - $O(N_{blocks} \times N_{moments} \times L^2)$
  - Lexicographical sorting
    - $O(N_{moments} \times N_{blocks} \times \log N_{blocks})$

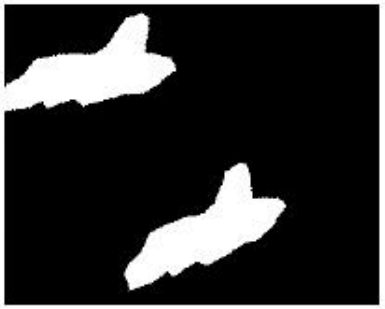
Experimental Results (1/6)

- Measuring the Forgery
  - Adopted Precision, Recall, and F1-measure
    - $$Precision = \frac{(Forged\ Region\ \cap\ Detected\ Region)}{Detected\ Region} \times 100\,[\%]$$

$$Recall = \frac{(Forged\ Region\ \cap\ Detected\ Region)}{Forged\ Region} \times 100\,[\%]$$

$$F_1 - measure = \frac{2}{\frac{1}{P} + \frac{1}{R}} = \frac{2PR}{P+R}$$


<Suspicious Image>

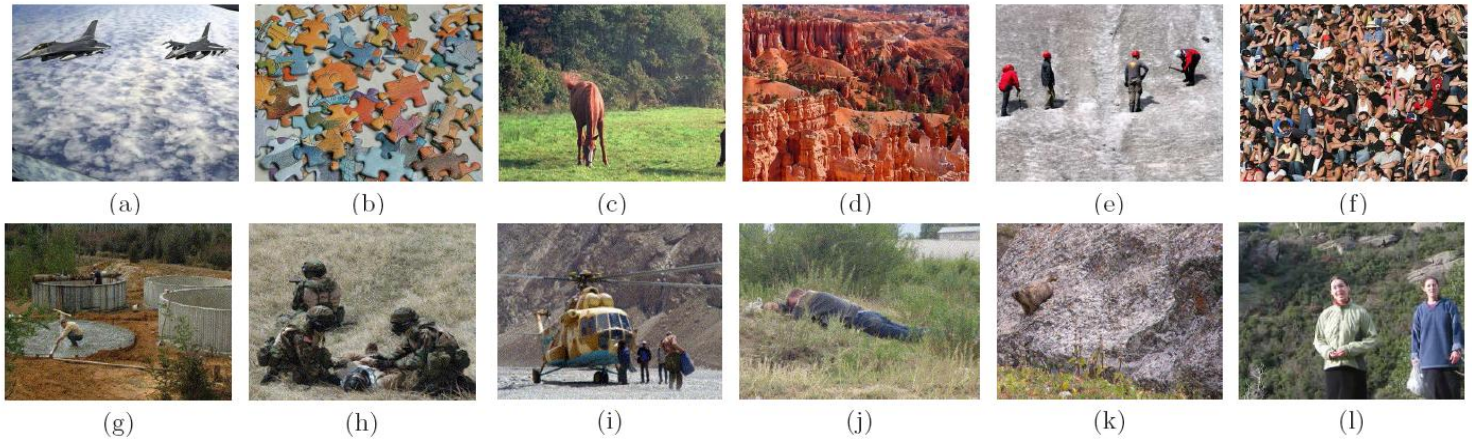

<Forged Region>


<Detected Region>


<Forged Region ∩ Detected Region>

Experimental Results (2/6)

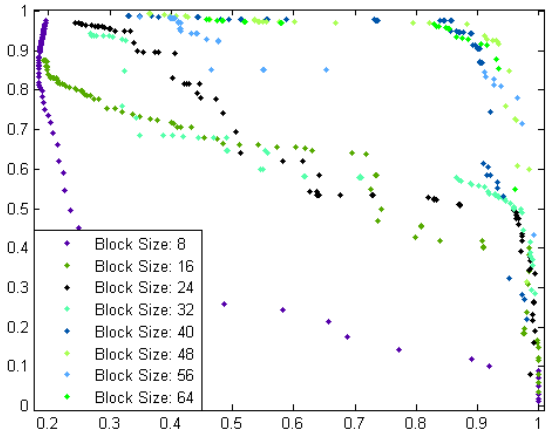
- Images used in the experiments



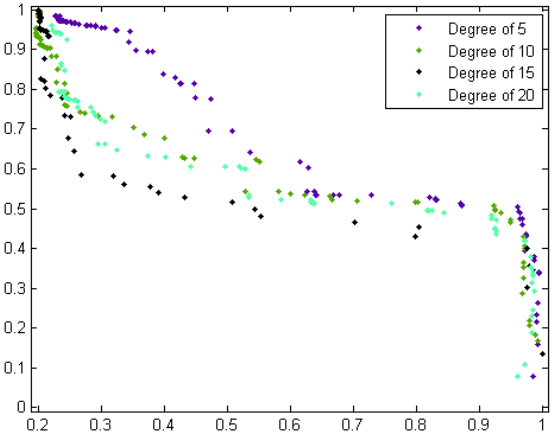
- Parameters
  - M, N, and L: 400, 320, and 24, respectively.
  - Degree of Zernike Moments: 5
  - Threshold
    - D1: 300, D2: 50
  - Size of Forged Region: 100 X 70

