Camera Identification task using VDNet and VDID

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Overview

Introduction

- PRNU is caused by the physical properties of the sensor itself
- The goal is to extract sensor's fingerprint from the captured image and compare this reference with other query fingerprints in order to perform a **camera identification task**
- Implementation from Binghamton University [1] gives significantly reliable results
- This method **doesn't work for some newest devices and social network processed images**. This is due to the fact that the heavy processing of images removes the fingerprint [2].

Research Activity

Our extension

We extended the original implementation by adding **two alternative denoising algorithms** that use Bayesian framework.

Different sources

We took comparisons using VISION dataset [3], social network processed images and with pitcures taken by huawei devices.

Additional studies

- **Zero mean normalization**: used to decorrelate neighbour pixels
- **Wiener filter**: to attenuate JPEG block artifacts

VDNet

VDNet[4] is a **unique Bayesian Network** that uses variational inference for image denoising.

Given the clean latent image z_j, the noise level σ_j, the noisy image y_j, the **objective function** is defined as follows:

$$\min_{W_D, W_S} -\sum_{j=1}^{n} \mathcal{L}(z_j, \sigma_j^2; y_j)$$

where $\mathcal{L}(z_j, \sigma_j^2; y_j)$ can be expressed in functions of the parameters that approximate the posterior of z_j and σ_j.

VDID

Variational Deep Image Denoise (VDID) [5] is a bayesian framework that can handle blind scenarios based on the variational approximation of objective functions **separating the complicated problem into simpler ones**.

Its main characteristics are:

- Trained in an end-to-end scheme without any additional noise information
- Requires fewer parameters than state-of-the-art denoisers
- It has **better performances in denoising than VDNet**.

VDID (Cont.)

The Denoiser is fully convolutional neural network adopting ResBlock as the basic building block. The last convolution layer infers the residual image. The Autoencoder is a feedforward convolutional network with a reparametrization trick.

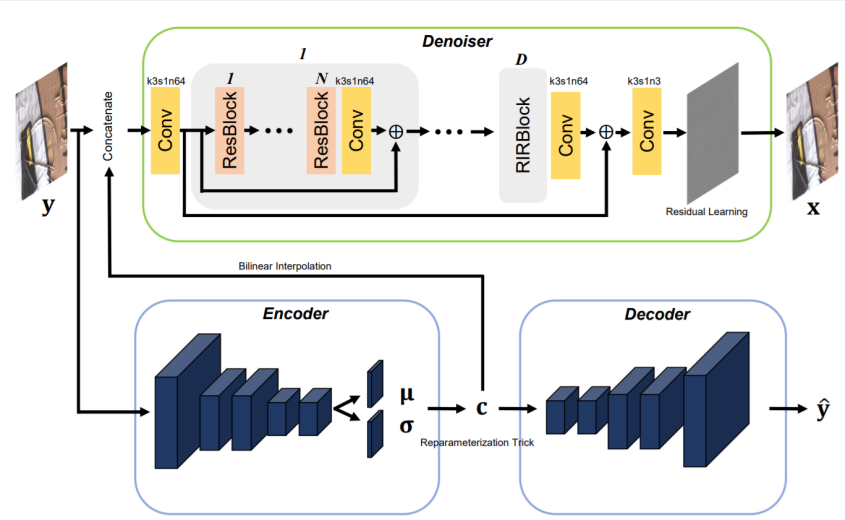

Figure 2: VDID architecture

Datasets

Provided by LESC laboratory [3].

- **VISION**: we took 30 devices (for which PRNU should work well)
  - 50 flat images for fingerprint extraction
  - 20 natural request images
- Same images **processed through Facebook and Whatsapp**
- Other images from two different devices of nine **Huawei models**

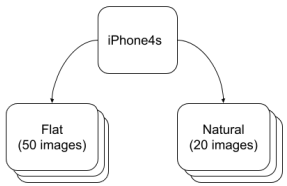

Figure 3: iPhone 4s subdirectory example

Experiments

- The experiments were carried out in four different configurations
  1. Original implementation
  2. Removing **zero mean normalization** from the original implementation
  3. Removing **Wiener filter** from the original implementation
  4. Removing **both** zero mean normalization and Wiener filter from the original implementation
- For each strategy 1-4 we compared the results obtained by original noise extractor, VDNet and VDID
- We measured PCR, TPR and FPR scores in order to evaluate the goodness of each solution

