

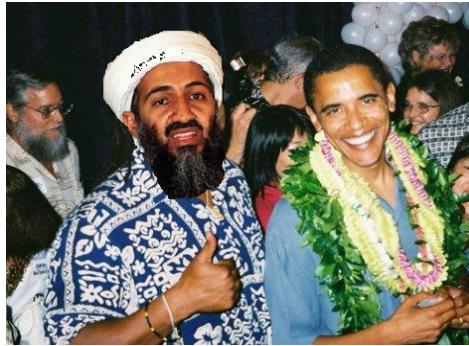
# Media forensics: digging up the invisible

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Signal Theory and Comms Dept.

University of Vigo, Spain





LEFT: Original frame from former Toledo Blade photographer Allan Detrich, taken at a University of Toledo-Kent State women's basketball game. RIGHT: The digitally altered version, with a basketball added to the frame. This version was submitted for consideration by Detrich, but did not run in the Blade or on the paper's Web site.



## Photoshopped?

Real



Photoshop



Real



Real



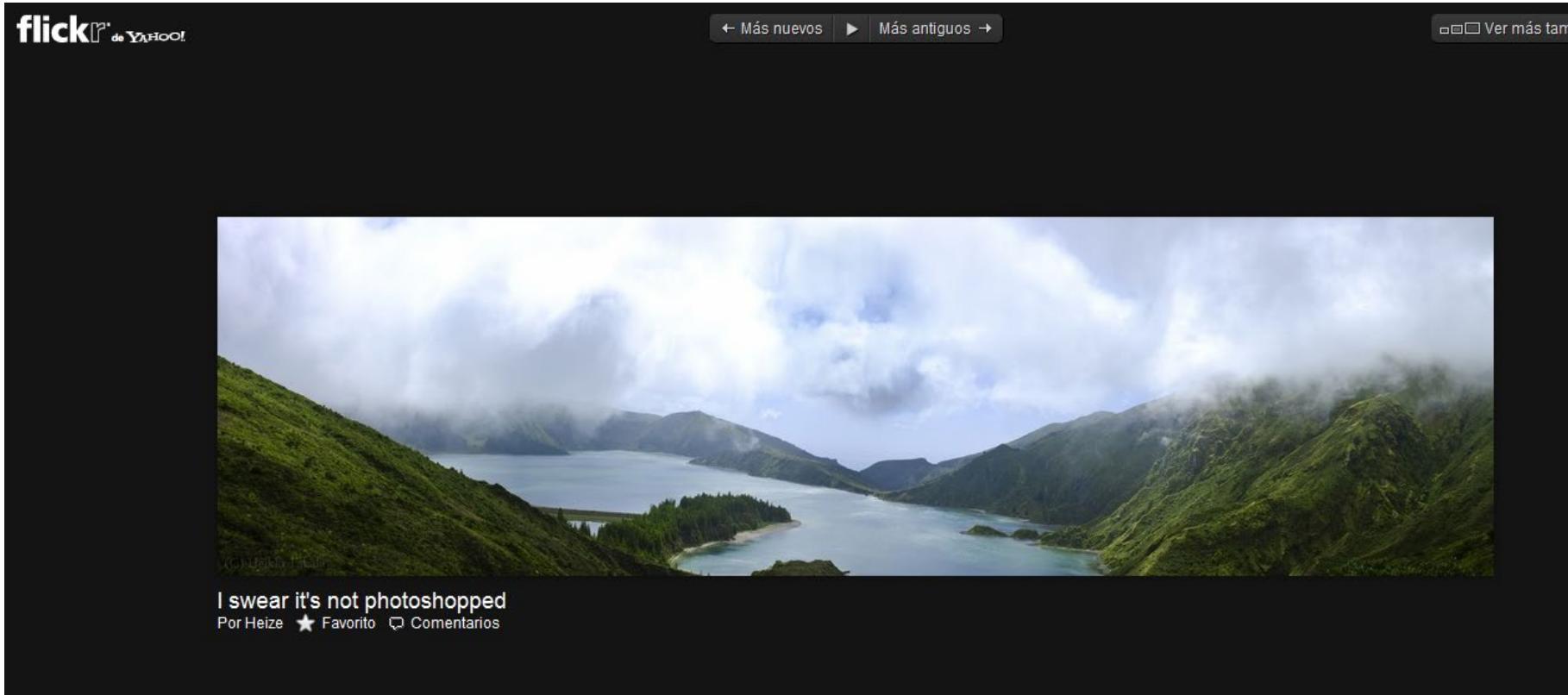
Real

Photoshop



Photoshop

## I swear it's not photoshopped





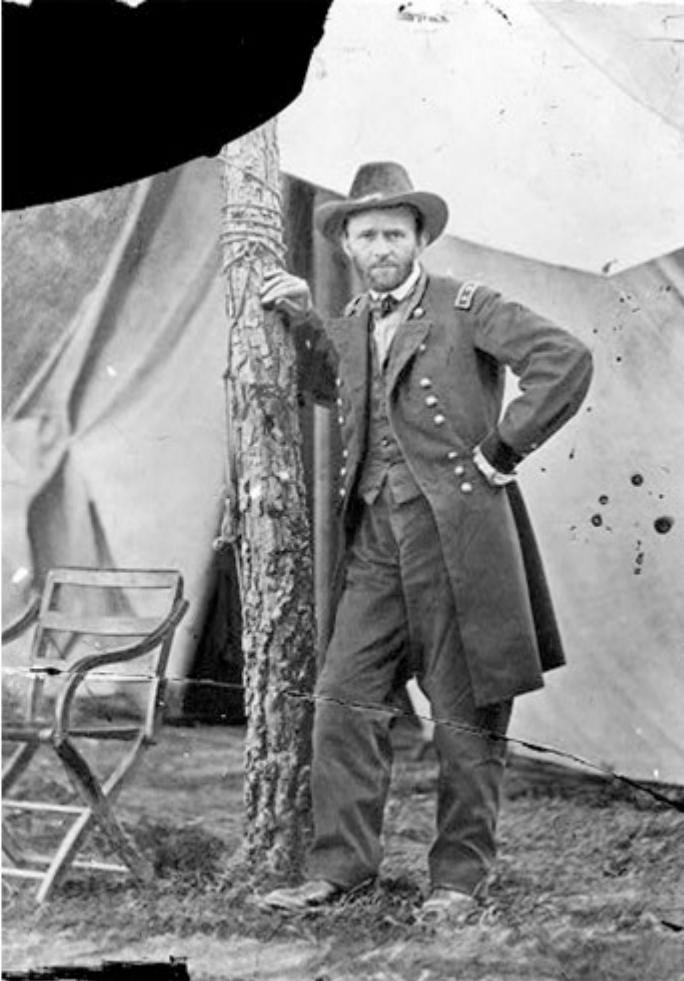
## Brush and aerograph

## Abraham Lincoln (1860)



## Ulysses S. Grant (1864)





## If you move, you won't show up

- Lenin, Trotsky, Lev Kamenev & Khalatov



## If you move, you won't show up

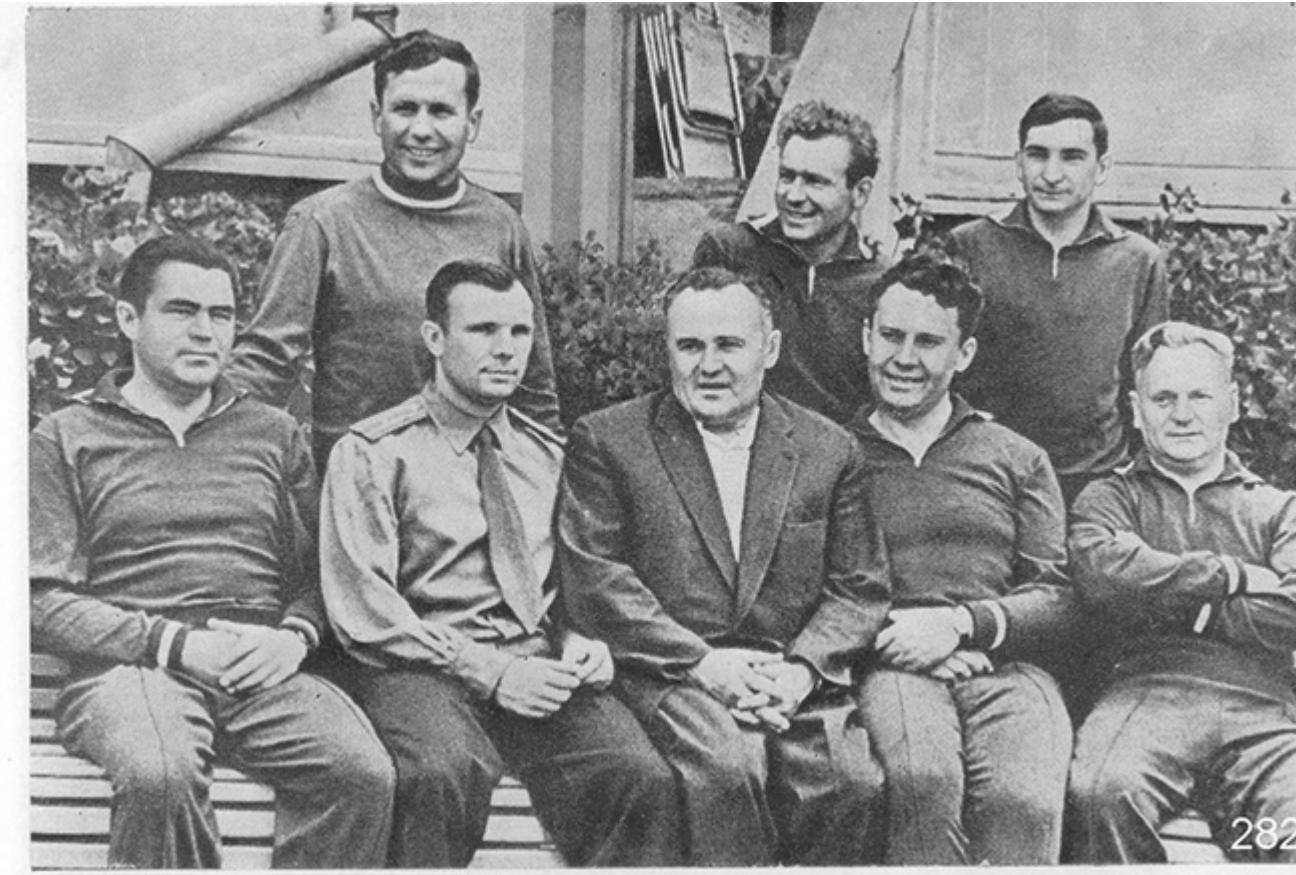
■ Stalin & Nikolai Yezhov



## Hide and seek



## Hide and seek



## Hide and seek



## Deepfakes



## Deepfakes



## Deepfakes as a service

The image shows a screenshot of the Deepfakes Web website. The background features a dark, slightly blurred image of a person's face. Overlaid on this image is the text "Online Deepfake Maker" in large white letters, followed by a smaller line of text: "Deepfake App to swap faces using AI.". At the bottom of the page is a prominent red button with the white text "Create a Deepfake Video". The top navigation bar is dark and contains the "DEEPFAKES WEB" logo on the left, and links for "Celebrity Deepfakes", "Premium", "Sign up", "Log in", "日本語" (Japanese), and "English" on the right.

<https://deepfakesweb.com/>

## How to Make a Deepfake Video

Step 1. Upload Your Source & Target Videos



<https://deepfakesweb.com/>

The screenshot shows the DeepfakesWeb website interface. At the top, there are two input fields: one for 'Choose image files(Not required)' with a limit of 'Max3MB, 1500images' and another for 'Choose image files(a video or images are required)' with the same limit. Below these is a 'Watch on YouTube' button. A red banner below the buttons states: 'We do not allow illegal, harmful or offensive content to be uploaded to our service. For more information, please refer to our [content policy](#).'. The main section features a large 'Pricing' heading and '\$3 / hour' price. It also lists 'Average Cost and Time' with options for 'Basic Deepfake (10,000 Iterations) - \$15' and 'High-Quality Deepfake (50,000 Iterations) - \$60'. At the bottom is a large red button labeled 'Create a Deepfake Video'.

Choose image files(Not required)  
Max3MB, 1500images

Choose image files(a video or images are required)  
Max3MB, 1500images

Watch on YouTube

We do not allow illegal, harmful or offensive content to be uploaded to our service. For more information, please refer to our [content policy](#).

## Pricing

\$3 / hour

Average Cost and Time

- Basic Deepfake (10,000 Iterations) - \$15
- High-Quality Deepfake (50,000 Iterations) - \$60

Create a Deepfake Video

<https://deepfakesweb.com/>

## Responsible Deepfake Technology



### Visible Watermarks

Every deepfake generated on our tool has a clear and visible watermark indicated that the video is a deepfake. We also leave clear traces of manipulation in the video data so it's easy to identify as fake. We believe deepfake technology should be clearly labelled.



### Imperfect by Design

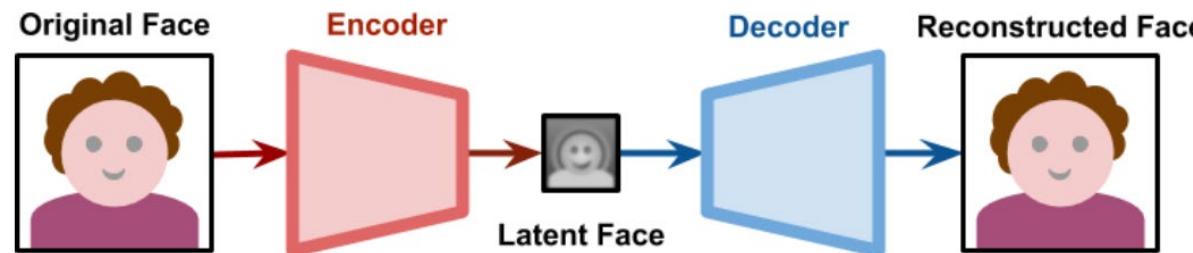
Deepfake technology is incredibly advanced and can easily fool humans. We intentionally don't push the limits, so deepfake videos can be enjoyed while still being able to identify it's fake through the imperfections.



### Accessibility

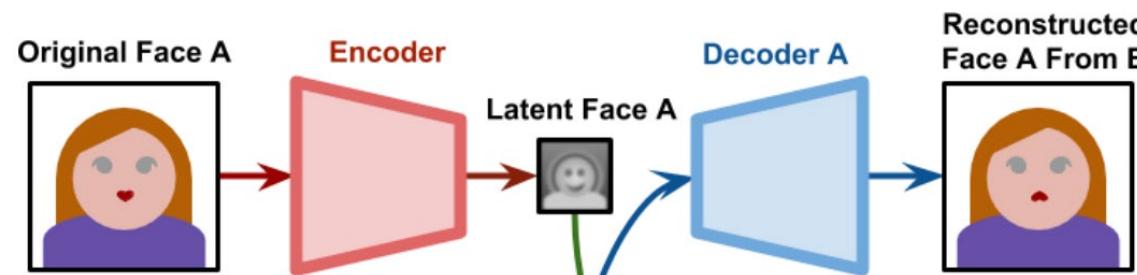
Deepfake technology has great potential in entertainment, gaming, satire and culture when used responsibly. Our system allows anyone to create a high quality deepfake at extremely low cost.