Experimental Results (3/6)

- Precision-Recall curve by change of block size

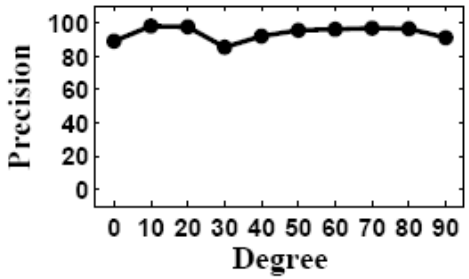


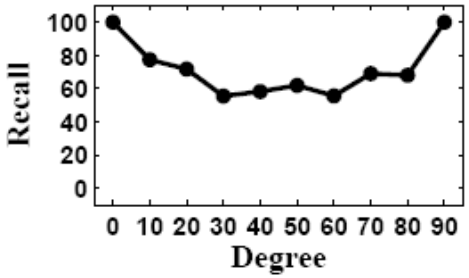
- Precision-Recall curve by change of degree of zernike moments

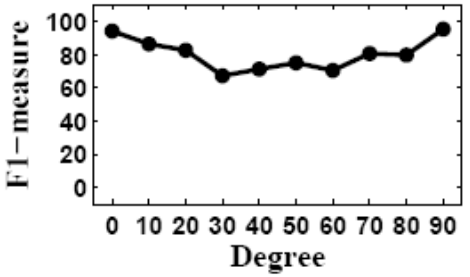


Experimental Results (4/6)

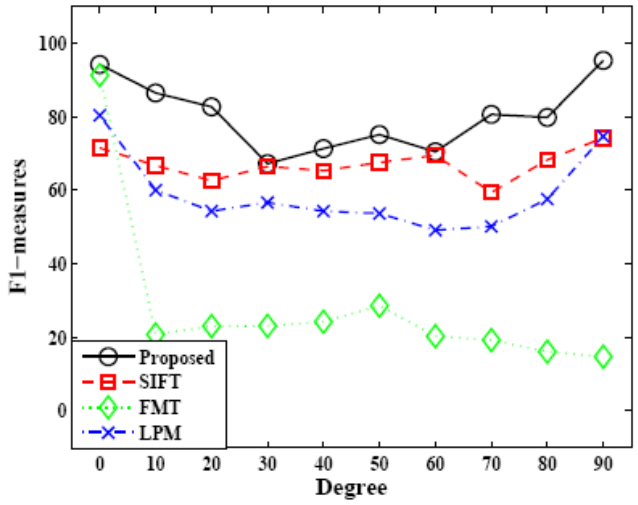
- CRM forgery detection results for image (a)

