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Hybrid G-PRNU: Optimal parameter selection for scale-invariant asymmetric source smartphone identification

Objective

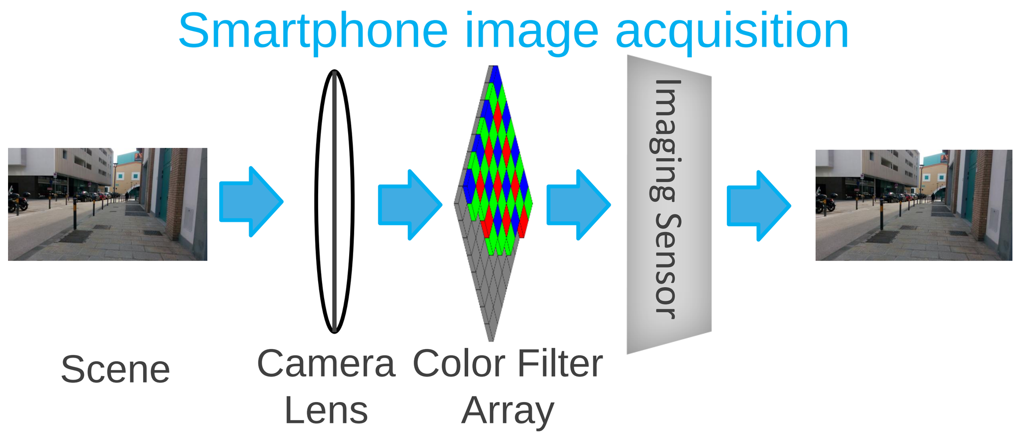
1. To answer affirmatively to the question of whether one can use reference PRNU fingerprint extracted from images, known to be of superior quality, to identify a video source smartphone.
2. To find the optimal parameters for a higher identification rate.

What is PRNU?

Photo Response Non-Uniformity, PRNU, of digital sensors[1] is a unique identification fingerprint used in source identification of images.

For use in video source identification, researchers have tried to treat video frames as images. However the quality of the reference PRNU fingerprint obtained from video frames is questionable. This is due to manufacturer specific post processing, and further due to the fact that unlike image capture, only a scaled, cropped or zoomed portion of the total spatial sensor area available is used for video capture.

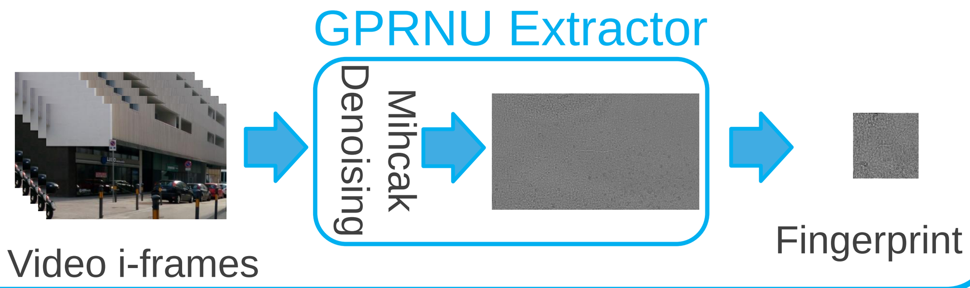
Smartphone image acquisition



Due to manufacturing imperfections of the silicon wafer, sensor pattern noise, PRNU, gets embedded, acting as the fingerprint.

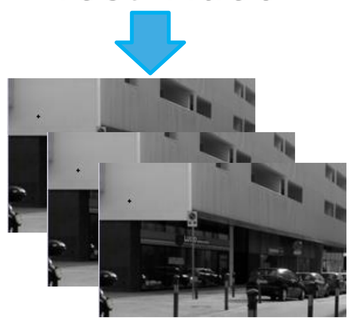
Smartphone video acquisition

GPRNU Extractor



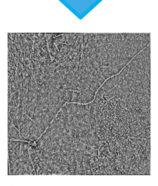
Method

Test Video



Video i-frames (Green channel)

GPRNU Extractor [4] + Li's enhancement [5]



