PRNU Variance Analysis for Morphed Face Image Detection

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Abstract

We propse a method to detect morphed face images based on Photo Response Non-Uniformity (PRNU). More specifically, the variance of PRNU-based features across image cells is estimated to distinguish bona fide from morphed and potentially post-processed morphed face images.

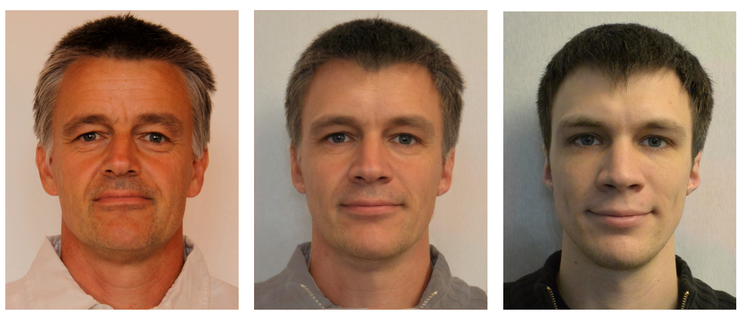
The proposed morph detector is shown to be robust against post-processing techniques, which are likely to be applied to conceal the morphing process. Tested on a database of 961 bona fide and 2,414 automatically morphed images, an overall detection equal error rate (D-EER) of 10.5% is obtained, including unaltered morphed images and various post-processing techniques.

Main Results

- Morphed face images pose a serious risk to Automated Border Control (ABC).
- PRNU shows non-uniform variations across image regions after morphing procedures.
- We proposed a variance analysis based approach of PRNU features for morphed image detection.
- Improved performance (D-EER of 10.5%) and robustness against post-processings of morphed images compared to previous work (D-EER of 15.7%).
- High robustness expected for other datasets and morphing techniques.

What is Face Morphing?

Morphing - Creation of an artificial target image which resembles information of two (or more) source images.



Subject 1 Morph Subejct 2

Figure 1: High Quality face morph of two subjects.

Basic steps for morphing face images:

- Definition of corresponding landmarks
- Averaging and triangulation
- Warping and alpha-blending

Motivation for Face Morph Detection

Face has been selected as primary biometric trait for electronic Machine Readable Travel Documents (eMRTD) in 2002.

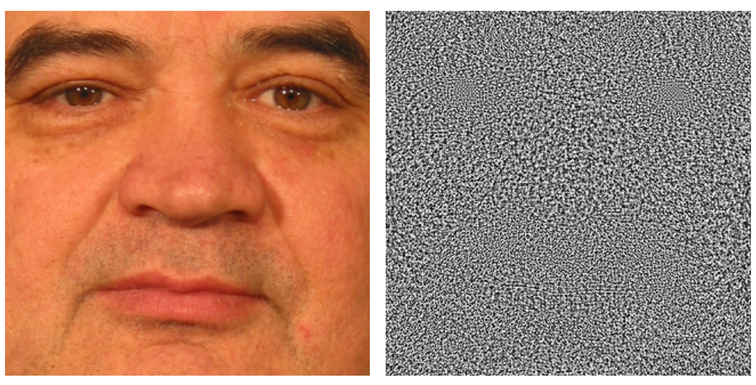
In 2014 Ferrara *et al.* [1] presented "The Magic Passport":

Figure 2: Passport application with morphed image.

SERIOUS RISK for Automated Border Control (ABC)

What is PRNU?

The PRNU is an intrinsic property of all digital imaging sensors, which is characterised by slight variations among individual pixels in their ability to convert photons to electrons. This noise-like pattern is cast onto every image it captures.