Results - VISION dataset

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
Apple_iPhone4s	1	0	1	0	1	0
Apple_iPhone5c	0.9	0	0.85	0	0.6	0
Samsung_GalaxyTab3	0.85	0	0.85	0	0.75	0
Apple_iPhone4	1	0	1	0	1	0
Samsung_GalaxyS3	1	0	1	0	0.85	0
Sony_XperiaZ1Compact	1	0	1	0	1	0
Wiko_Ridge4G	1	0	1	0	1	0
OnePlus_A3000	0.7	0	0.7	0	0.6	0
Samsung_GalaxyS5	1	0	1	0	1	0
AUC on CC	0.93		0.93		0.93	
AUC on PCE	0.99		0.98		0.96	

(a) Original implementation

(or: 0.83, VDNet: 0.82, VDID: 0.74)

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
Apple_iPhone4s	1	0	1	0	1	0
Apple_iPhone5c	0.9	0	0.85	0	0.7	0
Samsung_GalaxyTab3	0.85	0	0.85	0	0.8	0
Apple_iPhone4	1	0	1	0	1	0
Samsung_GalaxyS3	1	0	1	0.01	0.85	0
Sony_XperiaZ1Compact	1	0	1	0	1	0
Wiko_Ridge4G	1	0	1	0	1	0
OnePlus_A3000	0.7	0	0.7	0	0.65	0
Samsung_GalaxyS5	1	0	1	0	1	0
AUC on CC	0.93		0.93		0.93	
AUC on PCE	0.98		0.97		0.96	

(b) Removing normalization

(or: 0.83, VDNet: 0.83, VDID: 0.76)

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
Apple_iPhone4s	1	0	0.95	0	1	0
Apple_iPhone5c	0.9	0	0.9	0	0.7	0
Samsung_GalaxyTab3	0.9	0	0.9	0	0.6	0
Apple_iPhone4	1	0	1	0	0.4	0
Samsung_GalaxyS3	1	0	0.85	0	0.85	0
Sony_XperiaZ1Compact	1	0	1	0	1	0
Wiko_Ridge4G	1	0	1	0	1	0
OnePlus_A3000	0.8	0	0.7	0	0.6	0
Samsung_GalaxyS5	1	0	0.95	0	1	0
AUC on CC	0.95		0.94		0.94	
AUC on PCE	0.99		0.98		0.93	

(c) Removing Wiener filter

(or: 0.83, VDNet: 0.73, VDID: 0.71)

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
Apple_iPhone4s	1	0	0.85	0	0.4	0
Apple_iPhone5c	0.9	0	0.9	0	0	0
Samsung_GalaxyTab3	0.75	0	0.5	0	0	0
Apple_iPhone4	1	0	1	0	0	0
Samsung_GalaxyS3	1	0	0.6	0	0	0
Sony_XperiaZ1Compact	1	0	0.95	0	0	0
Wiko_Ridge4G	1	0	1	0	0.45	0
OnePlus_A3000	0.8	0	0.35	0	0	0
Samsung_GalaxyS5	1	0	0.95	0	0.55	0
AUC on CC	0.95		0.77		0.52	
AUC on PCE	0.99		0.94		0.68	

(d) Removing both

(or: 0.82, VDNet: 0.70, VDID: 0.14)

Results - VISION dataset

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
Apple_iPhone4s	1	0	1	0	1	0
Apple_iPhone5c	0.9	0	0.85	0	0.6	0
Samsung_GalaxyTab3	0.85	0	0.85	0	0.75	0
Apple_iPhone4	1	0	1	0	1	0
Samsung_GalaxyS3	1	0	1	0	0.85	0
Sony_XperiaZ1Compact	1	0	1	0	1	0
Wiko_Ridge4G	1	0	1	0	1	0
OnePlus_A3000	0.7	0	0.7	0	0.6	0
Samsung_GalaxyS5	1	0	1	0	1	0
AUC on CC	0.93		0.93		0.93	
AUC on PCE	0.99		0.98		0.96	

(a) Original implementation

(or: 0.83, VDNet: 0.82, VDID: 0.74)

