

# Camera Identification task using VNet and VDID

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# Overview

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# 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].

## 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 pictures taken by huawei devices.

## Additional studies

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

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

Given the clean latent image  $z_j$ , the noise level  $\sigma_j$ , 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  $\sigma_j$ .

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 VNet**.

# 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.

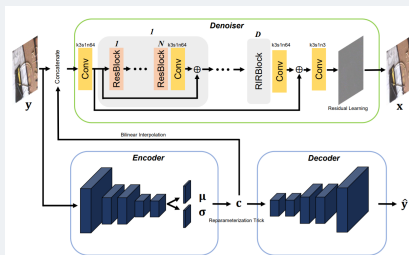


Figure 2: VDID architecture

The overall loss is the sum of three terms.

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**

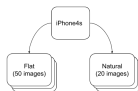


Figure 3: iPhone 4s subdirectory example



# 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, VNet and VNet
- ▶ 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
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	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
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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	
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(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	
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(d) Removing both

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

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	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)

## Summary:

- ▶ The original method remains the most robust in all the different configurations
- ▶ VNet has also good performances, specially in the 2nd configuration.
- ▶ The VNet, 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
- ▶ VNet 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	<u>0.25</u>	0	<u>0.25</u>	0	0.05	0
ane-lx1 12664195_N06	0	0	0	0	0	0
clt-al00 151215112_N02	<u>0.3</u>	<b>0.01</b>	<u>0.3</u>	<b>0.01</b>	<u>0.3</u>	<b>0.01</b>
clt-al00 97411860_N07	0.05	<b>0.01</b>	0.05	<b>0.01</b>	<u>0.1</u>	<b>0.01</b>
ele-l29 103949957_N08	0	<b>0.01</b>	0	<b>0.01</b>	0	<b>0.02</b>
ele-l29 109358335_N06	0	0	0	0	0	0
lya-l29 10457804_N06	<u>0.05</u>	<b>0.01</b>	<u>0.05</u>	<b>0.01</b>	<u>0.05</u>	<b>0.01</b>
lya-l29 11345399_N07	<u>0.1</u>	0	<u>0.1</u>	0	0	0
mar-lx1a						
101212512_N07	<u>0.35</u>	0	<u>0.35</u>	0	0.3	0
mar-lx1a 82398988_N03	<u>0.8</u>	0	<u>0.8</u>	0	0.45	0
pot-lx1 11827771_N06	<u>0.25</u>	0	<u>0.25</u>	0	0.05	0
pot-lx1 121953481_N02	<u>0.15</u>	0	<u>0.15</u>	0	<u>0.15</u>	0
sne-lx1 107743946_N08	<u>0.05</u>	0	<u>0.05</u>	0	<u>0.05</u>	0
sne-lx1 119610003_N04	<u>0.45</u>	0	<u>0.45</u>	0	0.15	0
vog-l29 12965995_N05	0	0	0	0	<u>0.05</u>	0
vog-l29 13639096_N06	0	0	0	0	0	0
vtr-l09 10471762_N02	<u>0.05</u>	0	<u>0.05</u>	0	0	0
vtr-l09 113815707_N06	<u>0.4</u>	0	<u>0.4</u>	0	0.25	0
AUC on CC	<u>0.82</u>		<u>0.82</u>		<u>0.82</u>	
AUC on PCE	<u>1</u>		0.76		<u>1</u>	
Time (s)	<u>185</u>		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	<u>0.35</u>	0	0.15	0	0.1	0