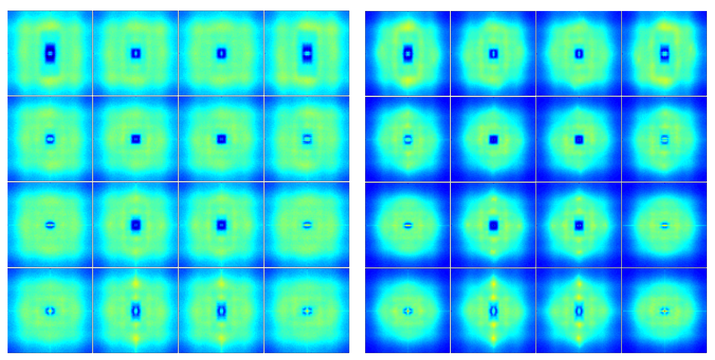


Face image Extracted PRNU

Figure 3: Extracted PRNU for an exemplary face image.

PRNU Characteristics

The PRNU's spectral characteristics reveal whether an image has been further processed [2]. Due to the different non-linear warping and averaging operations, the distribution of the PRNU values is affected [3]. The PRNU's DFT magnitude spectrum of morphed images shows a reduction of the high-frequency components as well as a compression of the whole spectrum.



Bona fide images Morphed images

Figure 4: Illustration of variations across DFT magnitude spectra for 4 × 4 image cells (average of all images in dataset).

PRNU-based Morph Detection

Analyse the variations in different parts of the image caused by morphing in spectral domain through non-linear warping.

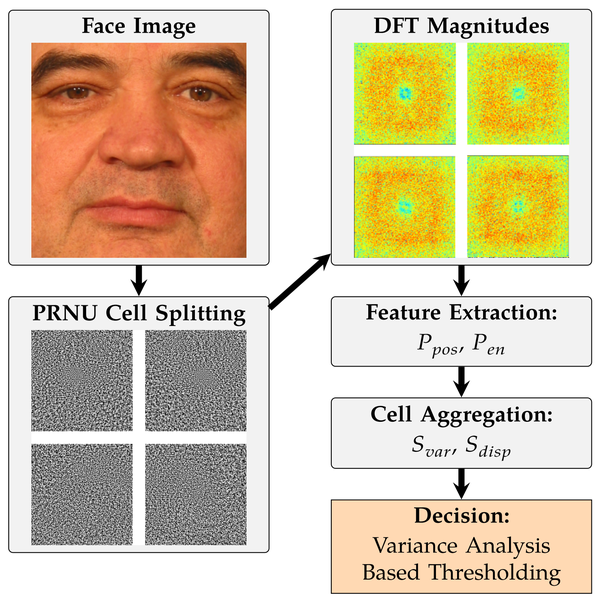


Figure 5: Proposed PRNU variance analysis based system for morphed face image detection.

PRNU Cell Splitting:
PRNU Extraction and splitting into cells (2x2 ...10x10).

Feature Extraction:

$$P_{pos} = \underset{n=1\ldots b}{arg\,max}\, H(n), \quad P_{en} = \sum_{x \in M} |x|^2$$

where b is the number of bins and H is the magnitude histogram of a cell, M are the DFT magnitudes within a cell and x their respective values.

Cell Aggregation:

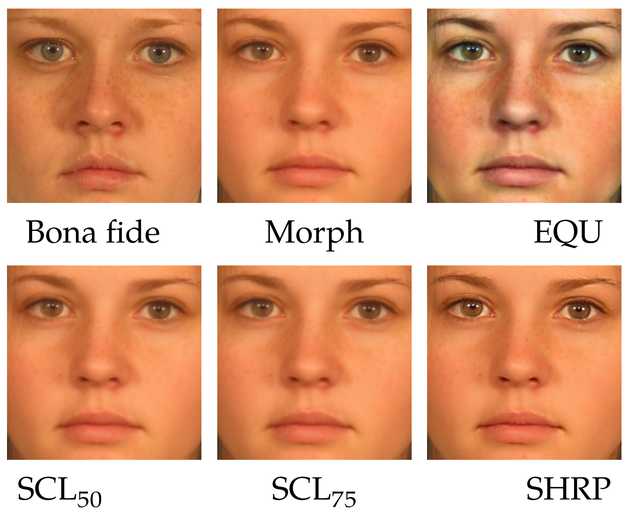
$$S_{var} = Var(P) = \frac{1}{N}\sum_{n=1}^{N}(P_n - \bar{P})^2, \quad S_{disp} = \frac{Var(P)}{\bar{P}}$$