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
Apple_iPhone4s	1	0	1	0	1	0
Apple_iPhone5c	0.9	0	0.85	0	0.7	0
Samsung_GalaxyTab3	0.85	0	0.85	0	0.8	0
Apple_iPhone4	1	0	1	0	1	0
Samsung_GalaxyS3	1	0	1	0.01	0.85	0
Sony_XperiaZ1Compact	1	0	1	0	1	0
Wiko_Ridge4G	1	0	1	0	1	0
OnePlus_A3000	0.7	0	0.7	0	0.65	0
Samsung_GalaxyS5	1	0	1	0	1	0
AUC on CC	0.93		0.93		0.93	
AUC on PCE	0.98		0.97		0.96	

(b) Removing normalization

(or: 0.83, VDNet: 0.83, VDID: 0.76)

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
Apple_iPhone4s	1	0	0.95	0	1	0
Apple_iPhone5c	0.9	0	0.9	0	0.7	0
Samsung_GalaxyTab3	0.9	0	0.9	0	0.6	0
Apple_iPhone4	1	0	1	0	0.4	0
Samsung_GalaxyS3	1	0	0.85	0	0.85	0
Sony_XperiaZ1Compact	1	0	1	0	1	0
Wiko_Ridge4G	1	0	1	0	1	0
OnePlus_A3000	0.8	0	0.7	0	0.6	0
Samsung_GalaxyS5	1	0	0.95	0	1	0
AUC on CC	0.95		0.94		0.94	
AUC on PCE	0.99		0.98		0.93	

(c) Removing Wiener filter

(or: 0.83, VDNet: 0.73, VDID: 0.71)

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
Apple_iPhone4s	1	0	0.85	0	0.4	0
Apple_iPhone5c	0.9	0	0.9	0	0	0
Samsung_GalaxyTab3	0.75	0	0.5	0	0	0
Apple_iPhone4	1	0	1	0	0	0
Samsung_GalaxyS3	1	0	0.6	0	0	0
Sony_XperiaZ1Compact	1	0	0.95	0	0	0
Wiko_Ridge4G	1	0	1	0	0.45	0
OnePlus_A3000	0.8	0	0.35	0	0	0
Samsung_GalaxyS5	1	0	0.95	0	0.55	0
AUC on CC	0.95		0.77		0.52	
AUC on PCE	0.99		0.94		0.68	

(d) Removing both

(or: 0.82, VDNet: 0.70, VDID: 0.14)

Results - VISION dataset

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
Apple_iPhone4s	1	0	1	0	1	0
Apple_iPhone5c	0.9	0	0.85	0	0.6	0
Samsung_GalaxyTab3	0.85	0	0.85	0	0.75	0
Apple_iPhone4	1	0	1	0	1	0
Samsung_GalaxyS3	1	0	1	0	0.85	0
Sony_XperiaZ1Compact	1	0	1	0	1	0
Wiko_Ridge4G	1	0	1	0	1	0
OnePlus_A3000	0.7	0	0.7	0	0.6	0
Samsung_GalaxyS5	1	0	1	0	1	0
AUC on CC	0.93		0.93		0.93	
AUC on PCE	0.99		0.98		0.96	

(a) Original implementation
(or: 0.83, VDNet: 0.82, VDID: 0.74)

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
Apple_iPhone4s	1	0	1	0	1	0
Apple_iPhone5c	0.9	0	0.85	0	0.7	0
Samsung_GalaxyTab3	0.85	0	0.85	0	0.8	0
Apple_iPhone4	1	0	1	0	1	0
Samsung_GalaxyS3	1	0	1	0.01	0.85	0
Sony_XperiaZ1Compact	1	0	1	0	1	0
Wiko_Ridge4G	1	0	1	0	1	0
OnePlus_A3000	0.7	0	0.7	0	0.65	0
Samsung_GalaxyS5	1	0	1	0	1	0
AUC on CC	0.93		0.93		0.93	
AUC on PCE	0.98		0.97		0.96	

(b) Removing normalization
(or: 0.83, VDNet: 0.83, VDID: 0.76)