# Deepfakes through autoencoding [Fakeapp, 2018]

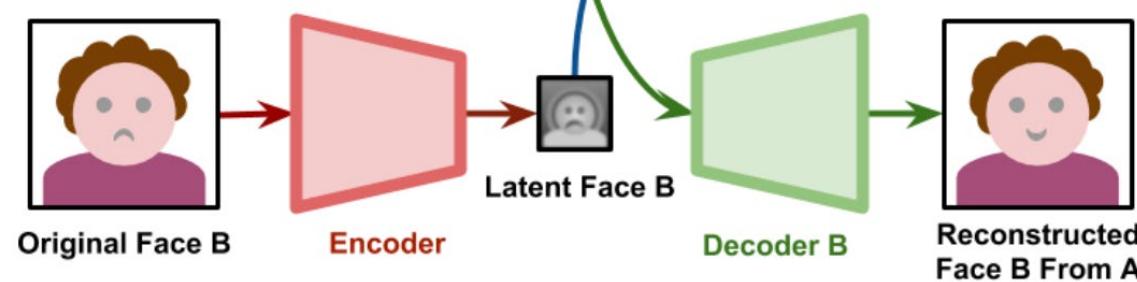


Training an autoencoder

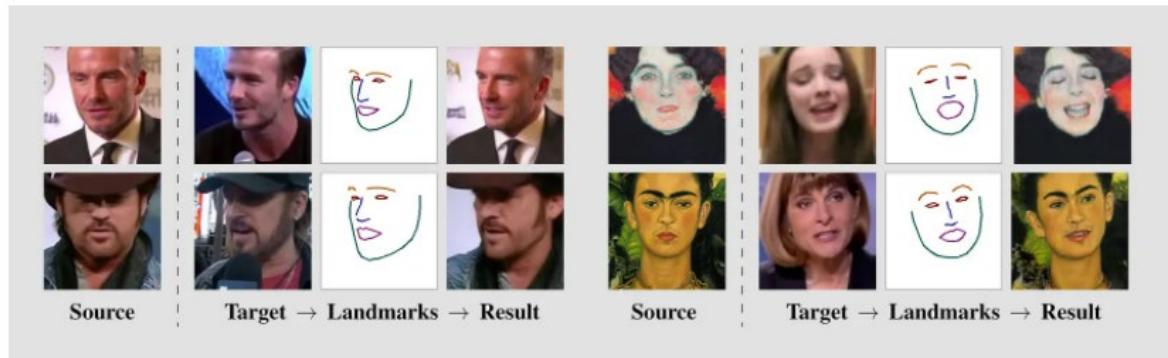
Source: alanzucconi.com



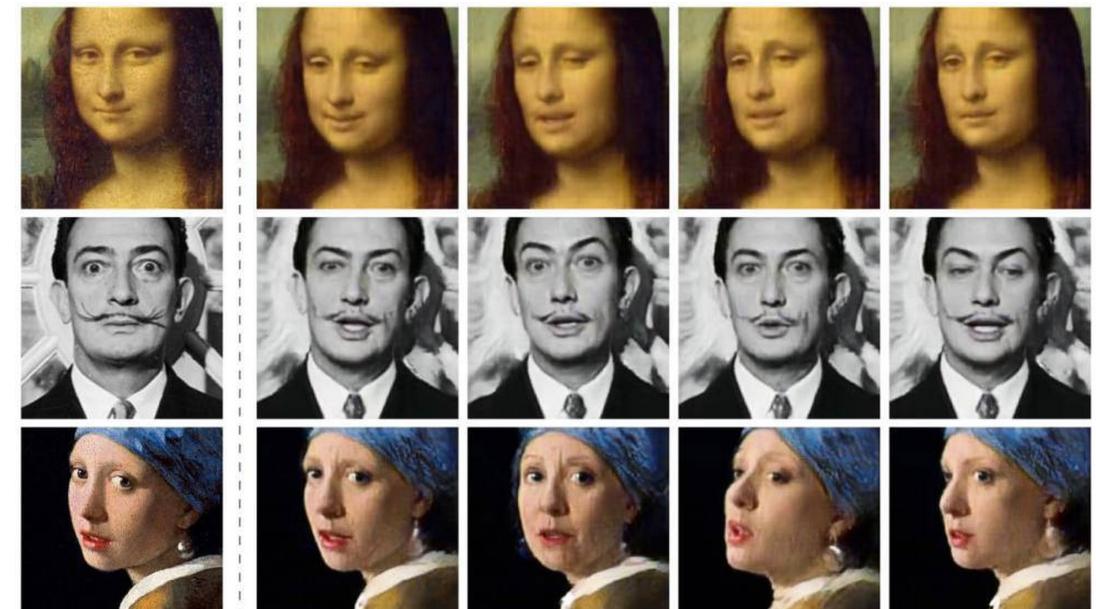
Using it to generate deepfakes



# Deepfakes through landmark mapping



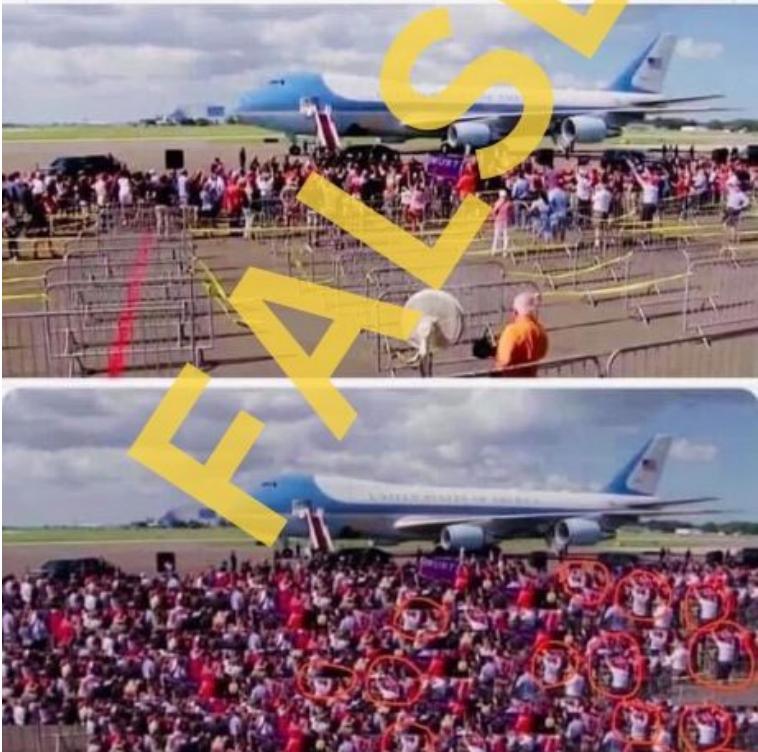
Using as little as one source image, the researchers were able to manipulate the facial expressions of people depicted in portraits and photos. EGOR ZAKHAROV; ALIAKSANDRA SHYSHEYNA; EGOR BURKOV; VICTOR LEMPITSKY



## Why is this a problem?

# Fake News

The first photo is the actual crowd size for #IQ45's speech. The second photo is what the #WhiteHouse released. The circles either show the same person, or lots of people dressed the same



## Reputational damage





## Identity theft

Forbes

Sep 3, 2019, 04:42pm EDT | 50.514 views

# A Voice Deepfake Was Used To Scam A CEO Out Of \$243,000

 **Jesse Damiani** Contributor ⓘ  
Consumer Tech  
*I cover the human side of VR/AR, Blockchain, AI, Startups, & Media.*

 Listen to article 3 minutes 

 This article is more than 2 years old.




## Identity theft

**Fake-Docs.Com**

Search by title, brand, category, etc.

SEARCH

home drivers license passport ID Card Bank Statement proof of address/utility bill selfie SSN free

Home > ID Card psd template > Germany ID Card Psd Template V2



### GERMANY ID CARD PSD TEMPLATE V2

- High Quality template
- Layer based & Fully editable
- Fonts Included
- Scan Effect
- Multiple background
- Support Bitcoin payment

\$ 20

In Stock

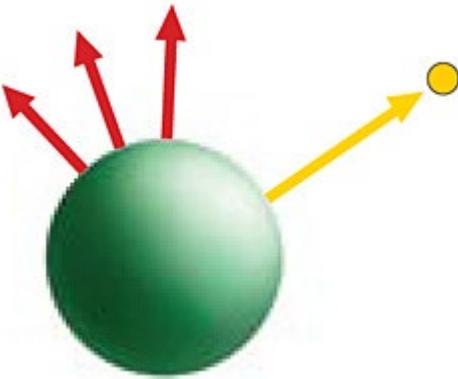
– +

Add to cart

## What are the solutions?

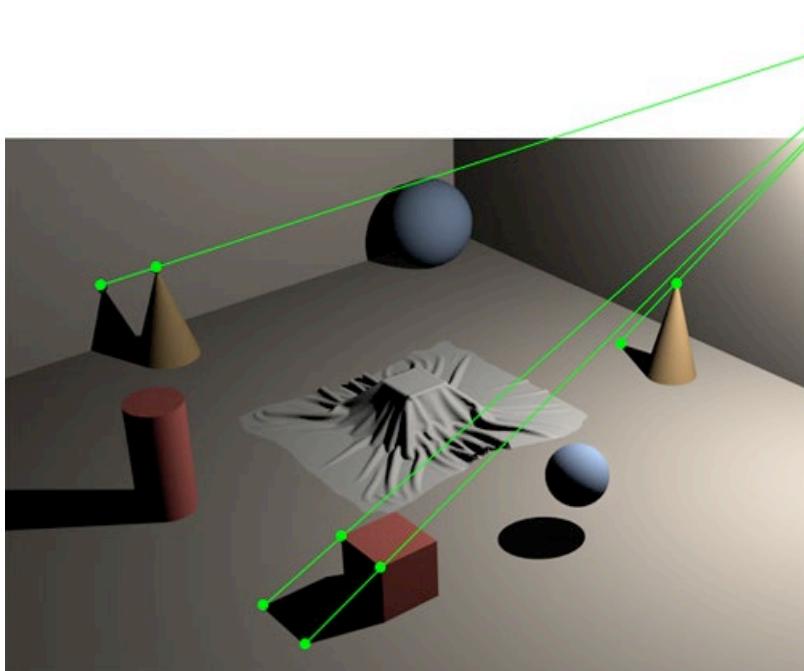
# Semantic forensic analysis

# Lighting inconsistencies



Source: Farid08

## Shadow inconsistencies



Source: fourandsix.com



Source: fourandsix.com

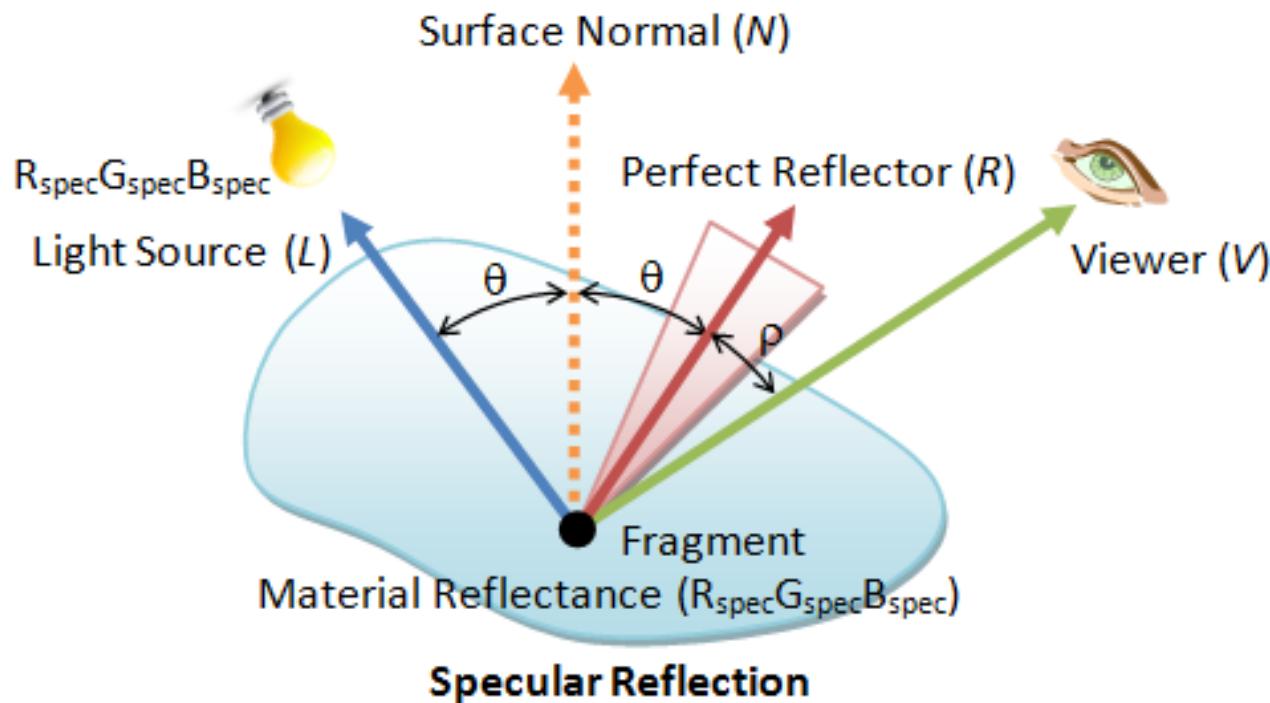
## “The accidental tourist”



## Was Kim Jong Il there? (2008)



# Specular reflection inconsistencies



Source: Chua Hock-Chuan. Intro to OpenGL

## National Geographic Prize (2008)



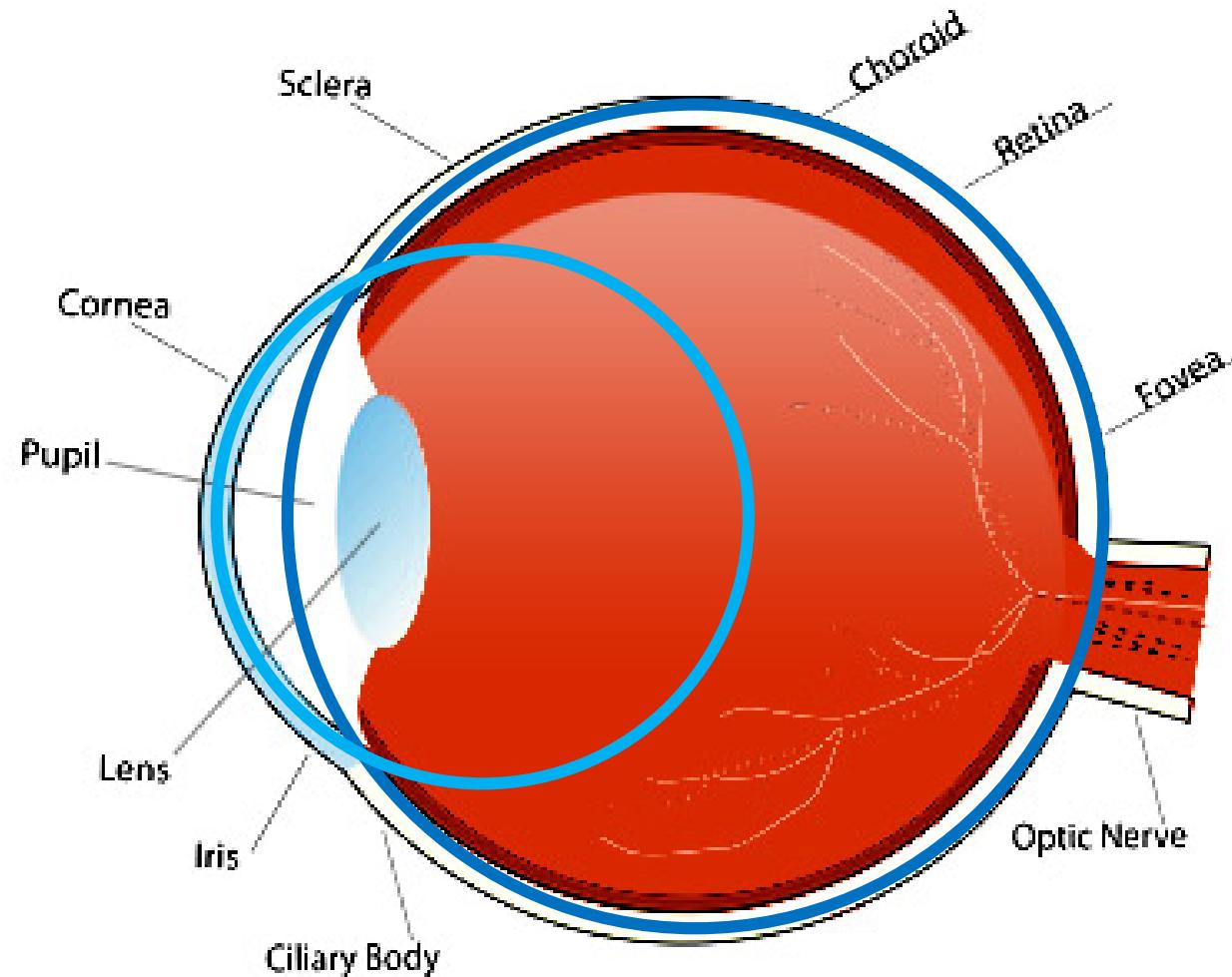
Photo and caption by Shibnath Basu, India

### Places Winner

These shallow waters are mainly famous for flamingos at Nal Sarovar near Ahmedabad, Gujarat, India. The picture shows the reflection of clouds on water.