GPRNU 256x256 px Bilinear

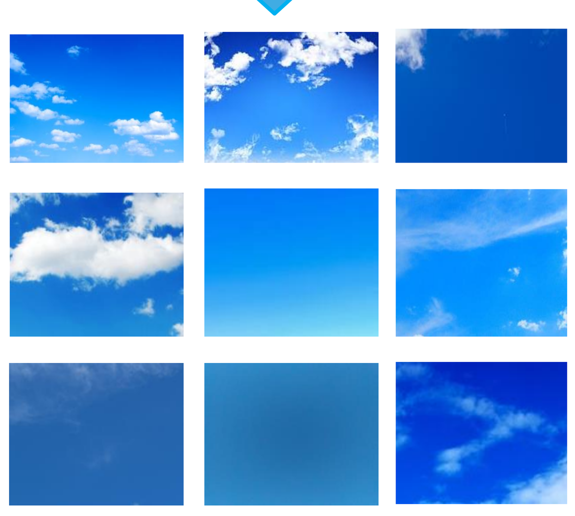
- Flat Field Images are used to compute the reference sensor pattern noise
- Video i-frames are used to compute the sensor patter noise as they offer better estimation.[2]
- Only the green channel is selected as it has a stronger PRNU compared to the other color channels.[3]
- To mitigate the matrix dimension mismatch, both reference noise pattern and the video GPRNU are resized to 256x256px using bilinear interpolation

$$corr(X,Y) = \frac{(X-\bar{X})\odot(Y-\bar{Y})}{||X-\bar{X}|| \cdot ||Y-\bar{Y}||}$$

Compare cross correlation

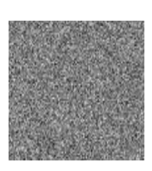
$$PCE = \frac{C[u_{peak}, v_{peak}]^2}{\frac{1}{mn-|N_{peak}|}\sum_{(u,v)\notin Npeak} C[u,v]^2}$$

Suspect Smartphone



Flat field images

GPRNU Extractor



GPRNU 256x256 px Bilinear

Dataset and Experiments

A benchmark dataset, VISION[6], released for the evaluation of image and video forensic research was used for the experiments.

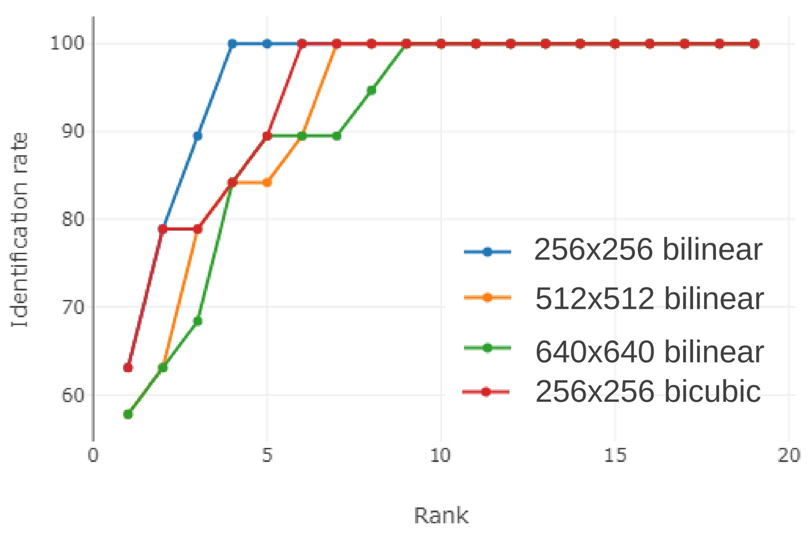
All the non stabilised videos acquiring devices present in the dataset were used to determine the optimal parameters. The GPRNU was extracted and compared using flat-field videos and images at 64x64px, 128x128px, 256x256px, 512x512px, 640x640px and at the video iframe's size, each with bilinear, bicubic and nearest neighbour interpolation methods.

For identification, the fingerprint from a test video is compared with high quality reference fingerprints obtained from flat field images using the best parameters. A reliability score is then computed to determine the confidence of the matches.