ane-lx1 12664195_N06	0	0	<u>0.05</u>	0	0	0
clt-al00 151215112_N02	0.3	<b>0.01</b>	0.3	<b>0.01</b>	<u>0.45</u>	<b>0.01</b>
clt-al00 97411860_N07	<u>0.1</u>	<b>0.01</b>	0	<b>0.01</b>	<u>0.1</u>	<b>0.01</b>
ele-l29 103949957_N08	0	<b>0.01</b>	0	<b>0.01</b>	<u>0.5</u>	<b>0.06</b>
ele-l29 109358335_N06	0	0	0	0	0	0
lya-l29 10457804_N06	<u>0.05</u>	<b>0.01</b>	<u>0.05</u>	<b>0.01</b>	<u>0.05</u>	<b>0.02</b>
lya-l29 11345399_N07	<u>0.1</u>	0	0	0	0	0
mar-lx1a 101212512_N07	<u>0.4</u>	0	0.25	0	0.3	0
mar-lx1a 82398988_N03	<u>0.85</u>	0	0.5	0	0.65	0
pot-lx1 11827771_N06	<u>0.3</u>	0	0.05	0	0.1	0
pot-lx1 121953481_N02	<u>0.2</u>	0	0.05	0	0.15	0
sne-lx1 107743946_N08	<u>0.1</u>	0	0.05	0	0.05	0
sne-lx1 119610003_N04	<u>0.45</u>	0	0.15	0	0.25	0
vog-l29 12965995_N05	0	0	0	0	<u>0.05</u>	0
vog-l29 13639096_N06	0	0	0	0	0	0
vtr-l09 10471762_N02	<u>0.1</u>	0	0	0	0	0
vtr-l09 113815707_N06	<u>0.45</u>	0	0.4	0	<u>0.45</u>	0
AUC on CC	0.83		0.82		<u>0.85</u>	
AUC on PCE	<u>1</u>		<u>1</u>		<u>1</u>	
Time (s)	<u>187</u>		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	<u>0.3</u>	0	0	0	0	0
ane-lx1 12664195_N06	0	0	0	0	0	0
clt-al00 151215112_N02	<u>0.25</u>	<b>0.01</b>	0.2	0	0.2	0
clt-al00 97411860_N07	<u>0.05</u>	0	0	0	0	0
ele-l29 103949957_N08	0	<b>0.01</b>	0	<b>0.01</b>	0	<b>0.01</b>
ele-l29 109358335_N06	0	0	0	0	0	0
lya-l29 10457804_N06	<u>0.05</u>	<b>0.01</b>	<u>0.05</u>	<b>0.01</b>	<u>0.05</u>	<b>0.01</b>
lya-l29 11345399_N07	0	0	0	0	0	0
mar-lx1a						
101212512_N07	<u>0.15</u>	0	0	0	0	0
mar-lx1a 82398988_N03	<u>0.35</u>	0	0.05	0	0	0
pot-lx1 11827771_N06	<u>0.25</u>	0	0.05	0	0	0
pot-lx1 121953481_N02	<u>0.1</u>	0	0.05	0	0.05	0
sne-lx1 107743946_N08	<u>0.1</u>	0	0	0	0	0
sne-lx1 119610003_N04	<u>0.45</u>	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	<u>0.05</u>	0	0	0	0	0
vtr-l09 113815707_N06	<u>0.15</u>	0	0.05	0	0	0
AUC on CC	<u>0.88</u>		0.81		0.8	
AUC on PCE	<u>1</u>		<u>1</u>		<u>1</u>	
Time (s)	<u>170</u>		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	<u>0.45</u>	0	0	0	0	0
ane-lx1 12664195_N06	<u>0.1</u>	0	0	0	0	0
clt-al00 151215112_N02	<u>0.25</u>	<b>0.01</b>	0.2	0	0.15	0
clt-al00 97411860_N07	<u>0.05</u>	0	0	0	0	0
ele-l29 103949957_N08	0	<b>0.01</b>	0	<b>0.01</b>	0	0
ele-l29 109358335_N06	0	0	0	0	0	0
lya-l29 10457804_N06	<u>0.05</u>	<b>0.01</b>	<u>0.05</u>	<b>0.01</b>	0	<b>0.01</b>
lya-l29 11345399_N07	0	0	0	0	0	0
mar-lx1a						
101212512_N07	<u>0.35</u>	0	0	0	0	0
mar-lx1a 82398988_N03	<u>0.65</u>	0	0.15	0	0	0
pot-lx1 11827771_N06	<u>0.35</u>	0	0.05	0	0	0
pot-lx1 121953481_N02	<u>0.2</u>	0	0.1	0	0	0
sne-lx1 107743946_N08	<u>0.15</u>	0	0	0	0	0
sne-lx1 119610003_N04	<u>0.45</u>	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	<u>0.05</u>	0	0	0	0	0
vtr-l09 113815707_N06	<u>0.2</u>	0	0.05	0	0	0
AUC on CC	<u>0.89</u>		0.63		0.51	
AUC on PCE	<u>1</u>		<u>1</u>		<u>1</u>	
Time (s)	<u>170</u>		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.
  - VDDID, unexpectedly, performs poorly despite being a better denoiser than VDDNet
  - 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 VDDNet with some changes together with the original method
- Retrain VDDNet with a more specific dataset for this task