## Catchlight inconsistencies



## Catchlight inconsistencies

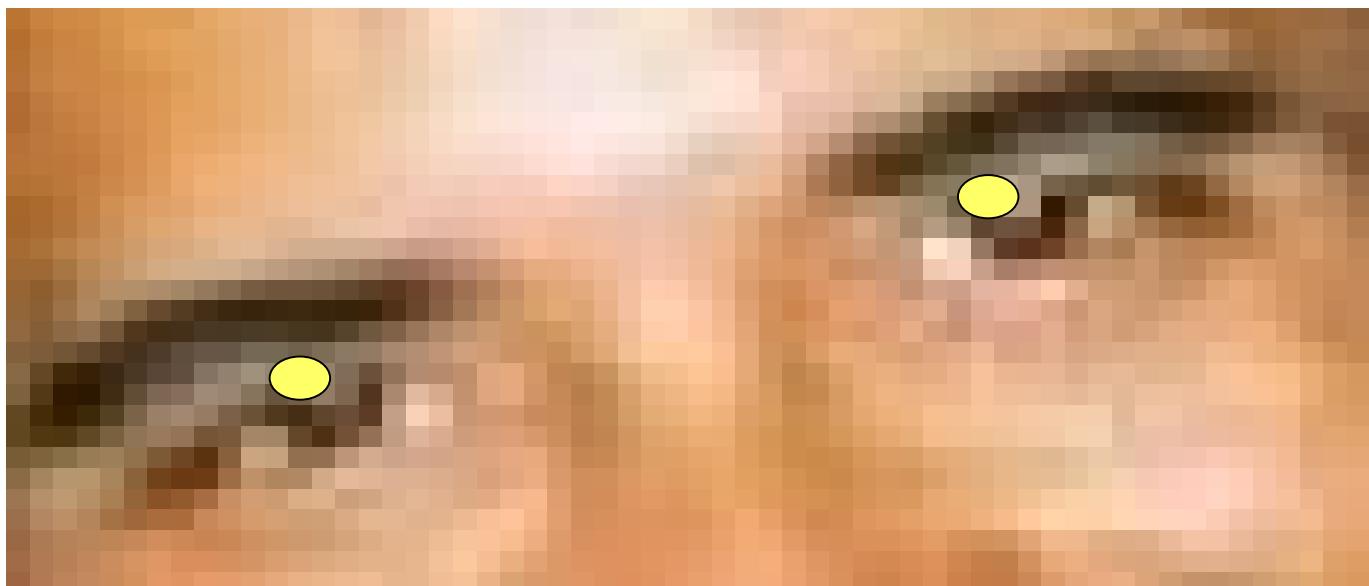
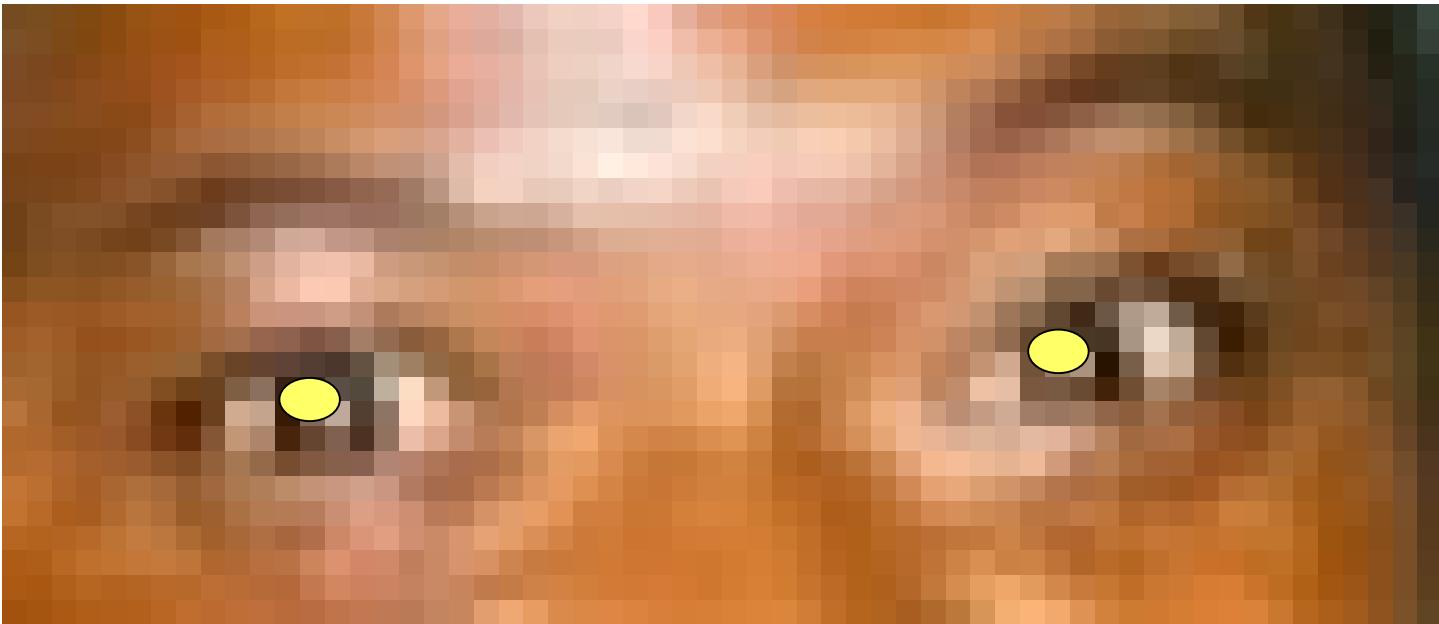


## The odd couple

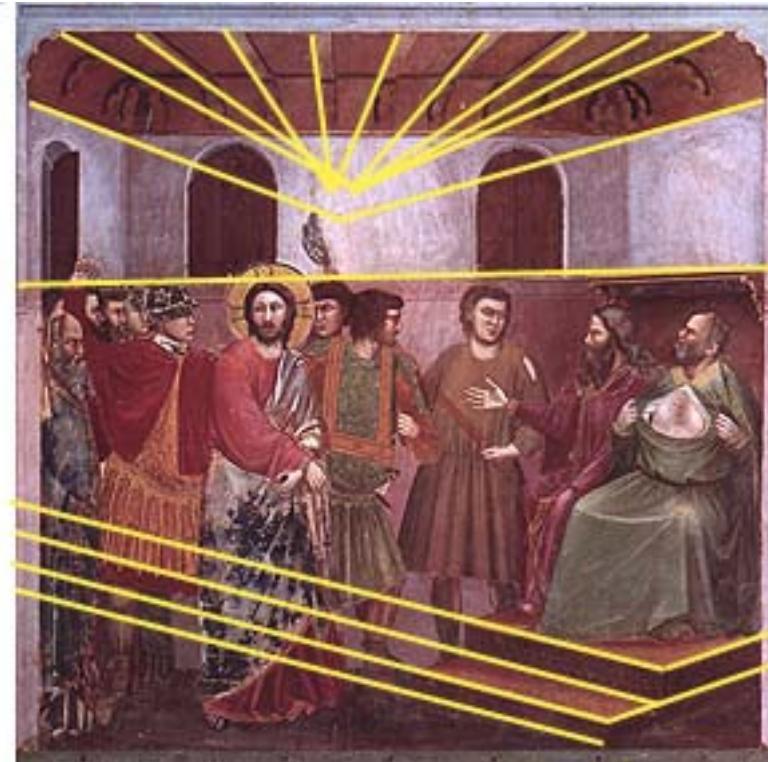








## Perspective inconsistencies



“Jesus Before the Caif”,  
Giotto, 1305.

Source: [cristophertyler.org](http://cristophertyler.org)

## Sometimes, you must look down



## Cropping traces



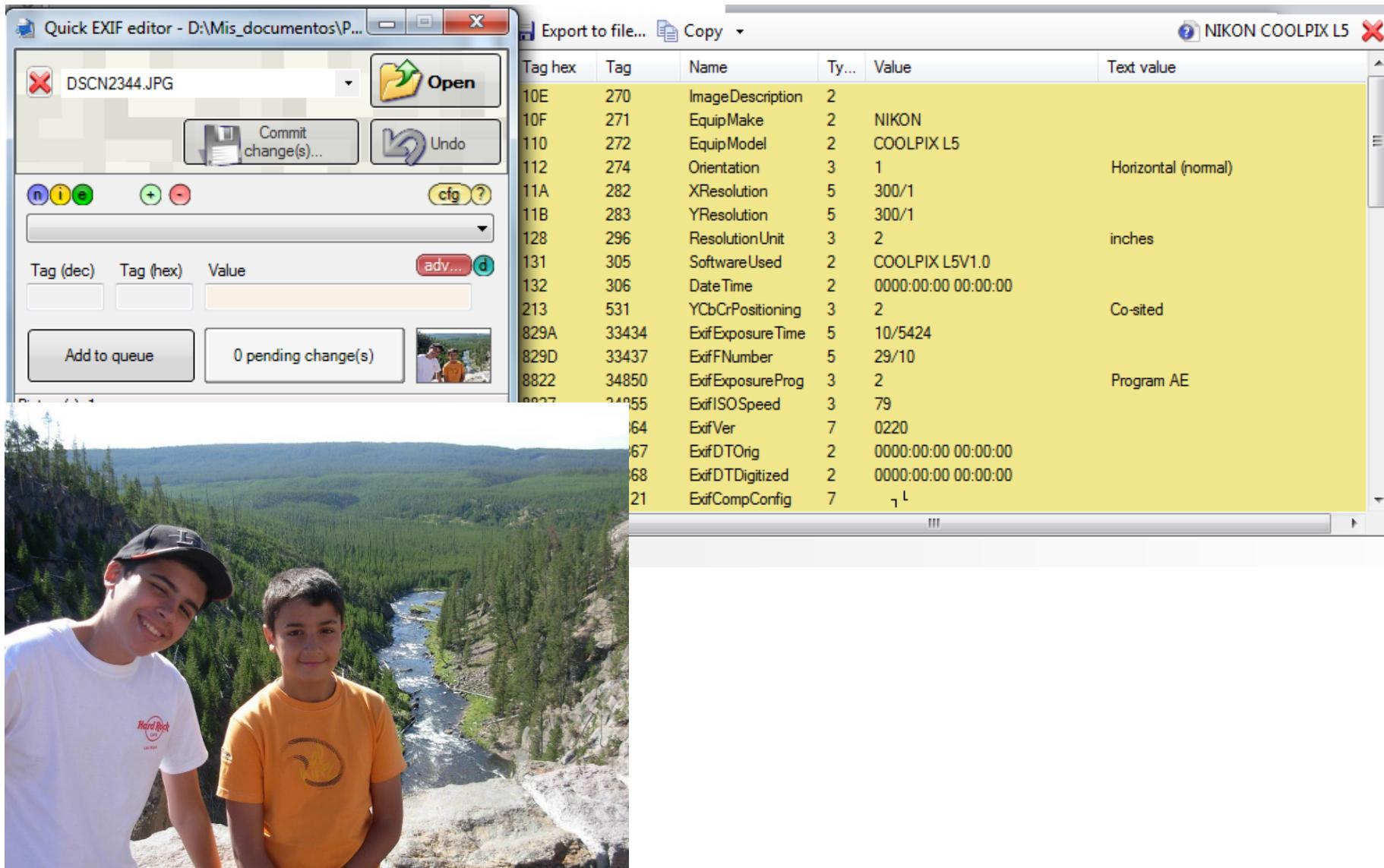
## Other semantic inconsistencies



# **Metadata forensic analysis**

## EXIF metadata format

- ◆ EXIF: Exchangeable Image Format.
- ◆ Some of the metadata are added by the camera, some by the photographer and some by the photo editing software.
- ◆ Date and time.
- ◆ Camera parameters: orientation, aperture, focal distance, etc.
- ◆ Thumbnail.
- ◆ Processing software.



The image displays two windows related to a photograph of two young boys standing on a rocky outcrop overlooking a river valley.

**Left Window: Quick EXIF editor**

This window shows the file path D:\Mis\_documentos\Photos\ and the file name DSCN2344.JPG. It includes a toolbar with Open, Commit changes, Undo, and configuration buttons (cfg, ?). Below the toolbar are fields for Tag (dec), Tag (hex), Value, and a preview image of the photo. A message indicates 0 pending change(s).

**Right Window: EXIF Data View**

This window lists the EXIF metadata for the image:

Tag hex	Tag	Name	Type	Value	Text value
10E	270	ImageDescription	2		
10F	271	EquipMake	2	NIKON	
110	272	EquipModel	2	COOLPIX L5	
112	274	Orientation	3	1	Horizontal (normal)
11A	282	XResolution	5	300/1	
11B	283	YResolution	5	300/1	
128	296	ResolutionUnit	3	2	inches
131	305	SoftwareUsed	2	COOLPIX L5V1.0	
132	306	DateTime	2	0000:00:00 00:00:00	
213	531	YCbCrPositioning	3	2	Co-sited
829A	33434	ExifExposureTime	5	10/5424	
829D	33437	ExifFNumber	5	29/10	
8822	34850	ExifExposureProg	3	2	Program AE
24055	ExifISOSpeed	3	79		
64	ExifVer	7	0220		
67	ExifDTOrig	2	0000:00:00 00:00:00		
68	ExifDTDigitized	2	0000:00:00 00:00:00		
21	ExifCompConfig	7	7L		

Quick EXIF editor - D:\Mis\_documentos\P...