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
Apple_iPhone4s	1	0	0.95	0	1	0
Apple_iPhone5c	0.9	0	0.9	0	0.7	0
Samsung_GalaxyTab3	0.9	0	0.9	0	0.6	0
Apple_iPhone4	1	0	1	0	0.4	0
Samsung_GalaxyS3	1	0	0.85	0	0.85	0
Sony_XperiaZ1Compact	1	0	1	0	1	0
Wiko_Ridge4G	1	0	1	0	1	0
OnePlus_A3000	0.8	0	0.7	0	0.6	0
Samsung_GalaxyS5	1	0	0.95	0	1	0
AUC on CC	0.95		0.94		0.94	
AUC on PCE	0.99		0.98		0.93	

(c) Removing Wiener filter
(or: 0.83, VDNet: 0.73, VDID: 0.71)

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
Apple_iPhone4s	1	0	0.85	0	0.4	0
Apple_iPhone5c	0.9	0	0.9	0	0	0
Samsung_GalaxyTab3	0.75	0	0.5	0	0	0
Apple_iPhone4	1	0	1	0	0	0
Samsung_GalaxyS3	1	0	0.6	0	0	0
Sony_XperiaZ1Compact	1	0	0.95	0	0	0
Wiko_Ridge4G	1	0	1	0	0.45	0
OnePlus_A3000	0.8	0	0.35	0	0	0
Samsung_GalaxyS5	1	0	0.95	0	0.55	0
AUC on CC	0.95		0.77		0.52	
AUC on PCE	0.99		0.94		0.68	

(d) Removing both
(or: 0.82, VDNet: 0.70, VDID: 0.14)

Results - VISION dataset (Cont.)

Summary:

- The original method remains **the most robust** in all the different configurations
- VDNet has also **good performances**, specially in the 2nd configuration.
- The VDID, on the other hand, obtains rather **poor results** in all the strategies.

Results - VISION dataset (Cont.)

Removing zero mean normalization:

- **overall performance increase**
- original gets +0.01 AUC on PCE
- VDNet gets +0.01 mean TPR
- VDID gets slightly better results (but still remains the worst choice)
- introduces some **false positive** cases

Removing Wiener filter:

- Decreases performances for VDID
- but reduce **FPR values to 0**

Removing both:

- Worst overall performances

Results - Facebook

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
Apple_iPhone4s	0	0	0	0	0	0
Apple_iPhone5c	0	0	0	0	0	0
Samsung_GalaxyTab3	**0.6**	0	0.6	0	0.15	0
Apple_iPhone4	0	0	0	0	0	0
Samsung_GalaxyS3	0	0	0	0	0	0
Sony_XperiaZ1Compact	0	0	0	0	0	0
Wiko_Ridge4G	0	0	0	0	0	0
OnePlus_A3000	0	0	0	0	0	0
Samsung_GalaxyS5	0	0	0	0	0	0
AUC on CC	**0.58**		**0.58**		0.56	
AUC on PCE	0.52		0.55		**0.57**	
Time (s)	**191**		275		6693	

(a) Original implementation

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
Apple_iPhone4s	0	0	0	0	0	0
Apple_iPhone5c	0	0	0	0	0	0
Samsung_GalaxyTab3	0.6	0	**0.65**	0	0.25	0
Apple_iPhone4	0	0	0	0	0	0
Samsung_GalaxyS3	0	0	0	0	0	0
Sony_XperiaZ1Compact	0	0	0	0	0	0
Wiko_Ridge4G	0	0	0	0	0	0
OnePlus_A3000	0	0	0	0	0	0
Samsung_GalaxyS5	0	0	0	0	0	0
AUC on CC	**0.59**		0.58		0.57	
AUC on PCE	0.52		0.55		**0.57**	
Time (s)	**184**		214		6416	

(b) Removing normalization

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
Apple_iPhone4s	0	0	0	0	0	0
Apple_iPhone5c	0	0	0	0	0	0
Samsung_GalaxyTab3	**0.7**	0	0.5	0	0.15	0
Apple_iPhone4	0	0	0	0	0	0
Samsung_GalaxyS3	0	0	0	0	0	0
Sony_XperiaZ1Compact	0	0	0	0	0	0
Wiko_Ridge4G	0	0	0	0	0	0
OnePlus_A3000	0	0	0	0	0	0
Samsung_GalaxyS5	0	0	0	0	0	0
AUC on CC	**0.58**		**0.58**		0.56	
AUC on PCE	0.51		**0.57**		0.55	
Time (s)	**173**		203		6550	