where N is the number of PRNU cells, P_n is the feature obtained for PRNU cell C_n, and $\bar{P}$ is the average feature value for all PRNU cells C.

Dataset

Subset of FRGCv2:

- Image resolution of 320x320 pixels (ICAO compliant)
- 961 bona fide (male/female), 2414 morphed images
- Morph post-processings: CLAHE (*EQU*), scaling (*SCL*), sharpening (*SHRP*)

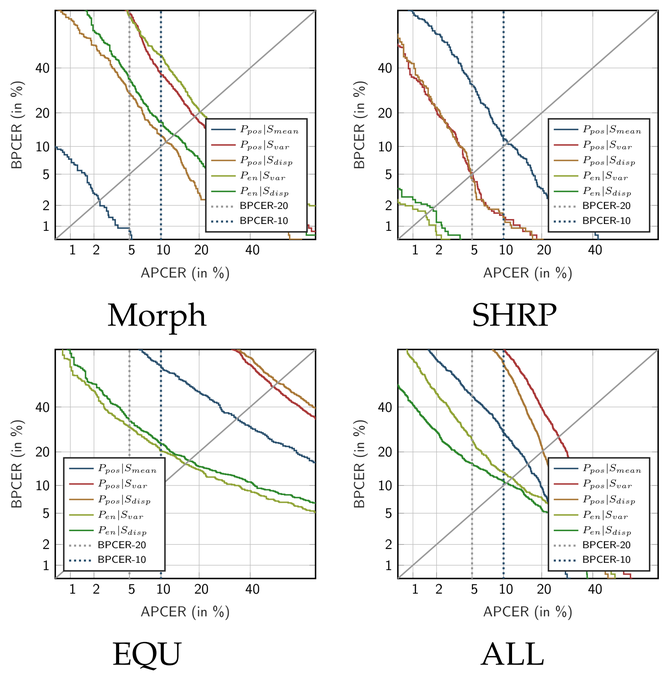


Bona fide Morph EQU

SCL_{50} SCL_{75} SHRP

Figure 6: Data set examples for bona fide and morphed images.

Experimental Results



Morph SHRP

EQU ALL

Figure 7: DET curves for PRNU-based morph detectors (10 × 10 cells).

Algorithm	Cells	D-EER Morph	EQU	SCL_{50}	SCL_{75}	SHRP	ALL
Baseline [3]	8	2.2%	33.8%	0.7%	0.0%	10.8%	15.7%
Proposed	10	11.0%	15.9%	2.6%	3.8%	1.5%	10.5%
Difference		+ 8.8%	-17,9%	+1,9%	+3,8%	-9,3%	-5,2%

Table 1: D-EER performance comparison of proposed PRNU variance analysis based detector with baseline proposed in [3]. The column *ALL* reports the D-EER including all attacks (*Morph* to *SHRP*).

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References

[1] M. Ferrara, A. Franco, and D. Maltoni, "The magic passport," in *Proc. Int. Joint Conf. on Biometrics (IJCB)*, 2014.

[2] J. Fridrich, "Digital image forensic using sensor noise," *IEEE Signal Processing Magazine*, vol. 26, no. 2, 2009.

[3] L. Debiasi, U. Scherhag, C. Rathgeb, A. Uhl, and C. Busch, "PRNU-based detection of morphed face images," in *2018 6th Intl. Workshop on Biometrics and Forensics (IWBF)*, IEEE, 2018.