Comparison of PRNU Enhancement Techniques to Generate PRNU Fingerprints for Biometric Source Sensor Attribution

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2 Data Sets and Experiments

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Outline

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Digital Image Forensics

Digital image sensors add signatures to the data they produce

- Intrinsic: Artifacts due to optical, electrical or mechanical limitations
- Extrinsic: Modifications when the data is processed
- Forensic characterization: Identify characteristics of the device by observing the produced data
- Forensic tasks:
 - Device Identification
 - Device linking
 - Recovery of processing history
 - Detection of digital forgeries









Photo-response non-uniformity

- Intrinsic property of CCD/CMOS sensors
- Noise-like pattern
- Variations in quantum efficiency among pixels
- PRNU noise residual W_l:

$$W_l = I - F(I)$$

PRNU fingerprint \hat{K} :

$$\hat{K} = rac{\sum_{i=1}^{N} W_i^i I^i}{\sum_{i=1}^{N} (I^i)^2}$$

where *I*... Image, *F*... Denoising Filter, *i*... *i*-th Image, *N*... Number of images

PRNU Contaminations



Image content related artifacts [1]

- Undesired contaminations affect both PRNU fingerprints and noise residuals
- Sources:
 - Non-unique artefacts (NUAs)
 - Image content
- Degrade quality of PRNU and decrease discriminative power of sensors





Focal length dependent NUAs [2]

2 mn

- Clustering of images acquired with the same source sensor from a mixed set of images
- Questions: How many distinct sensors are in the dataset? Which source sensor does each image belong to?
- Usually cameras are unknown and also their number
- Extraction of PRNU noise residual W_l for each image I
- Application of different clustering techniques using the noise residuals W₁

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Data Sets

| Data set name | Sensor model | Modality | Size (px) | GT |
|---------------|----------------------------|-------------|----------------------------------|----|
| Lamp | OKI Irispass-h | Iris | 640 × 480 | ? |
| H100_2009 | Irisguard H100 IRT | Iris | 640 	imes 480 | ? |
| H100_2013 | Irisguard H100 IRT | Iris | 640 	imes 480 | 1 |
| IPH_2009 | OKI Irispass-h | Iris | 640 	imes 480 | ? |
| IPH_2013 | OKI Irispass-h | Iris | 640 	imes 480 | 1 |
| FPV5 | Digital Persona UrU4000 | Fingerprint | 328 	imes 356 | ? |
| URU_1 | Digital Persona UrU4000 #1 | Fingerprint | 328 	imes 356 | 1 |
| URU_2 | Digital Persona UrU4000 #2 | Fingerprint | $\textbf{328}\times\textbf{356}$ | 1 |



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- PRNU extraction from a 256 × 256 pixels patch in the image centre
- Wavelet-based denoising filter by Lukas et al. [3]
- PRNU Similarity Measure: Peak correlation energy (PCE)
- Common PRNU enhancements:
 - Wiener Filter in DFT
 - Zero mean
- Applied source sensor attribution techniques:
 - (KS)BCFAIC
 - (KS)SWFP
- Experiments:
 - Uncorrelated data PRNU FP vs. content related PRNU Enhancement
 - Uncorrelated data PRNU FP combined with content related PRNU Enhancement

Blind Camera Fingerprinting and Image Clustering (BCFAIC)

- Proposed by G. Bloy [4]
- Agglomerative clustering
- Construction of PRNU fingerprints from a mixed set of images
- Threshold function for comparison of FPs and noise residuals
- Generates list of clusters with associated images
- Known sensor extension (KSBCFAIC):
 - Use PRNU FP generated with uncorrelated data in first iteration of the algorithm
 - All images from this sensor should be assigned to the first cluster

Sliding Window Fingerprinting (SWFP)

- Proposed in [5]
- "Sliding window" moves sequentially over data
- Arbitrary but fixed window size
- PRNU FP is generated from images within window at each iteration
- Cross-comparison of all generated PRNU FPs at the end
- Difference in similarity scores shows transition between sensors
- Known sensor extension (KSSWFP):
 - Use PRNU FP generated with uncorrelated data and compares it to all generated PRNU FPs
 - High similarity scores show images from the same sensor



Uncorrelated data PRNU FP

- Acquisition of uncorrelated data challenging with some sensors
 - Liveness/Spoofing detection
 - No manual control of exposure or focus
 - Optimized to acquire sharp iris images
- Goal: Bright images with smooth content
- Generation of PRNU fingerprint (FP) for each sensor with uncorrelated images



Content Related PRNU Enhancement

- Image content related contamination of the PRNU
 - High-frequency components (e.g. edges and textured regions)
 - Correlated content among various images
 - Hard to separate and visible in the extracted PRNU
- Idea: The larger a component in the PRNU, the more likely it is contaminated by the image content
- Suppression performed using attenuation model 3 in DWT domain (*ELi*) proposed in [6] by C.-T. Li



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| BCFAIC ELi | Lamp | H100_2009 | H100_2013 | IPH_2009 | IPH_2013 | FPV5 | URU_1 | URU_2 |
|--------------------|-------|-----------|-----------|----------|----------|-------|-------|-------|
| Images | 16213 | 908 | 1451 | 1620 | 970 | 19958 | 1000 | 1000 |
| Total partitions | 7 | 2 | 1 | 3 | 3 | 3 | 2 | 2 |
| Partitions > 500 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Partitions < 10 | 3 | 1 | 0 | 1 | 1 | 1 | 1 | 0 |
| KSBCFAIC | Lamp | H100_2009 | H100_2013 | IPH_2009 | IPH_2013 | FPV5 | URU_1 | URU_2 |
| Total partitions | 8 | 2 | 1 | 3 | 3 | 3/3 | 2 | 2 |
| Partitions > 500 | 3 | 1 | 1 | 1 | 1 | 2/2 | 1 | 1 |
| Partitions < 10 | 4 | 0 | 0 | 1 | 1 | 0/0 | 50 | 0 |
| KSBCFAIC ELi | Lamp | H100_2009 | H100_2013 | IPH_2009 | IPH_2013 | FPV5 | URU_1 | URU_2 |
| Total partitions | 7 | 3 | 1 | 3 | 3 | 3/3 | 2 | 2 |
| Partitions > 500 | 2 | 1 | 1 | 1 | 1 | 2/2 | 14 | |
| | 2 | 2 | 0 | 2 | 2 | 0/0 | 0 | 0 |

(KS)SWFP: Uncorr. Data vs. PRNU Enhancement



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Results KSSWFP: Combination of Uncorr. Data with PRNU Enhancement



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- Comparison of two different PRNU FP enhancement techniques:
 - Uncorrelated Data
 - Content related PRNU Enhancement
- Biometric sensors from two biometric modalities
- Iris sensors:
 - Use of uncorrelated data improved similarity between images for 1 sensor data sets
 - PRNU Enhancements helped clarify that 1 sensor was used for two data sets without ground truth
 - Combination of both enhancement techniques lowered the similarity scores
- Fingerprint sensors:
 - Results highly variable and unclear, even for data sets with ground truth
 - Uncorrelated data and PRNU enhancement did not affect results significantly
 - Probable cause: Quality of extracted PRNU

Thank you for your attention!



References

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