DSCN2344\_bis.jpg

Open

Commit change(s)... Undo

n i e + - cfg ?

Tag (dec) Tag (hex) Value adv... d

Add to queue 0 pending change(s)

Picture(s): 1



Export to file... Copy

Nikon COOLPIX L5

Tag hex	Tag	Name	Type	Value	Text value
10E	270	ImageDescription	2		
10F	271	EquipMake	2	NIKON	
110	272	EquipModel	2	COOLPIX L5	
112	274	Orientation	3	1	Horizontal (normal)
11A	282	XResolution	5	300/1	
11B	283	YResolution	5	300/1	
128	296	ResolutionUnit	2	2	inches
131	305	SoftwareUsed	2	GIMP 2.8.0	
132	306	DateTime	2	2012:06:23 08:51:05	
213	531	YCbCrPositioning	3	2	Co-sited
829A	33434	ExifExposureTime	5	1/60	
829D	33437	ExifFNumber	5	29/10	
8822	34850	ExifExposureProg	3	2	Program AE
8827	34855	ExifISOSpeed	3	79	
8834	34864	ExifVer	7	0220	
67	ExifDTOrig	2		0000:00:00 00:00:00	
68	ExifDTDigitized	2		0000:00:00 00:00:00	
21	ExifCompConfig	7		1 L	

# Thumbnails

Very small versions of the original image which enable faster organization and viewing



**EXIF Metadata**

Image Size	:	5520x4144
Megapixels	:	22.9
Speed	:	1/33
Create Date	:	2017:05:05 13:22:57.35
Date/Time Original	:	2017:05:05 13:22:57.35
Modify Date	:	2017:05:05 13:22:57.35
<b>Thumbnail Image</b>	:	(Binary data 36864 bytes)
Focal Length	:	4.2 mm
Light Value	:	8.1



(zoomed  
version)

And also to uncover some editing:



**EXIF Metadata**

Image Size	:	5984x3376
Megapixels	:	20.2
Speed	:	1/100
Create Date	:	2017:09:02 11:57:12.40
Date/Time Original	:	2017:09:02 11:57:12.40
Modify Date	:	2017:09:02 11:57:12.40
<b>Thumbnail Image</b>	:	(Binary data 36864 bytes)
Focal Length	:	4.2 mm
Light Value	:	9.6



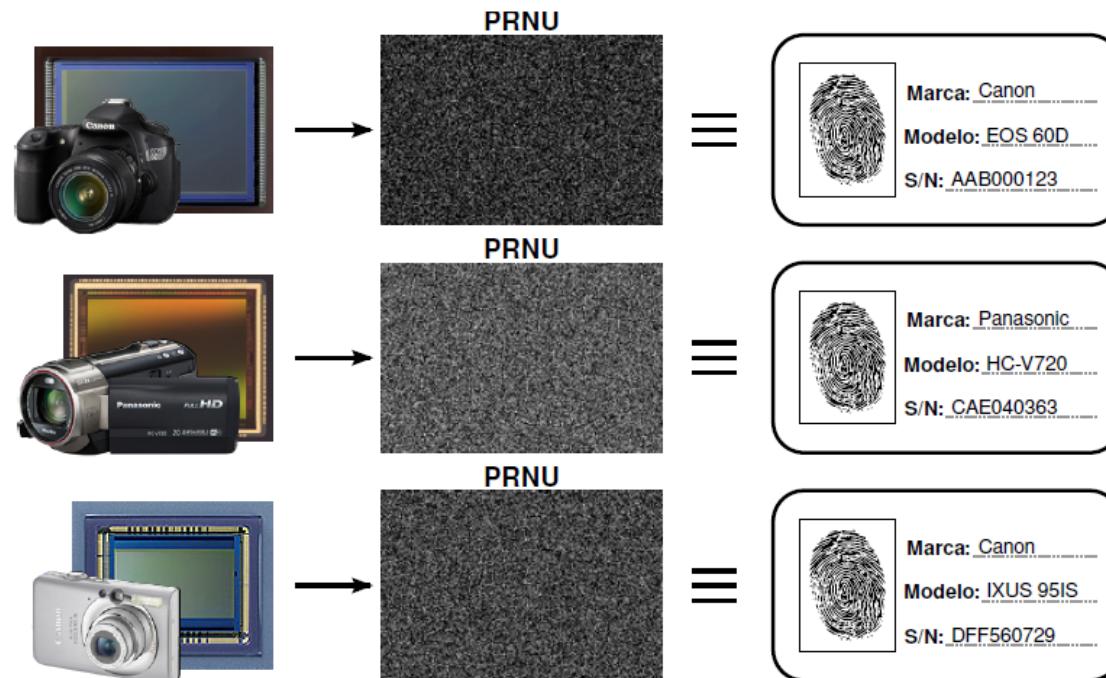
(zoomed  
version) 

# **Structural forensic analysis**

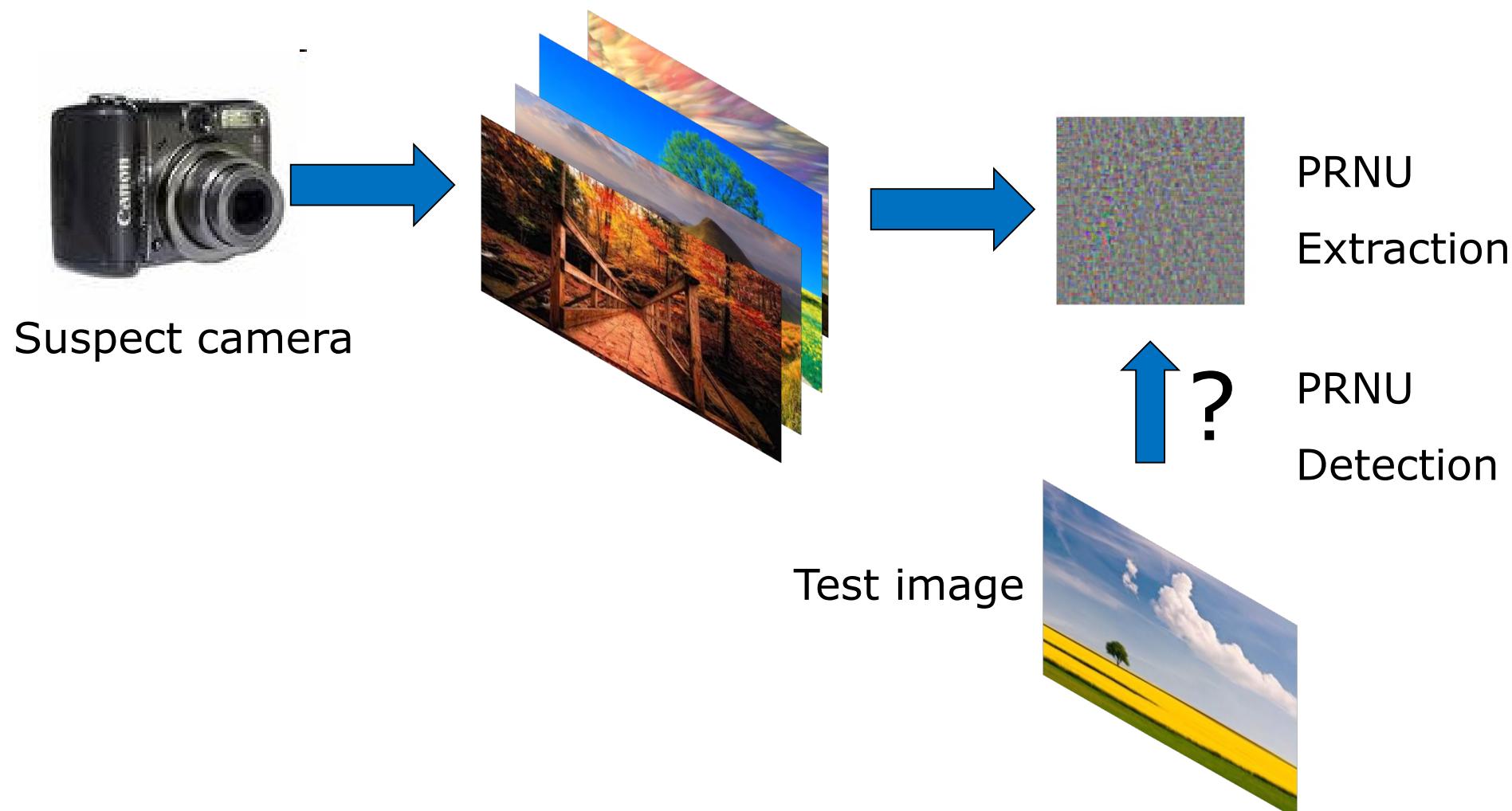
# **Camera identification**

## Capturing device identification

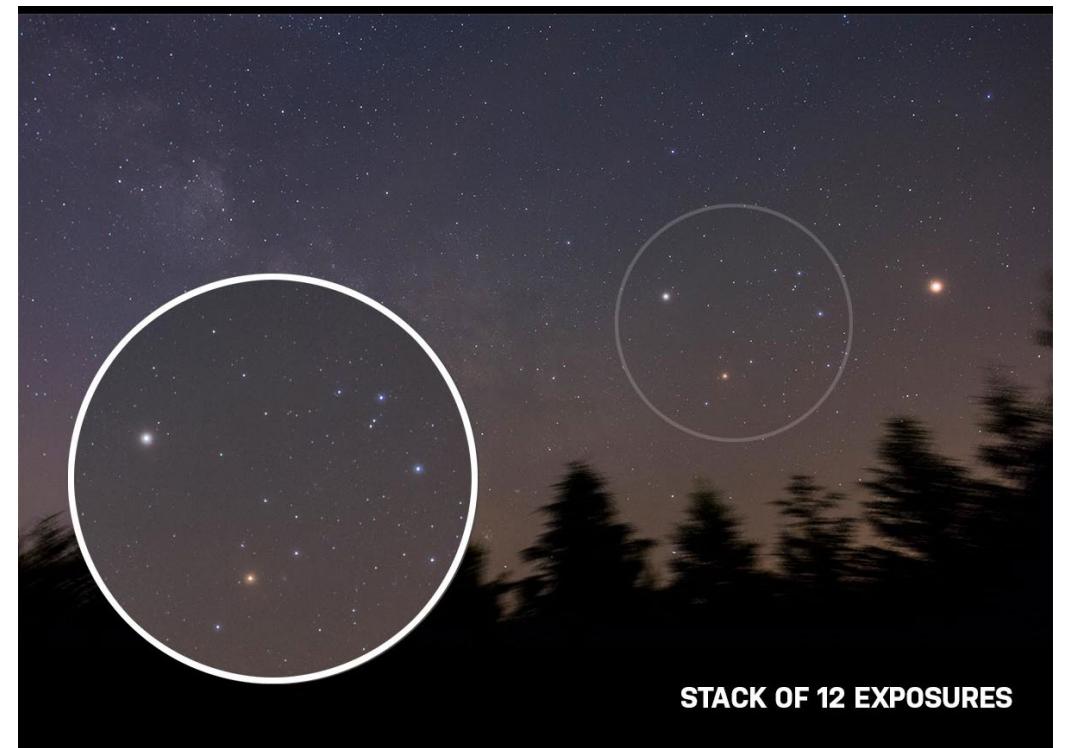
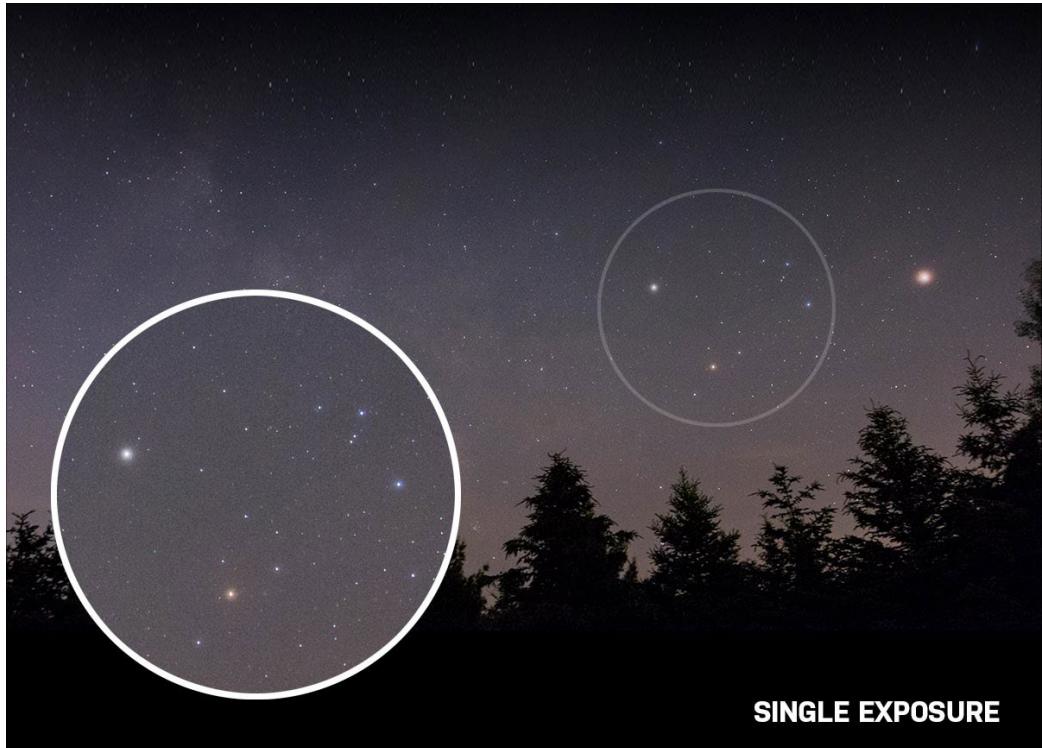
- ◆ Practically all sensors (CMOS, CCD, etc.) contain an intrinsic noise pattern: PRNU (Photo Response Non Uniformity)
  - ★ **PRNU properties:** robustness, stability, universality
  - ★ Dark current noise can be also used (but works worse)