(c) Removing Wiener filter

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
Apple_iPhone4s	0	0	0	0	0	0
Apple_iPhone5c	0	0	0	0	0	0
Samsung_GalaxyTab3	**0.5**	0	0.2	0	0	0
Apple_iPhone4	0	0	0	0	0	0
Samsung_GalaxyS3	0	0	0	0	0	0
Sony_XperiaZ1Compact	0	0	0	0	0	0
Wiko_Ridge4G	0	0	0	0	0	0
OnePlus_A3000	0	0	**0.05**	0	0	0
Samsung_GalaxyS5	0	0	0	0	0	0
AUC on CC	**0.58**		0.54		0.49	
AUC on PCE	0.50		**0.56**		0.50	
Time (s)	**170**		192		6332	

(d) Removing both

Results - Whatsapp

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
Normal comparison	0	0	0	0	0	0
Removing zero mean	0	0	0	0	0	0
Removing Wiener	0	0	0	0	0	0
Removing Both	0	0	0	0	0	0

Figure 6: A summary of comparisons using downloaded images from WhatsApp

Results - Huawei

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
ane-lx1 10808472_N05	**0.25**	0	**0.25**	0	0.05	0
ane-lx1 12664195_N06	0	0	0	0	0	0
clt-al00 151215112_N02	**0.3**	0.01	**0.3**	0.01	**0.3**	0.01
clt-al00 97411860_N07	0.05	0.01	0.05	0.01	**0.1**	0.01
ele-l29 103949957_N08	0	0.01	0	0.01	0	0.02
ele-l29 109358335_N06	0	0	0	0	0	0
lya-l29 10457804_N06	**0.05**	0.01	**0.05**	0.01	**0.05**	0.01
lya-l29 11345399_N07	**0.1**	0	**0.1**	0	0	0
mar-lx1a 101212512_N07	**0.35**	0	**0.35**	0	0.3	0
mar-lx1a 82398988_N03	**0.8**	0	**0.8**	0	0.45	0
pot-lx1 11827771_N06	**0.25**	0	**0.25**	0	0.05	0
pot-lx1 121953481_N02	**0.15**	0	**0.15**	0	**0.15**	0
sne-lx1 107743946_N08	**0.05**	0	**0.05**	0	**0.05**	0
sne-lx1 119610003_N04	**0.45**	0	**0.45**	0	0.15	0
vog-l29 12965995_N05	0	0	0	0	**0.05**	0
vog-l29 13639096_N06	0	0	0	0	0	0
vtr-l09 10471762_N02	**0.05**	0	**0.05**	0	0	0
vtr-l09 113815707_N06	**0.4**	0	**0.4**	0	0.25	0

AUC on CC	**0.82**	**0.82**	**0.82**
AUC on PCE	**1**	0.76	**1**
Time (s)	**185**	275	6639

Figure 7: Original implementation
(mean TPR for original: 0.18, VDNet: 0.18, VDID: 0.10)

Results - Huawei

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
ane-lx1 10808472_N05	**0.35**	0	0.15	0	0.1	0
ane-lx1 12664195_N06	0	0	**0.05**	0	0	0
clt-al00 151215112_N02	0.3	0.01	0.3	0.01	**0.45**	0.01
clt-al00 97411860_N07	**0.1**	0.01	0	0.01	**0.1**	0.01
ele-l29 103949957_N08	0	0.01	0	0.01	**0.5**	0.06
ele-l29 109358335_N06	0	0	0	0	0	0
lya-l29 10457804_N06	**0.05**	0.01	**0.05**	0.01	**0.05**	0.02
lya-l29 11345399_N07	**0.1**	0	0	0	0	0
mar-lx1a 101212512_N07	**0.4**	0	0.25	0	0.3	0
mar-lx1a 82398988_N03	**0.85**	0	0.5	0	0.65	0
pot-lx1 11827771_N06	**0.3**	0	0.05	0	0.1	0
pot-lx1 121953481_N02	**0.2**	0	0.05	0	0.15	0
sne-lx1 107743946_N08	**0.1**	0	0.05	0	0.05	0
sne-lx1 119610003_N04	**0.45**	0	0.15	0	0.25	0
vog-l29 12965995_N05	0	0	0	0	**0.05**	0
vog-l29 13639096_N06	0	0	0	0	0	0
vtr-l09 10471762_N02	**0.1**	0	0	0	0	0
vtr-l09 113815707_N06	**0.45**	0	0.4	0	**0.45**	0