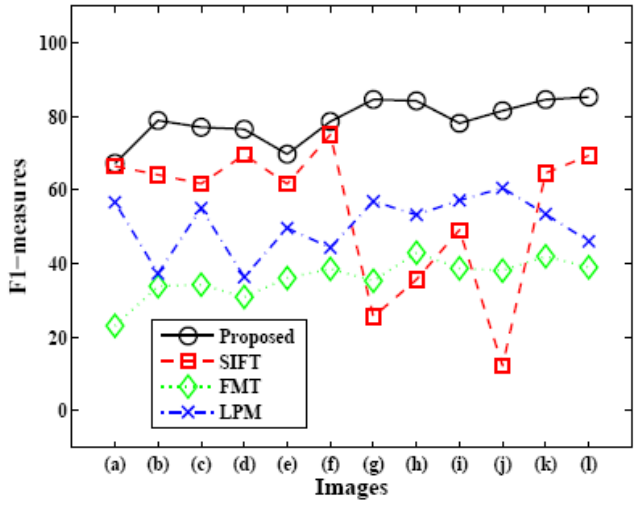






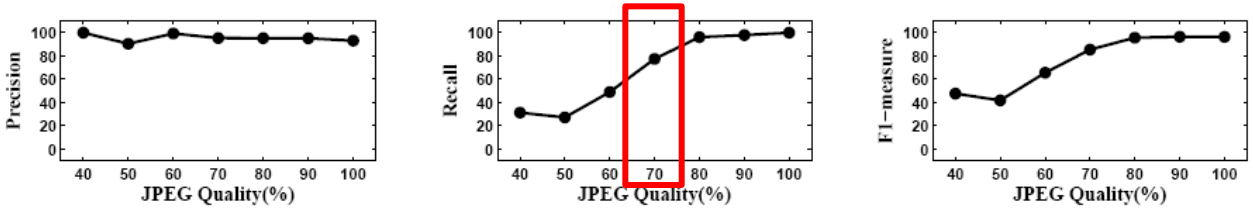
- Detection results for CRM among several detectors



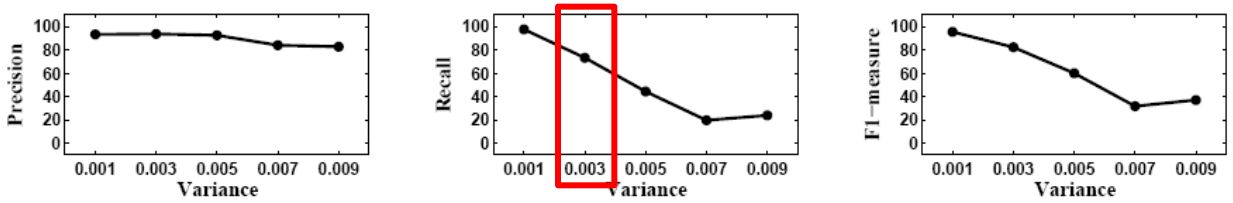


Experimental Results (5/6)

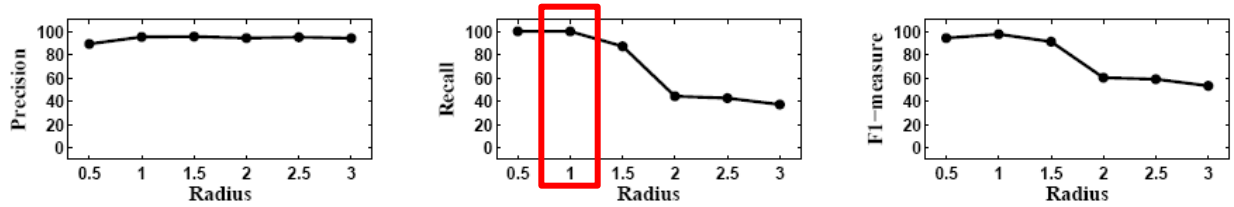
- Test for Intended Distortions for (a)
  - JPEG compression



  - Additive Noise

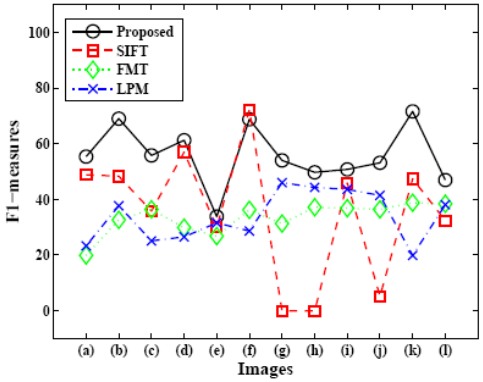


  - Blurring

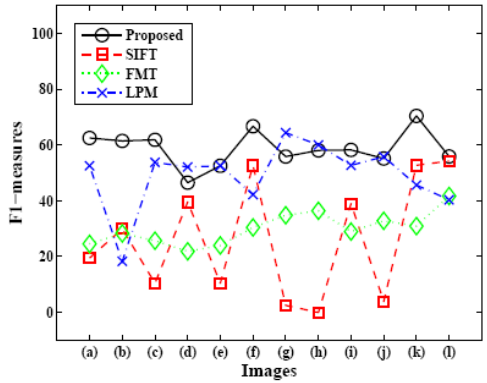


Experimental Results (6/6)

- Test for Combined Manipulation
  - CRM of 10°, AWGN with var = 0.003, JPEG compression (QF=80%)



  - CRM of 10°, Blurring with radius = 1, JPEG compression (QF=80%)



Conclusion

- With the rapid progress of image processing technology
  - An appropriate forensic application has become more important
- Copy-Rotate-Move detection scheme
  - Calculate the magnitude of Zernike moments
  - Then sorted in lexicographical order
  - Investigate the similarity of adjacent vectors
- Future works
  - Weak against scaling or the other tampering based on Affine transform
  - Adopt an efficient data structure to represent nearest neighbors