## PRNU-based camera identification

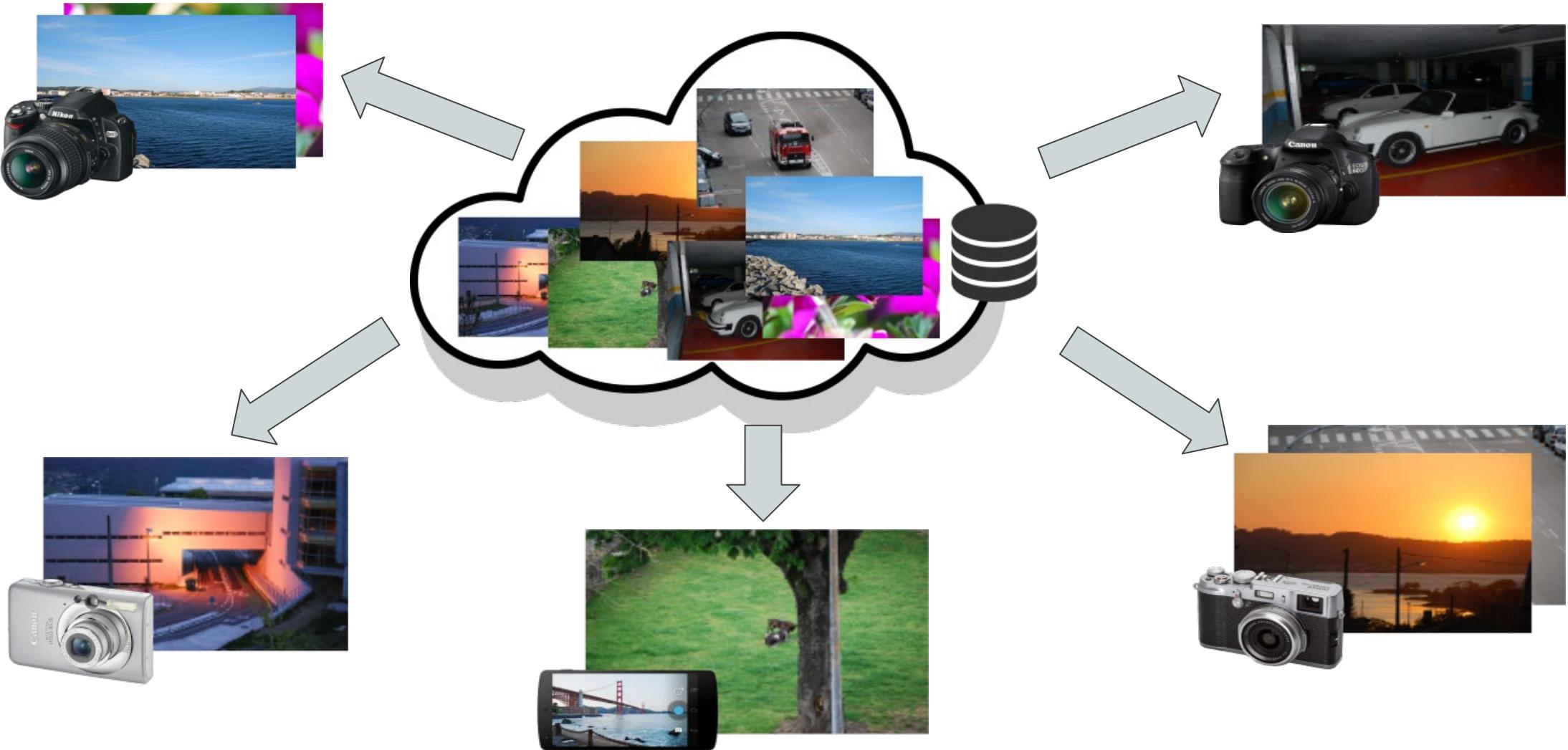


## PRNU Extraction

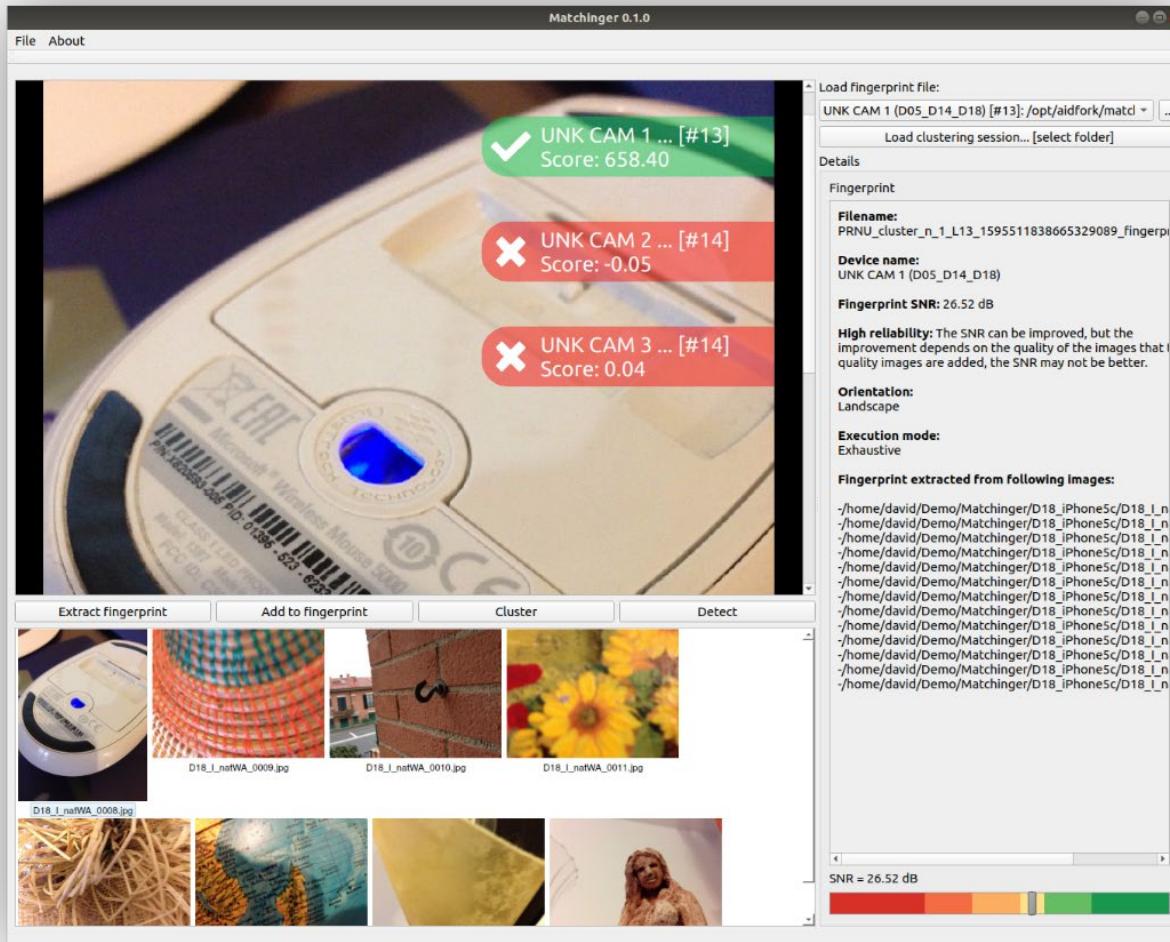


Source: <https://astrobackyard.com/tutorials/stack-exposures/>

## PRNU-based image clustering



# Matchinger



# Matchinger: extraction and detection



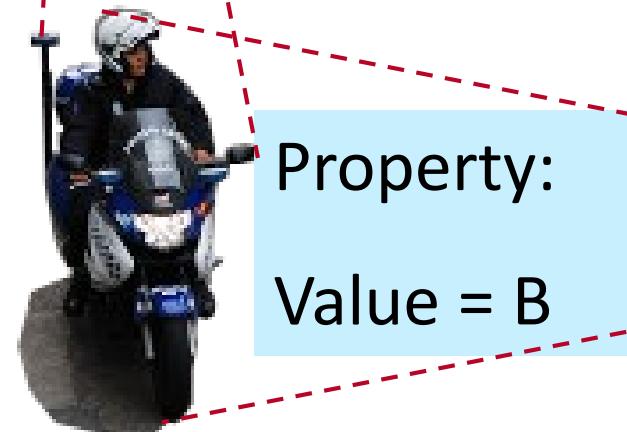
# Matchinger: clustering



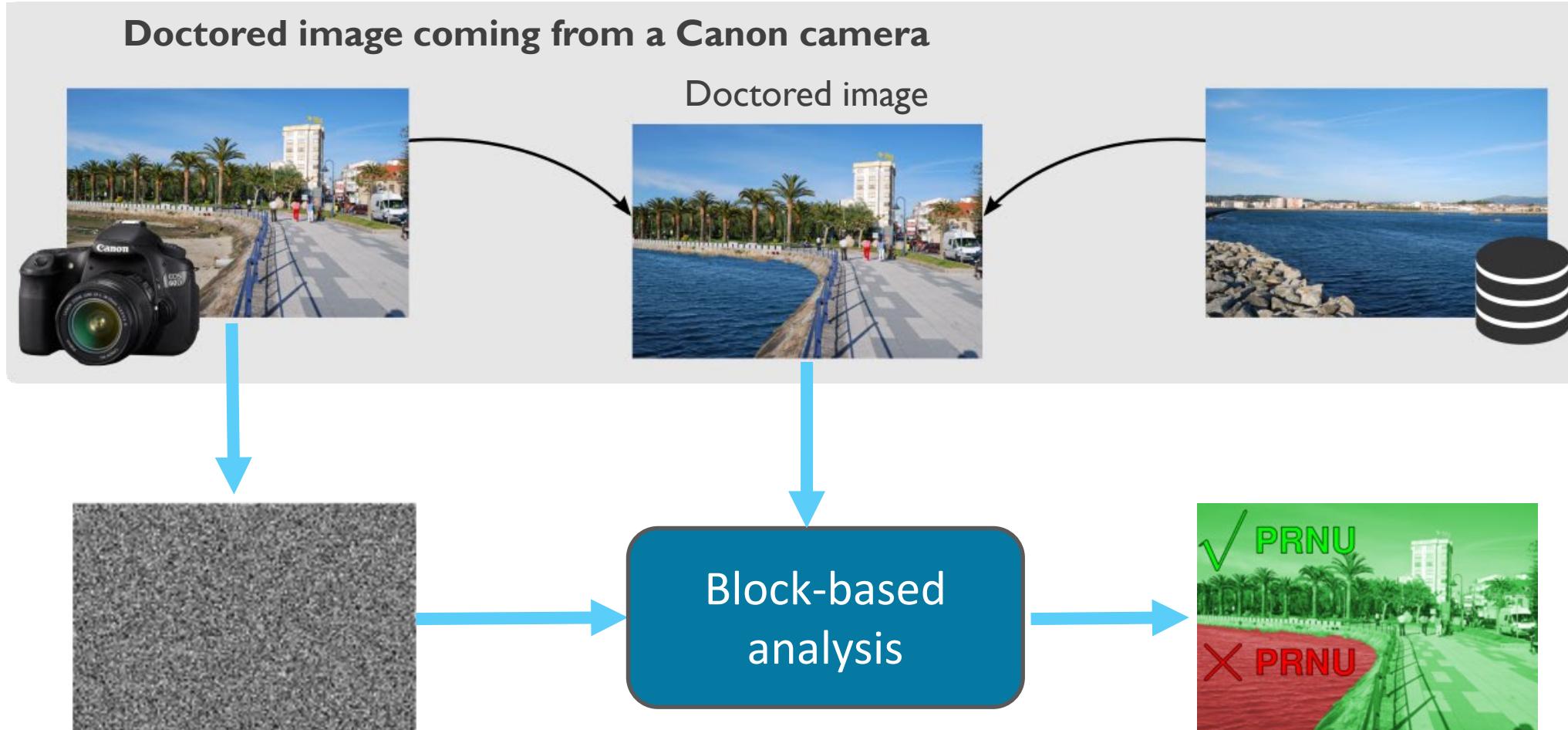
# **Forgery detection and localization**

## Forgery detection

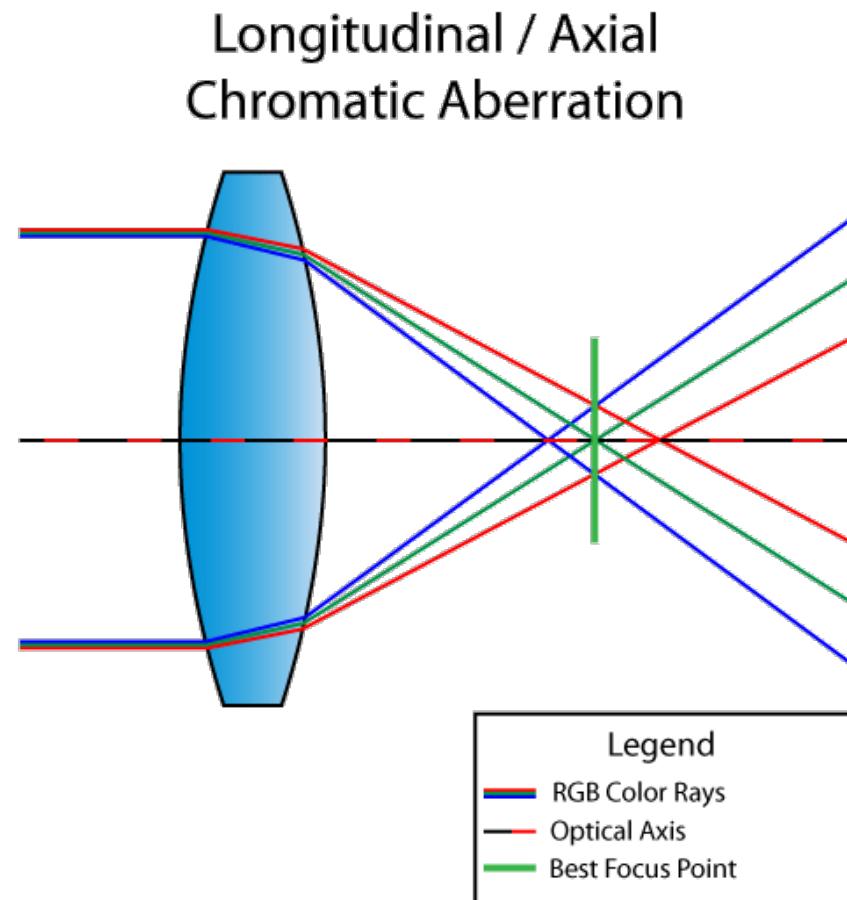
Property: Value = A



## PRNU-based detection

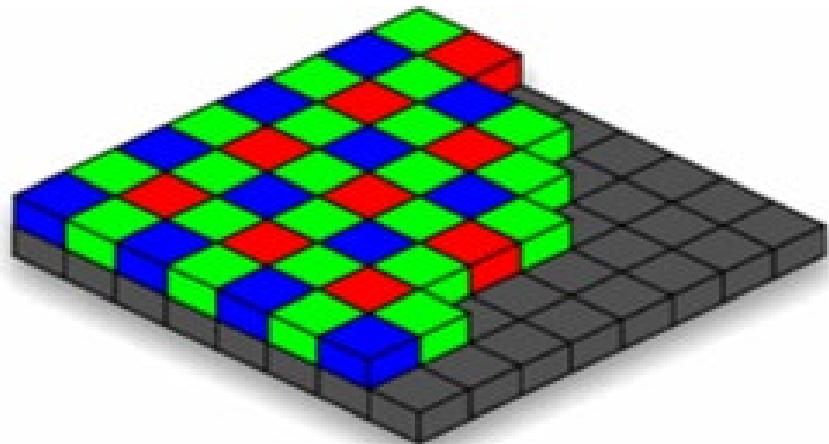
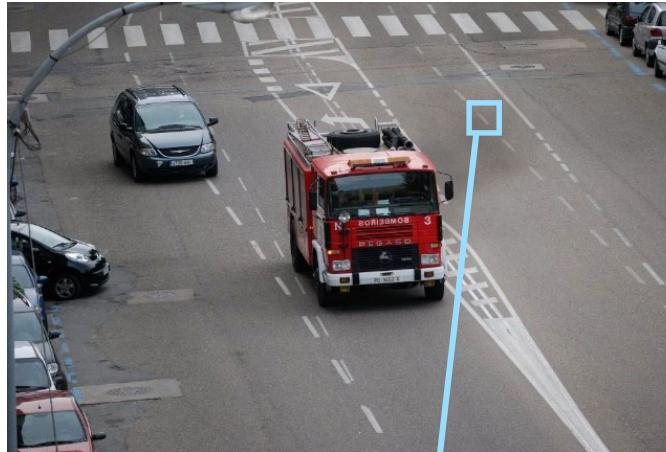
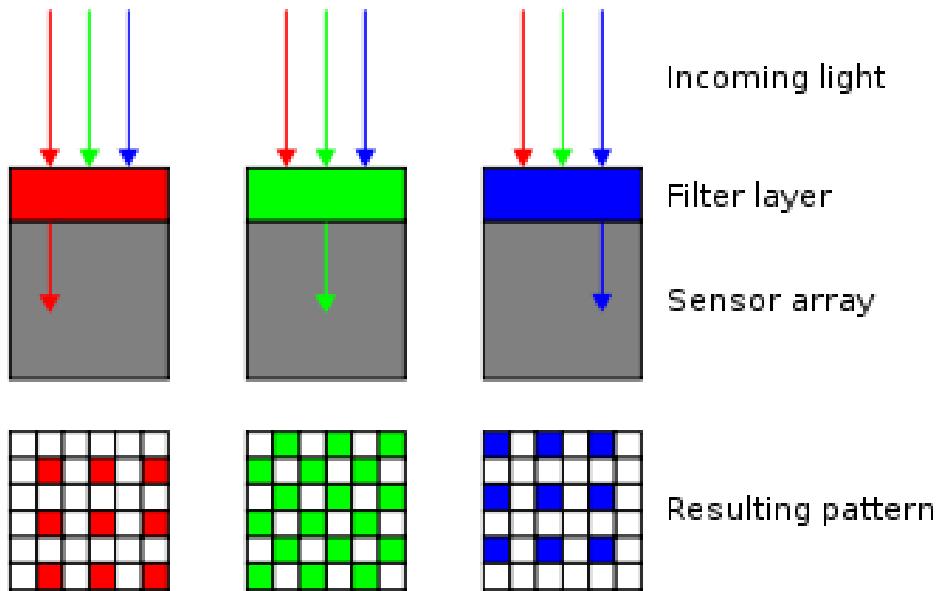