AUC on CC	0.83	0.82	**0.85**
AUC on PCE	**1**	**1**	**1**
Time (s)	**187**	270	6620

Figure 7: Removing zero mean normalization
(mean TPR for original: 0.20, VDNet: 0.11, VDID: 0.17)

Results - Huawei

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
ane-lx1 10808472_N05	**0.3**	0	0	0	0	0
ane-lx1 12664195_N06	0	0	0	0	0	0
clt-al00 151215112_N02	**0.25**	0.01	0.2	0	0.2	0
clt-al00 97411860_N07	**0.05**	0	0	0	0	0
ele-l29 103949957_N08	0	0.01	0	0.01	0	0.01
ele-l29 109358335_N06	0	0	0	0	0	0
lya-l29 10457804_N06	**0.05**	0.01	**0.05**	0.01	**0.05**	0.01
lya-l29 11345399_N07	0	0	0	0	0	0
mar-lx1a 101212512_N07	**0.15**	0	0	0	0	0
mar-lx1a 82398988_N03	**0.35**	0	0.05	0	0	0
pot-lx1 11827771_N06	**0.25**	0	0.05	0	0	0
pot-lx1 121953481_N02	**0.1**	0	0.05	0	0.05	0
sne-lx1 107743946_N08	**0.1**	0	0	0	0	0
sne-lx1 119610003_N04	**0.45**	0	0.05	0	0	0
vog-l29 12965995_N05	0	0	0	0	0	0
vog-l29 13639096_N06	0	0	0	0	0	0
vtr-l09 10471762_N02	**0.05**	0	0	0	0	0
vtr-l09 113815707_N06	**0.15**	0	0.05	0	0	0

AUC on CC	**0.88**	0.81	0.8
AUC on PCE	**1**	**1**	**1**
Time (s)	**170**	221	6579

Figure 7: Removing Wiener filter
(mean TPR for original: 0.12, VDNet: 0.02, VDID: 0.01)

Results - Huawei

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
ane-lx1 10808472_N05	**0.45**	0	0	0	0	0
ane-lx1 12664195_N06	**0.1**	0	0	0	0	0
clt-al00 151215112_N02	**0.25**	0.01	0.2	0	0.15	0
clt-al00 97411860_N07	**0.05**	0	0	0	0	0
ele-l29 103949957_N08	0	0.01	0	0.01	0	0
ele-l29 109358335_N06	0	0	0	0	0	0
lya-l29 10457804_N06	**0.05**	0.01	**0.05**	0.01	0	0.01
lya-l29 11345399_N07	0	0	0	0	0	0
mar-lx1a 101212512_N07	**0.35**	0	0	0	0	0
mar-lx1a 82398988_N03	**0.65**	0	0.15	0	0	0
pot-lx1 11827771_N06	**0.35**	0	0.05	0	0	0
pot-lx1 121953481_N02	**0.2**	0	0.1	0	0	0
sne-lx1 107743946_N08	**0.15**	0	0	0	0	0
sne-lx1 119610003_N04	**0.45**	0	0.05	0	0	0
vog-l29 12965995_N05	0	0	0	0	0	0
vog-l29 13639096_N06	0	0	0	0	0	0
vtr-l09 10471762_N02	**0.05**	0	0	0	0	0
vtr-l09 113815707_N06	**0.2**	0	0.05	0	0	0

AUC on CC	**0.89**	0.63	0.51
AUC on PCE	**1**	**1**	**1**
Time (s)	**170**	210	6420

Figure 7: Removing both Wiener and zero mean
(mean TPR for original: 0.18, VDNet: 0.03, VDID: 0.008)

Conclusions

We determined noise (fingerprint) using three different noise extractors

- **Four different strategies**
  - Removing zero mean normalization or the Wiener filter can improve performances.
  - VDID, unexpectedly, performs poorly despite being a better denoiser than VDNet
  - The removal of both normalization and filter produces worse results
- All methods **fail** the analysis of images processed by social networks
- There are no significant differences removing zero mean normalization and Wiener filter on social media

For **future works**:

- Integrate VDNet with some changes together with the original method
- Retrain VDNet with a more specific dataset for this task

Thanks! Any questions?