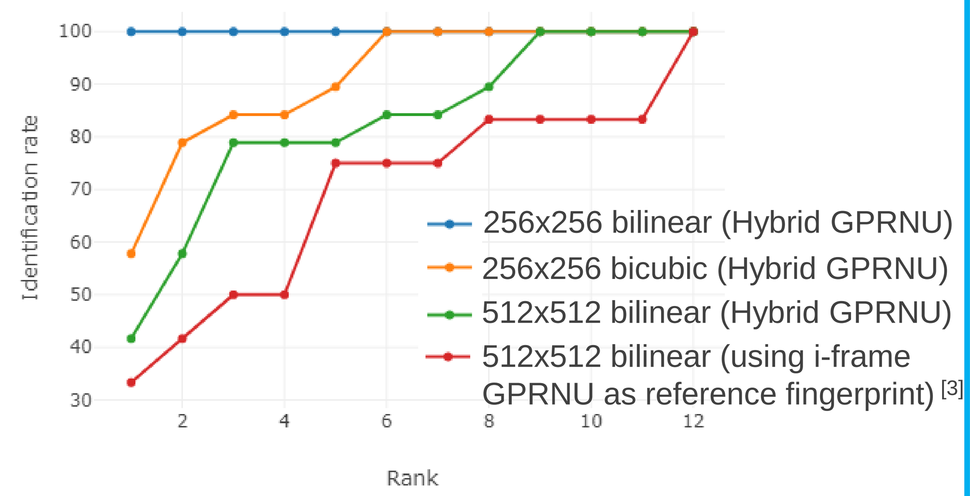
$$\text{Reliability Score} = \frac{(\text{rank 2 score} - \text{rank 1 score})}{(\text{rank 3 score} - \text{rank 1 score})}$$

Results

We are presenting the results as cumulative match characteristic (CMC) curve where "rank" describes how many top correlated scores are considered to declare a match, and, "identification rate" is the percentage of devices that are correctly identified. These are based on the experiments on the non-stabilized video acquiring smartphones. More experiments and results are mentioned in the paper.



CMC - finding best parameters



CMC - Identification

For finding the best parameters, flat field images and videos were used and natural videos from 12 devices were used for identification. Reliability scores of each device identified are presented in the table below

Device	D03	D07	D09	D11	D16	D17
Score	0.9806	0.9640	0.9972	0.9718	0.9384	0.9810
Device	D21	D22	D24	D27	D28	D30
Score	0.9832	0.9508	0.8895	0.9940	0.9114	0.6945

ATTRIBUTES:

Hybrid, Asymmetric : video source matched against image PRNU reference

GPRNU: Only green channel used to extract the PRNU fingerprint

Scale-Invariant: independent of the original size of the image PRNU fingerprint and the video fingerprint, and thus invariant to crop and scaling.

Observation and Conclusion

- Interpolating to a smaller dimension reduces GPRNU computation time drastically but increases chances of false positives (as in the cases of 64x64px and 128x128px).
- Comparing GPRNUs computed at 256x256px with bilinear interpolation proved to give the best correlation results.
- Reliability score analysis throws light on "imposter devices" whose image GPRNU correlates well with fingerprints of multiple smartphones.

The method described eliminates the need to determine geometric similarities between the PRNU extracted from images and from the video frames of a device, as in [7]. As a next step we are extending the study to devices with digitally stabilised videos where the sensor pattern noise is further affected.

[1] Lukas et.al., Digital camera identification from sensor pattern noise - DOI: 10.1109/TIFS.2006.873602
[2] Galdi et. al., Secure user Authentication on Smartphones via Sensor and Face Recognition on Short Video Clips. - April 2017 - DOI: https://doi.org/10.1007/978-3-319-57186-7_2
[3] Al-Athamneh et. al., Digital Video Source Identification Based on Green-Channel Photo Response Non-Uniformity (G-PRNU) - September 2016 DOI 10.5121/csit.2016.61105
[4] https://github.com/reepjyoti/Forensics-G-PRNU-Extractor
[5] Li et. al., Enhancing Sensor Pattern Noise via Filtering Distortion Removal. - January 2016 - DOI: 10.1109/LSP.2016.2521349
[6] Shullani et. al., VISION: a video and image dataset for source identification. EURASIP Journal on Information Security (2017) 2017:15 - DOI 10.1186/s13635-017-0067-2
[7] Iuliani et. al., A Hybrid Approach to Video Source Identification. May 2017) - arXiv:1705.01854 [cs.MM]