# Detection based on chromatic aberration



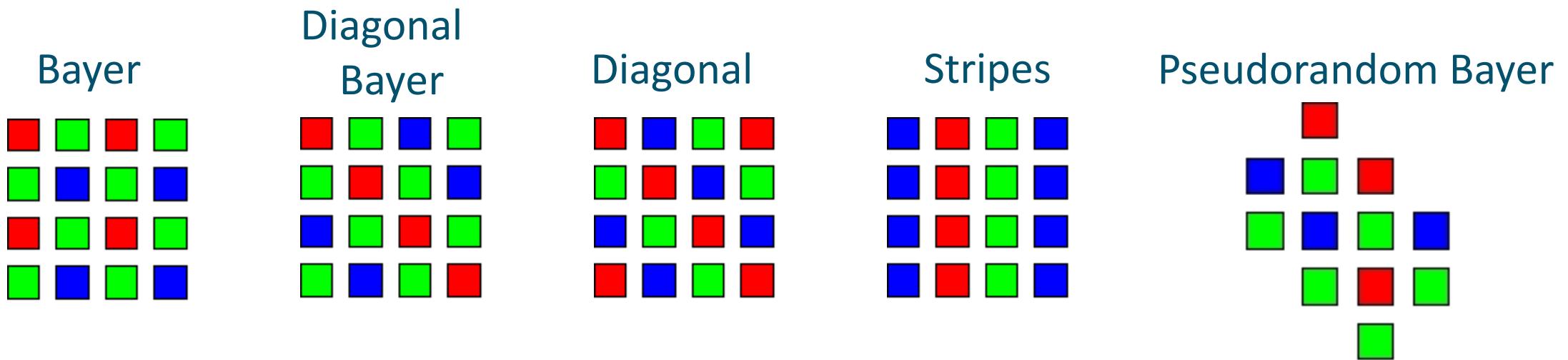


## Color Filter Array (CFA)



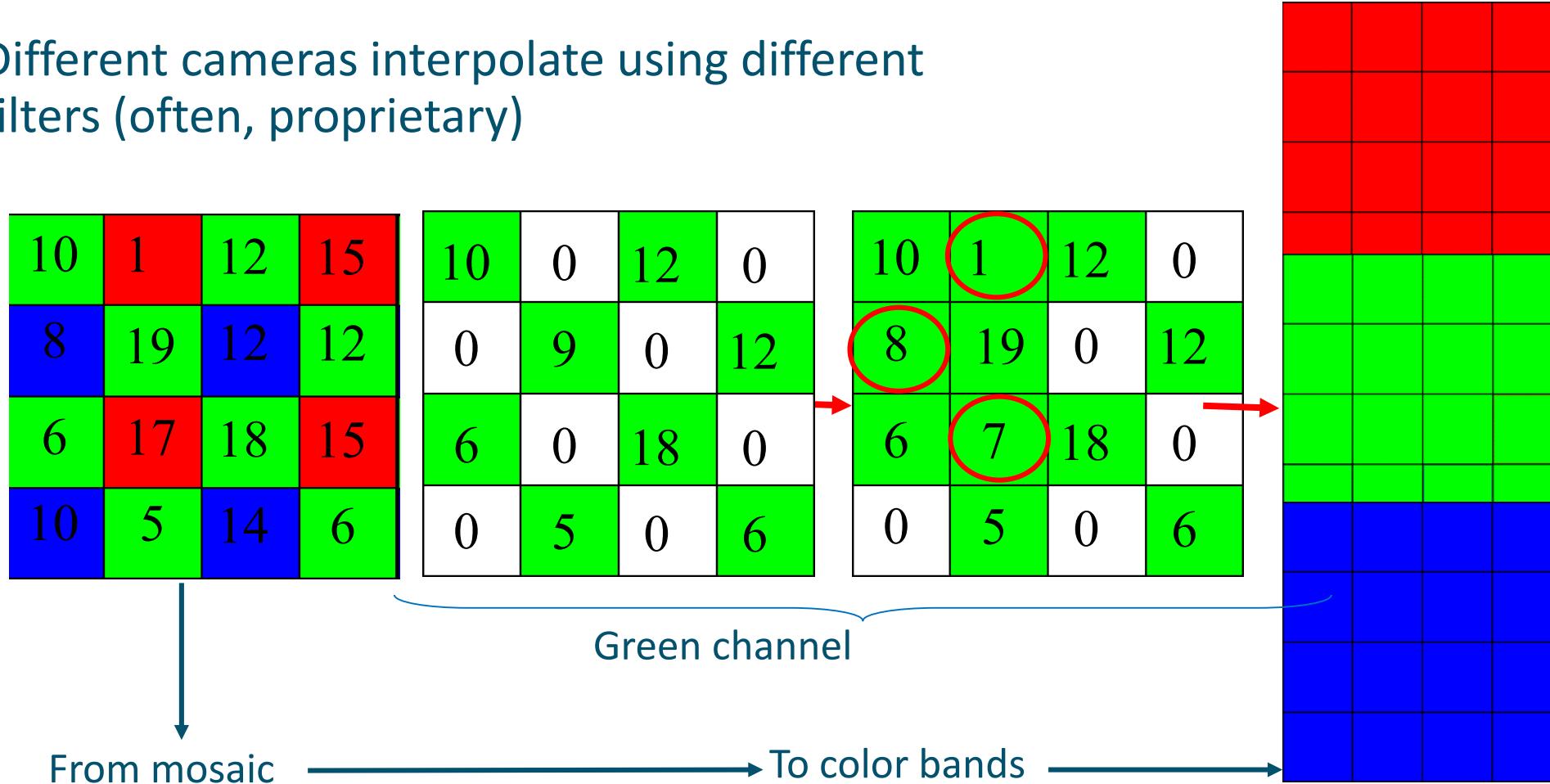
## Color Filter Array (CFA)

- Different cameras may have different patterns



## Color Filter Array (CFA)

- Different cameras interpolate using different filters (often, proprietary)