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Results - other devices

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
Apple_iPhone4s	**1**	0	**1**	0	**1**	0
Apple_iPhone5c	**0.9**	0	0.85	0	0.6	0
Samsung_GalaxyTab3	**0.85**	0	**0.85**	0	0.75	0
Apple_iPhone4	**1**	0	**1**	0	**1**	0
Samsung_GalaxyS3	**1**	0	**1**	0	0.85	0
Sony_XperiaZ1Compact	**1**	0	**1**	0	**1**	0
Wiko_Ridge4G	**1**	0	**1**	0	**1**	0
OnePlus_A3000	**0.7**	0	**0.7**	0	0.6	0
Samsung_GalaxyS5	**1**	0	**1**	0	**1**	0
Huawei_P9	**0.25**	0	0.2	0	0.15	0
LG_D290	**0.95**	0	**0.95**	0	0.8	0
Lenovo_P70A	**1**	0	**1**	0	**1**	0
Apple_iPhone5c	**0.75**	0	**0.75**	0	0.5	0
Apple_iPhone6	**1**	0	**1**	0	0.8	0
Huawei_P9Lite	**0.4**	0	0.35	0	0.35	0
Microsoft_Lumia640LTE	**0.95**	0	**0.95**	0	0.85	0
Apple_iPhone5c	**0.95**	0	**0.95**	0	0.8	0
Apple_iPhone6Plus	**1**	0	**1**	0	0.75	0
Asus_Zenfone2Laser	**1**	0	**1**	0	**1**	0
Xiaomi_RedmiNote3	**1**	0	**1**	0	**1**	0
Huawei_P8	**0.15**	0	0.1	0	0	0
Apple_iPhone5	**1**	0	**1**	0	0.9	0
Huawei_Honor5c	**0.35**	0	**0.35**	0	**0.35**	0

AUC on CC	**0.93**	**0.93**	**0.93**
AUC on PCE	**0.96**	0.94	0.91
Time (s)	**188**	268	6679

Figure 8: Original implementation
(mean TPR for original: 0.83, VDNet: 0.82, VDID: 0.74)

Results - other devices

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
Apple_iPhone4s	**1**	0	**1**	0	**1**	0
Apple_iPhone5c	**0.9**	0	0.85	0	0.7	0
Samsung_GalaxyTab3	**0.85**	0	**0.85**	0	0.8	0
Apple_iPhone4	**1**	0	**1**	0	**1**	0
Samsung_GalaxyS3	**1**	0	**1**	0.01	0.85	0
Sony_XperiaZ1Compact	**1**	0	**1**	0	**1**	0
Wiko_Ridge4G	**1**	0	**1**	0	**1**	0
OnePlus_A3000	**0.7**	0	**0.7**	0	0.65	0
Samsung_GalaxyS5	**1**	0	**1**	0	**1**	0
Huawei_P9	**0.25**	0	**0.25**	0	0.15	0
LG_D290	**0.95**	0	**0.95**	0	0.9	0
Lenovo_P70A	**1**	0	**1**	0	**1**	0
Apple_iPhone5c	**0.75**	0	**0.75**	0	0.5	0
Apple_iPhone6	**1**	0.01	**1**	0	0.8	0.01
Huawei_P9Lite	**0.4**	0	0.35	0	0.35	0
Microsoft_Lumia640LTE	**0.95**	0	**0.95**	0	0.85	0
Apple_iPhone5c	**0.95**	0	**0.95**	0	0.85	0
Apple_iPhone6Plus	**1**	0	**1**	0	0.85	0.01
Asus_Zenfone2Laser	**1**	0	**1**	0	**1**	0
Xiaomi_RedmiNote3	**1**	0	**1**	0	**1**	0
Huawei_P8	**0.15**	0	**0.15**	0	0.05	0
Apple_iPhone5	**1**	0	**1**	0	**1**	0
Huawei_Honor5c	**0.35**	0	**0.35**	0	**0.35**	0

AUC on CC	**0.94**	**0.94**	**0.94**
AUC on PCE	**0.97**	0.94	0.93
Time (s)	**178**	224	6345