## Thanks! Any questions?



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[http://dde.binghamton.edu/download/camera\\_fingerprin](http://dde.binghamton.edu/download/camera_fingerprin).
- [2] Marco Fontani Massimo Iuliani and Alessandro Piva. “A Leak in PRNU Based Source Identification — Questioning Fingerprint Uniqueness”. In: *IEEE ACCESS* (2021).
- [3] *LESC laboratory*. <https://lesc.dinfo.unifi.it>.
- [4] Qian Zhao Zongsheng Yue Hongwei Yong. “Variational Denoising Network: Toward Blind Noise Modeling and Removal”. In: *33rd Conference on Neural Information Processing Systems (NeurIPS 2019), Vancouver, Canada* (2019).
- [5] Nam Ik Cho Jae Woong Soh. “Variational Deep Image Denoising”. In: *ArXiv e-prints* (2021).

# 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	<b>1</b>	0	0.85	0	0.4	0
Apple_iPhone5c	<b>0.9</b>	0	<b>0.9</b>	0	0	0
Samsung_GalaxyTab3	<b>0.75</b>	0	0.5	0	0	0
Apple_iPhone4	<b>1</b>	0	<b>1</b>	0	0	0
Samsung_GalaxyS3	1	0	0.6	0	0	0
Sony_XperiaZ1Compact	<b>1</b>	0	0.95	0	0	0
Wiko_Ridge4G	<b>1</b>	0	<b>1</b>	0	0.45	0
OnePlus_A3000	<b>0.8</b>	0	0.35	0	0	0
Samsung_GalaxyS5	<b>1</b>	0	0.95	0	0.55	0
Huawei_P9	<b>0.05</b>	0	0	0	0	0
LG_D290	<b>0.95</b>	0	<b>0.95</b>	0	0	0
Lenovo_P70A	<b>1</b>	0	<b>1</b>	0	0.6	0
Apple_iPhone5c	<b>0.75</b>	0	0.2	0	0.05	0
Apple_iPhone6	<b>1</b>	0	0.75	0	0	0
Huawei_P9Lite	<b>0.4</b>	0	0.35	0	0.25	0
Microsoft_Lumia640LTE	<b>0.95</b>	0	<b>0.95</b>	0	0.35	0
Apple_iPhone5c	<b>0.95</b>	0	<b>0.95</b>	0	0.15	0
Apple_iPhone6Plus	<b>0.95</b>	0	0.8	0	0	0
Asus_Zenfone2Laser	<b>1</b>	0	0.9	0	0	0
Xiaomi_RedmiNote3	<b>1</b>	0	<b>1</b>	0	0	0
Huawei_P8	<b>0.15</b>	0	0.05	0	0	0
Apple_iPhone5	<b>1</b>	0	0.95	0	0.2	0
Huawei_Honor5c	<b>0.35</b>	0	<b>0.35</b>	0	<b>0.35</b>	0
AUC on CC	<b>0.95</b>		0.75		0.52	
AUC on PCE	<b>0.96</b>		0.92		0.75	
Time (s)	<b>182</b>		207		6679	

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