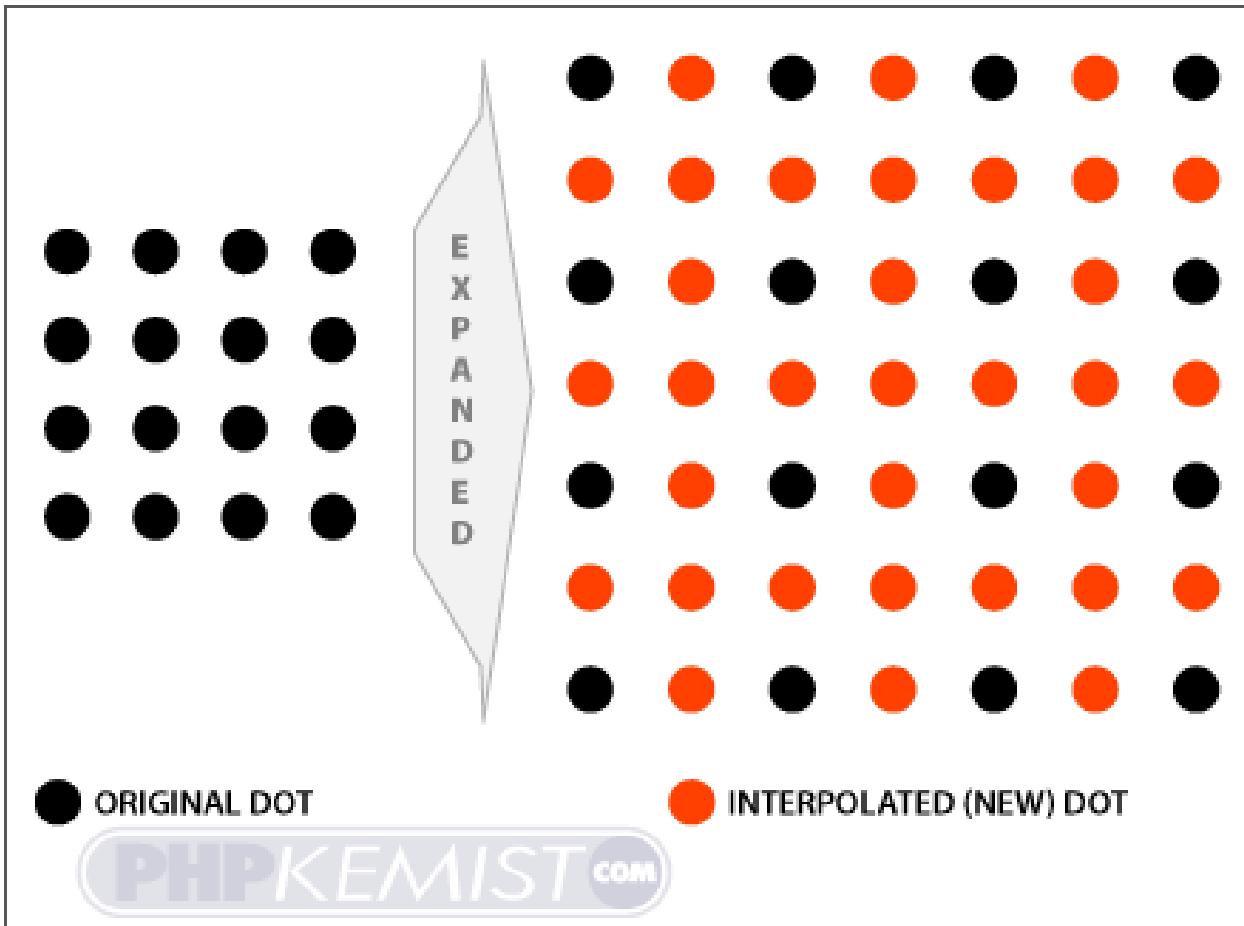


## Resampling traces

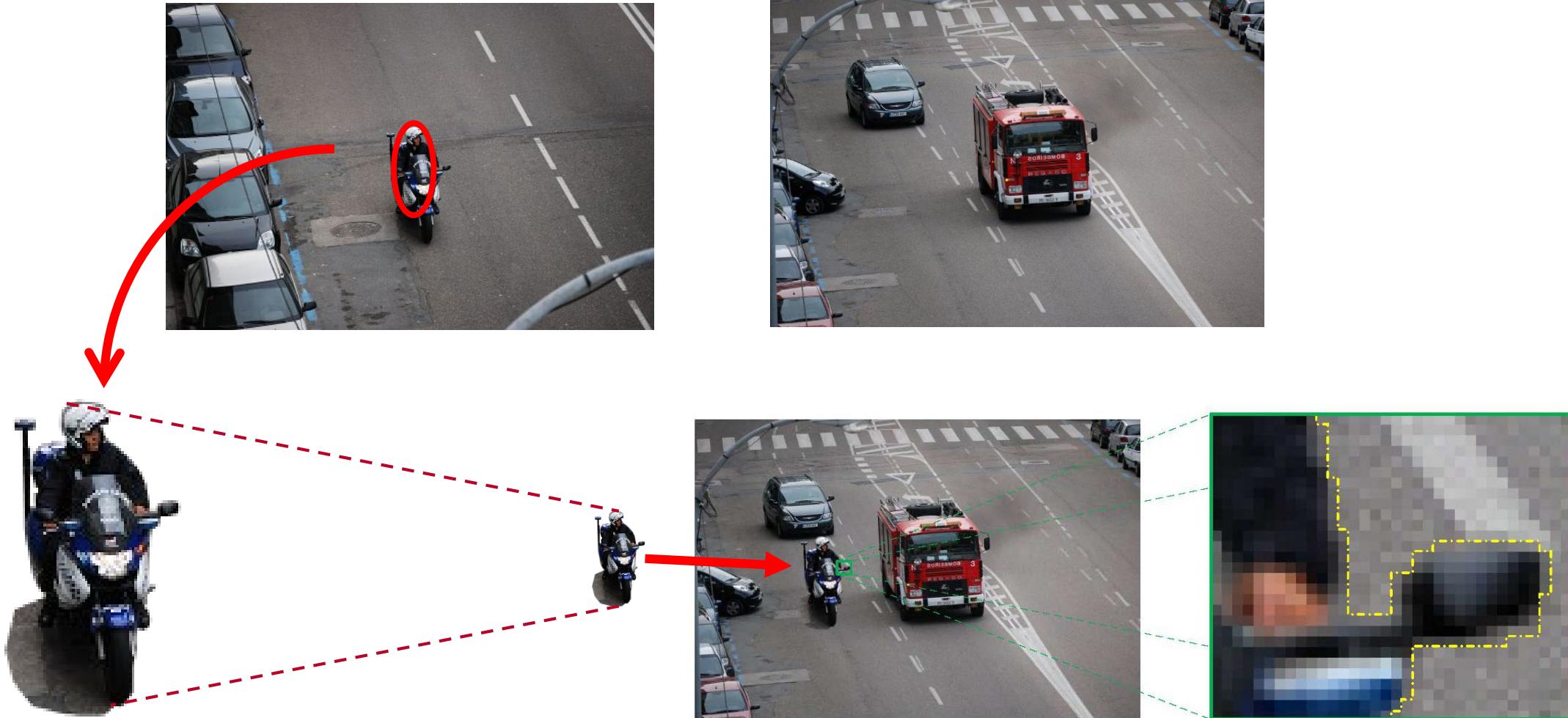


## Resampling traces

***IMAGE EXPANDED TO LARGER DIMENSIONS***

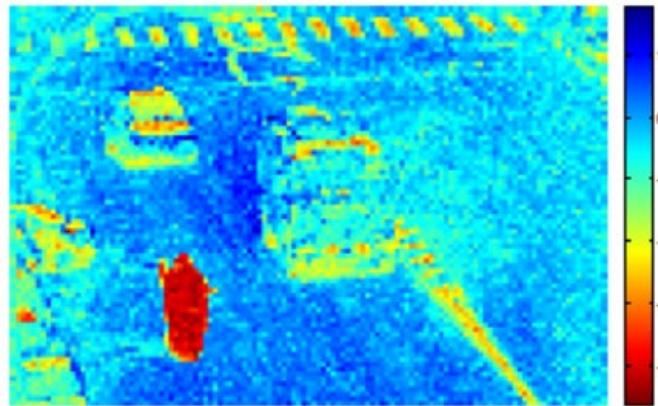


## Resampling traces





(a) Forged image

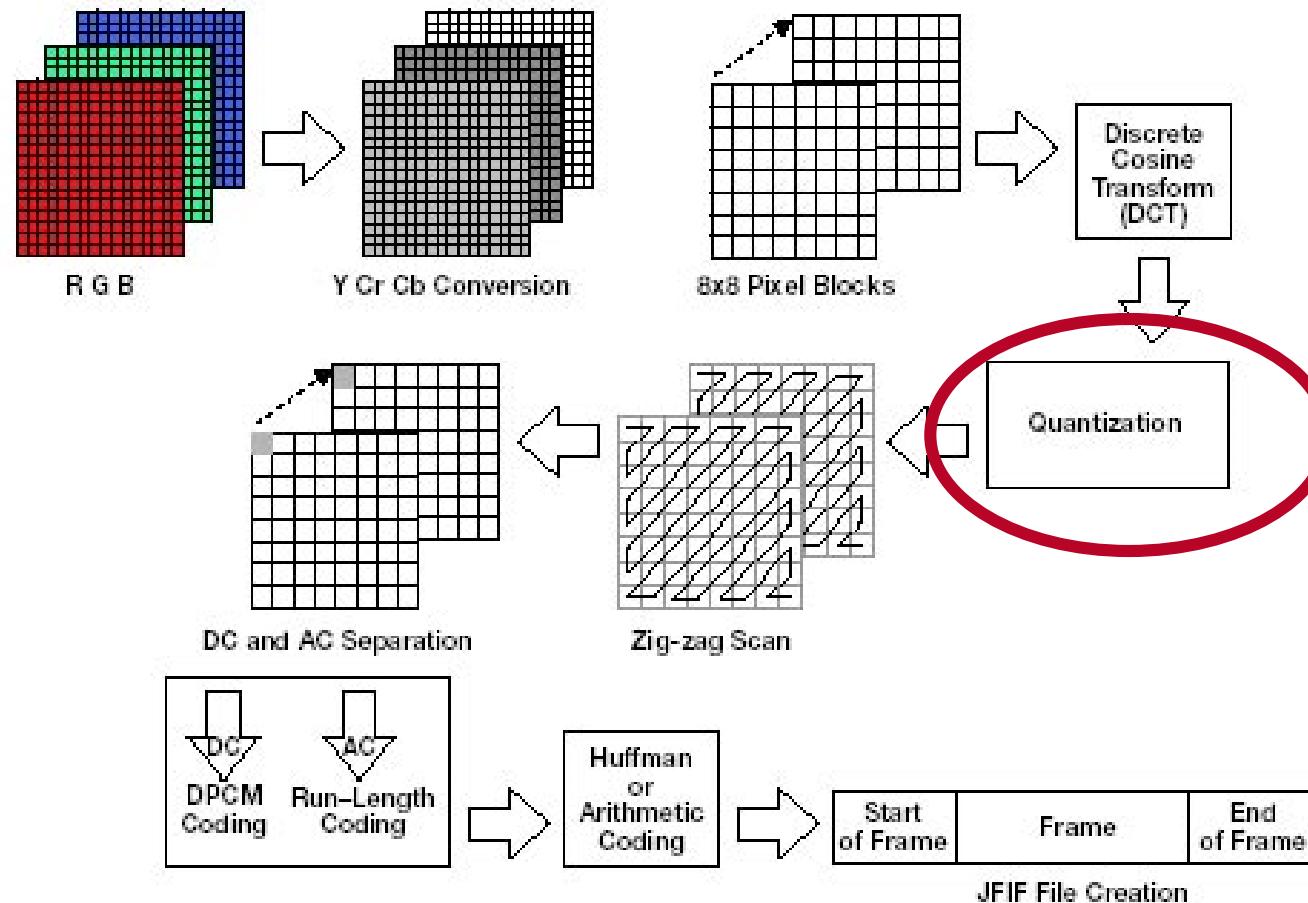


(b) log- $\kappa$  map



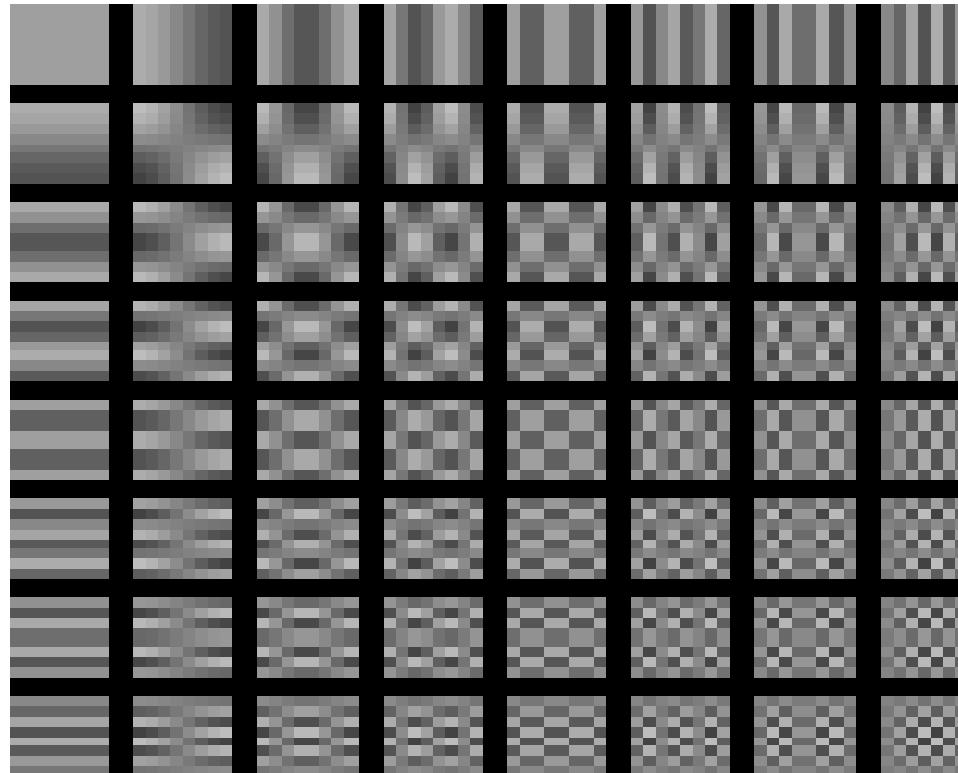
(c) Binary mask

## Double compression detection: the DCT



Source: Katz&Gentile, EE Times 2003.

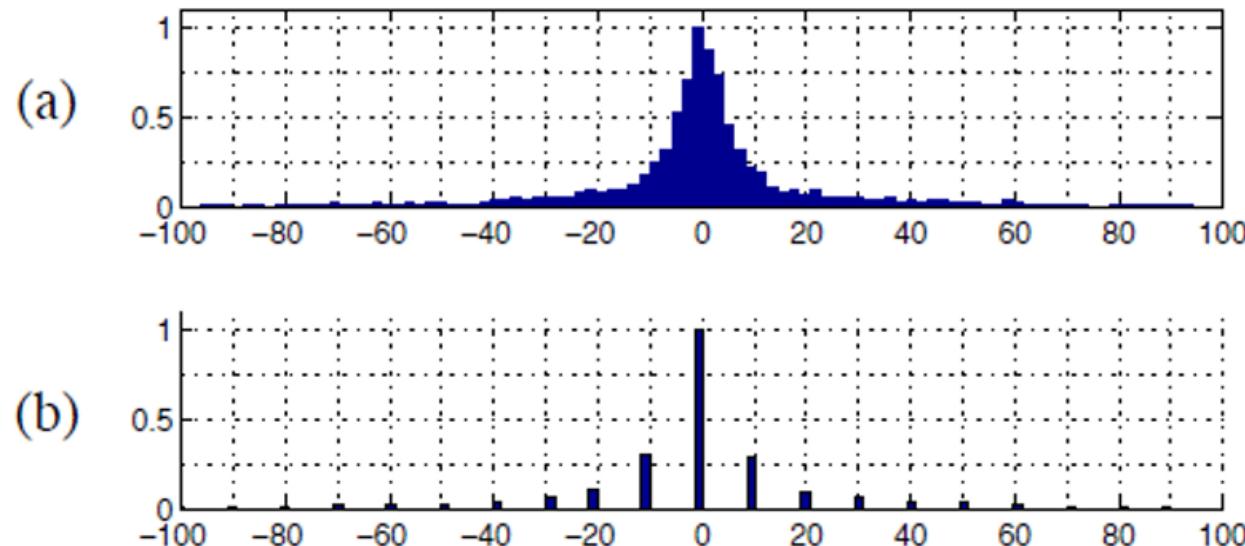
## DCT: Frequency Distribution



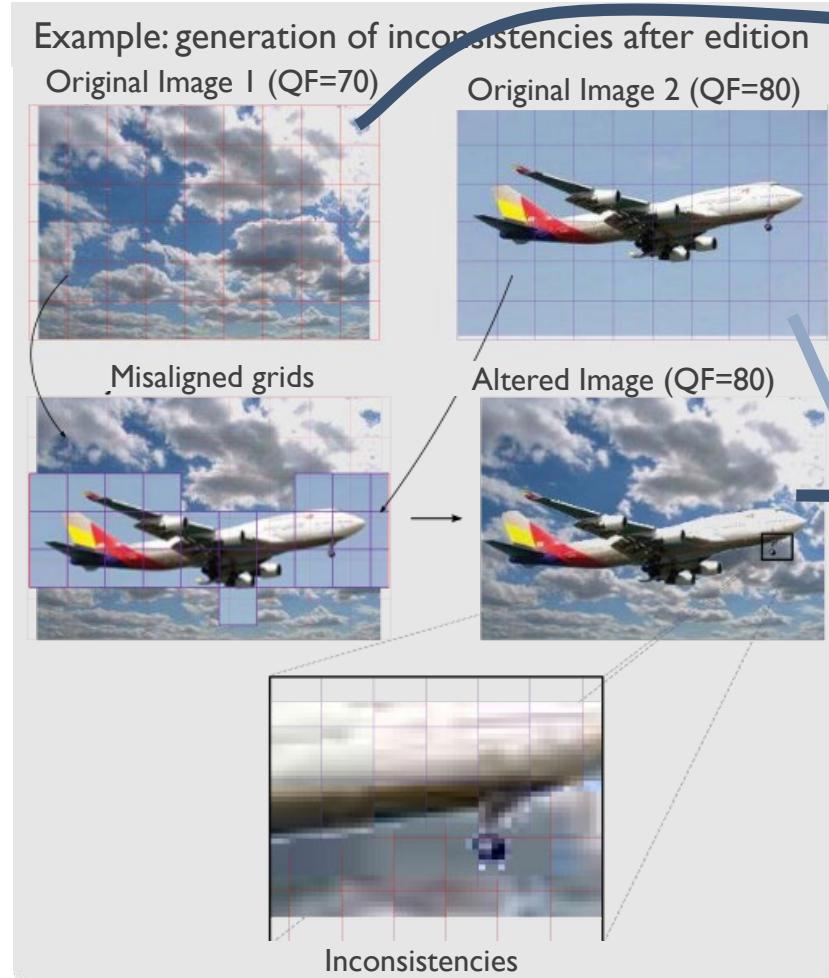
Source: Richard Kelley: the DCT

## Compression effects on histogram

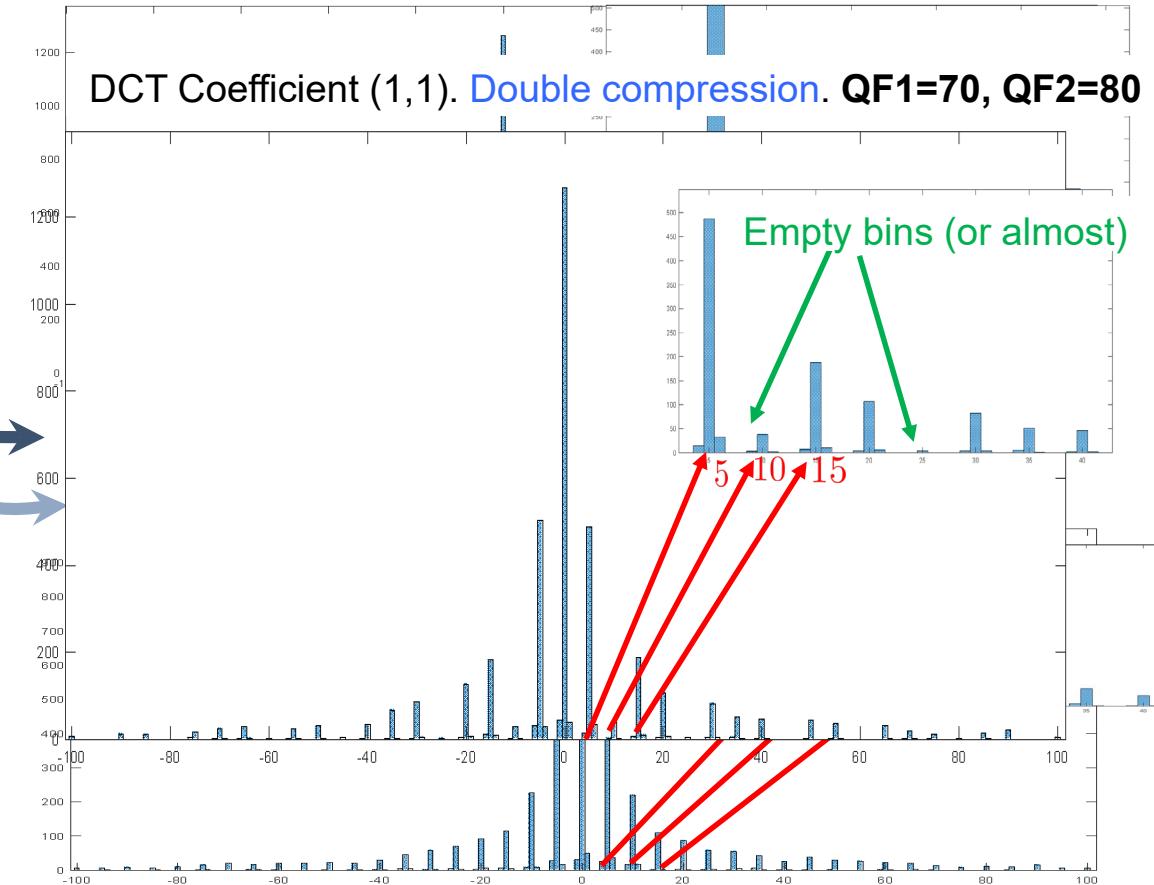
- ◆ (2,2) DCT coefficient
- ◆ Step size = 10