Figure 8: Removing zero mean normalization
(mean TPR for original: 0.83, VDNet: 0.83, VDID: 0.76)

Results - other devices

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
Apple_iPhone4s	**1**	0	0.95	0	**1**	0
Apple_iPhone5c	**0.9**	0	**0.9**	0	0.7	0
Samsung_GalaxyTab3	**0.9**	0	**0.9**	0	0.6	0
Apple_iPhone4	**1**	0	**1**	0	0.4	0
Samsung_GalaxyS3	**1**	0	0.85	0	0.85	0
Sony_XperiaZ1Compact	**1**	0	**1**	0	**1**	0
Wiko_Ridge4G	**1**	0	**1**	0	**1**	0
OnePlus_A3000	**0.8**	0	0.7	0	0.6	0
Samsung_GalaxyS5	**1**	0	0.95	0	**1**	0
Huawei_P9	**0.05**	0	0	0	0	0
LG_D290	**0.95**	0	**0.95**	0	0.9	0
Lenovo_P70A	**1**	0	0.85	0	0.85	0
Apple_iPhone5c	**0.75**	0	0.7	0	0.5	0
Apple_iPhone6	**1**	0	0.95	0	0.85	0
Huawei_P9Lite	**0.35**	0	0.3	0	0.25	0
Microsoft_Lumia640LTE	**0.95**	0	**0.95**	0	0.85	0
Apple_iPhone5c	**0.95**	0	**0.95**	0	0.9	0
Apple_iPhone6Plus	**0.95**	0	**0.95**	0	0.8	0
Asus_Zenfone2Laser	**1**	0	**1**	0	**1**	0
Xiaomi_RedmiNote3	**1**	0	**1**	0	0.9	0
Huawei_P8	**0.3**	0	0.05	0	0.05	0
Apple_iPhone5	**1**	0	**1**	0	1	0
Huawei_Honor5c	**0.35**	0	**0.35**	0	**0.35**	0

AUC on CC	**0.97**	0.95	0.95
AUC on PCE	**0.96**	0.94	0.91
Time (s)	**169**	210	6676

Figure 8: Removing Wiener filter
(mean TPR for original: 0.83, VDNet: 0.73, VDID: 0.71)

Results - other devices

	Original		VDNet		VDID	
	TPR	FPR	TPR	FPR	TPR	FPR
Apple_iPhone4s	**1**	0	0.85	0	0.4	0
Apple_iPhone5c	**0.9**	0	**0.9**	0	0	0
Samsung_GalaxyTab3	**0.75**	0	0.5	0	0	0
Apple_iPhone4	**1**	0	**1**	0	0	0
Samsung_GalaxyS3	1	0	0.6	0	0	0
Sony_XperiaZ1Compact	**1**	0	0.95	0	0	0
Wiko_Ridge4G	**1**	0	**1**	0	0.45	0
OnePlus_A3000	**0.8**	0	0.35	0	0	0
Samsung_GalaxyS5	**1**	0	0.95	0	0.55	0
Huawei_P9	**0.05**	0	0	0	0	0
LG_D290	**0.95**	0	**0.95**	0	0	0
Lenovo_P70A	**1**	0	**1**	0	0.6	0
Apple_iPhone5c	**0.75**	0	0.2	0	0.05	0
Apple_iPhone6	**1**	0	0.75	0	0	0
Huawei_P9Lite	**0.4**	0	0.35	0	0.25	0
Microsoft_Lumia640LTE	**0.95**	0	**0.95**	0	0.35	0
Apple_iPhone5c	**0.95**	0	**0.95**	0	0.15	0
Apple_iPhone6Plus	**0.95**	0	0.8	0	0	0
Asus_Zenfone2Laser	**1**	0	0.9	0	0	0
Xiaomi_RedmiNote3	**1**	0	**1**	0	0	0
Huawei_P8	**0.15**	0	0.05	0	0	0
Apple_iPhone5	**1**	0	0.95	0	0.2	0
Huawei_Honor5c	**0.35**	0	**0.35**	0	**0.35**	0

AUC on CC	**0.95**	0.75	0.52
AUC on PCE	**0.96**	0.92	0.75
Time (s)	**182**	207	6679

Figure 8: Removing both Wiener and zero mean
(mean TPR for original: 0.82, VDNet: 0.70, VDID: 0.14)