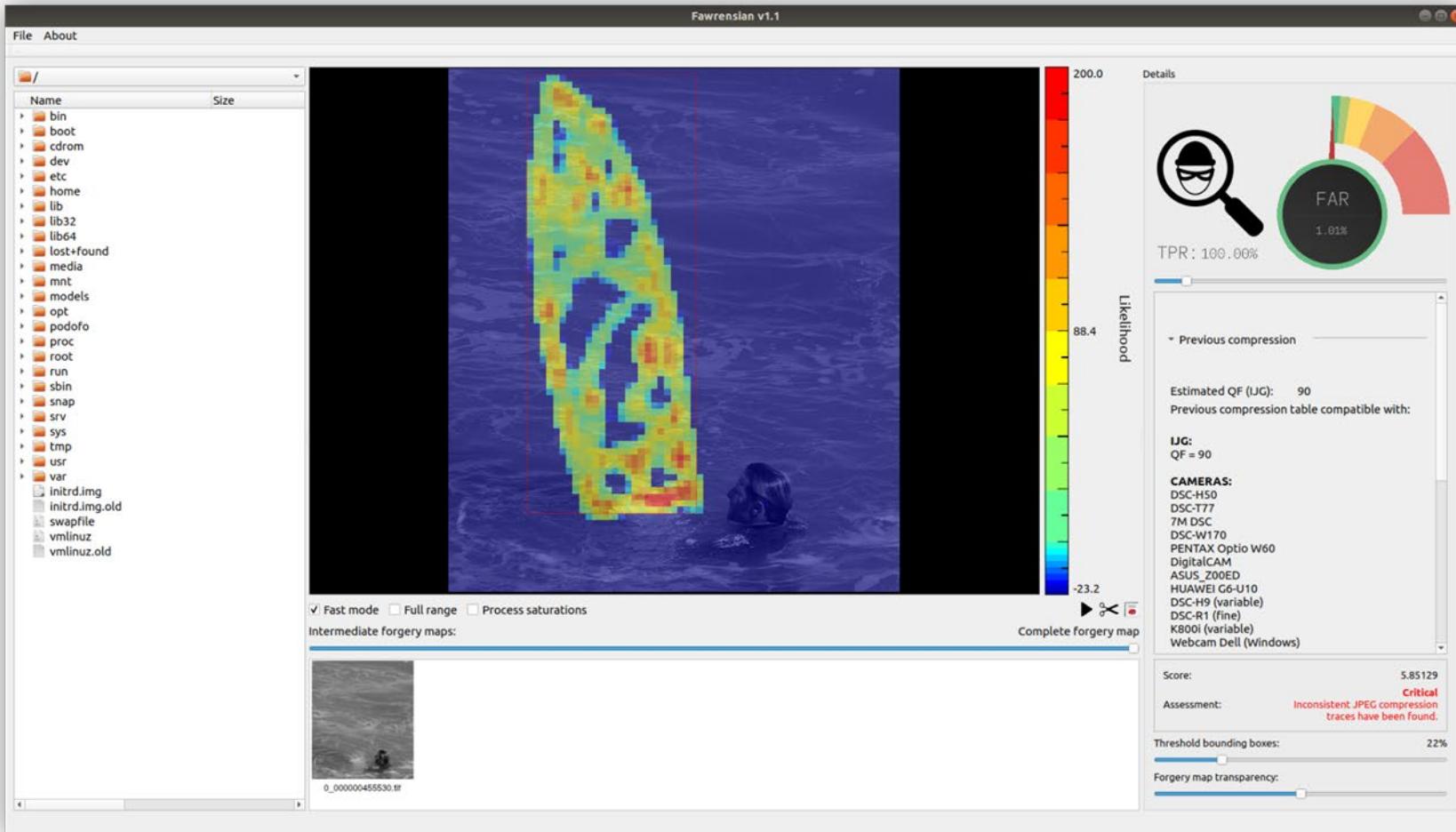
# Double compression detection



DCT Coefficient (1,1). Single compression. QF=70



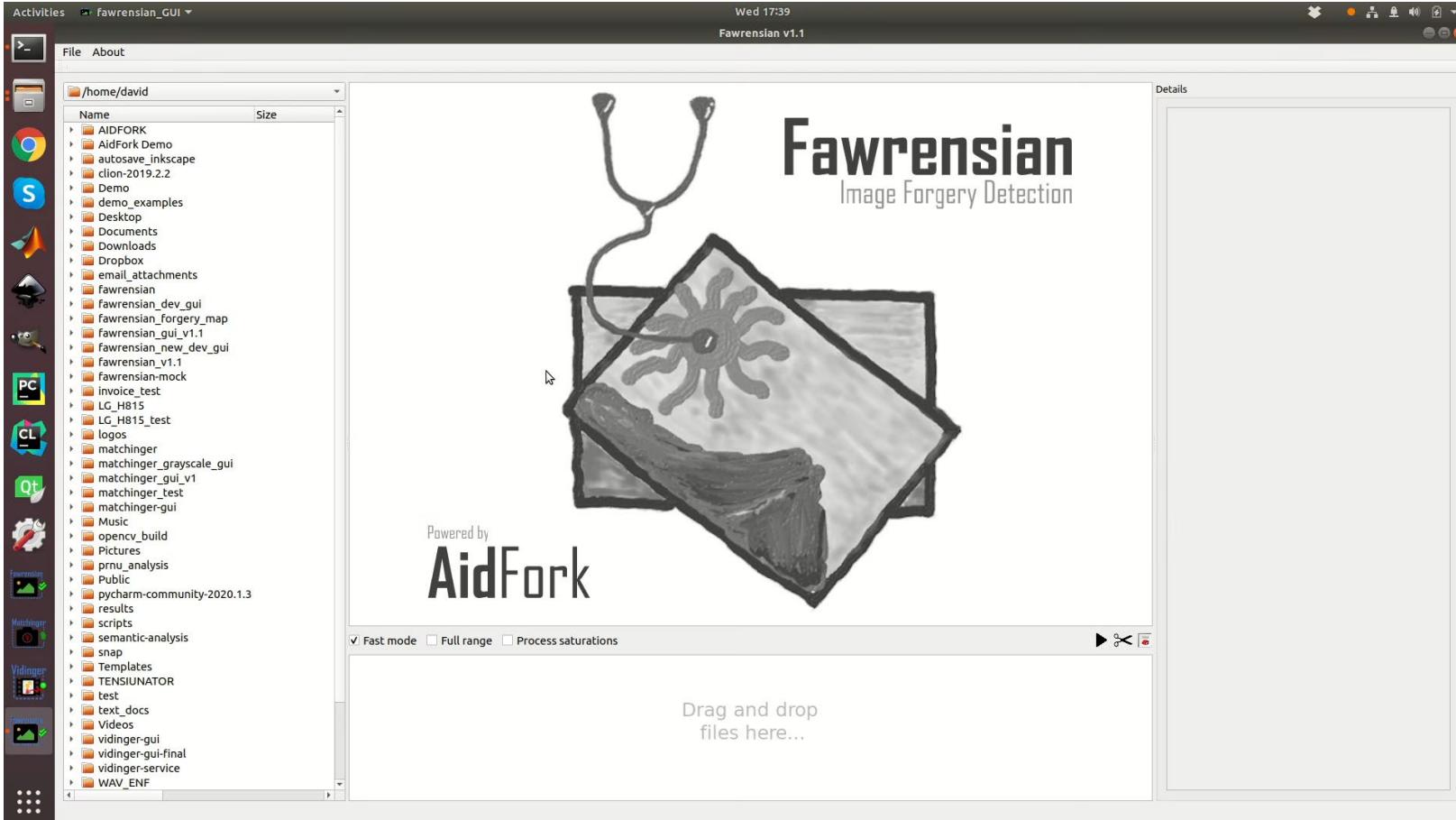
# Fawrensan



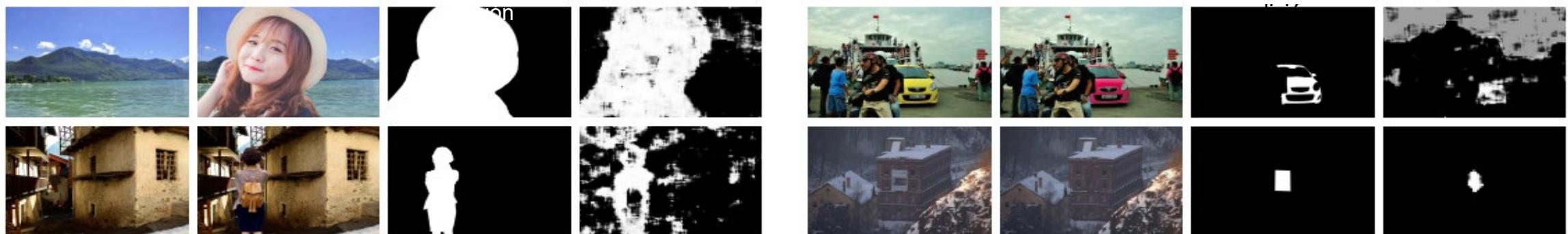
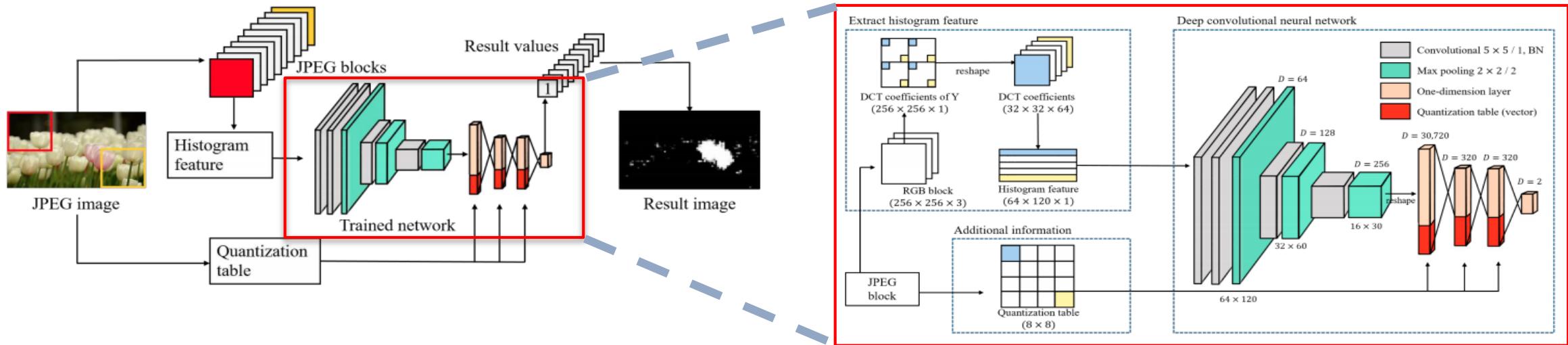
# Fawrensián: 3 examples and 2 faces



# Fawrensián: example with GIMP

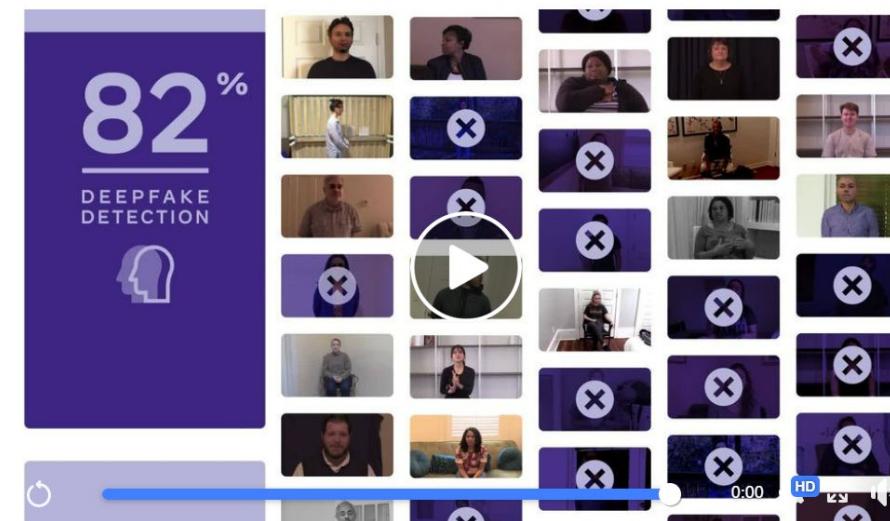


# Detection with DNNs



## Facebook's Deepfake detection challenge [2020]

- ◆ More than 2000 participants.
- ◆ Dataset of more than 100,000 videos.
- ◆ More than 35,000 models submitted to the competition.
- ◆ 82% detection on public dataset; BUT down to 65.18 on black-box (also wilder) dataset.
- ◆ Most top contestants used variants of the EfficientNet networks, with data augmentations.

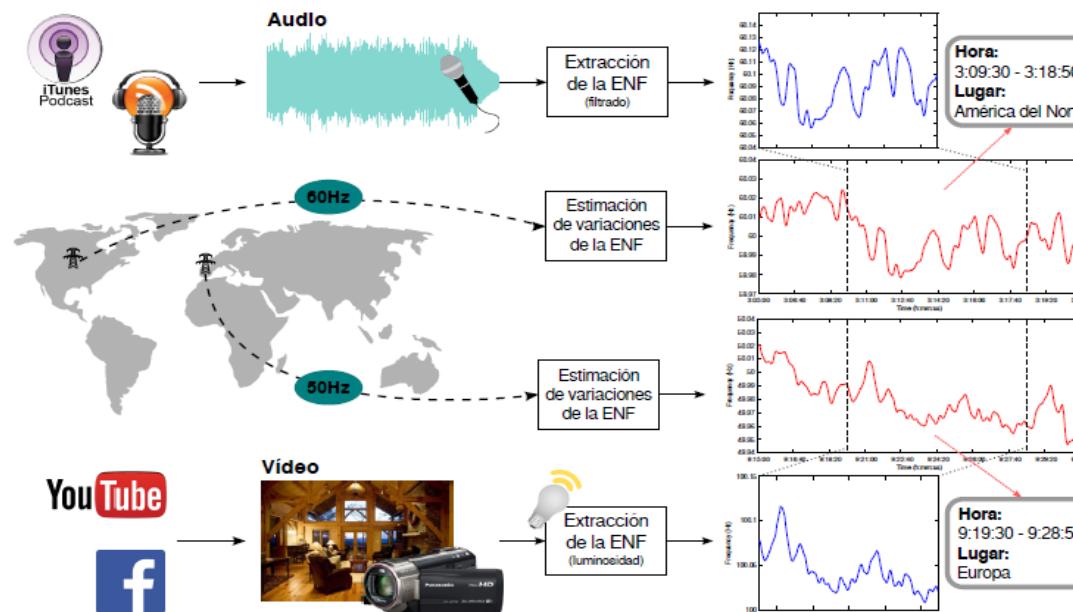


# **Estimation of time of recording from videos**

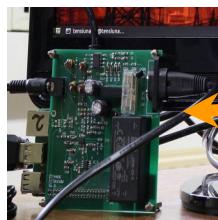
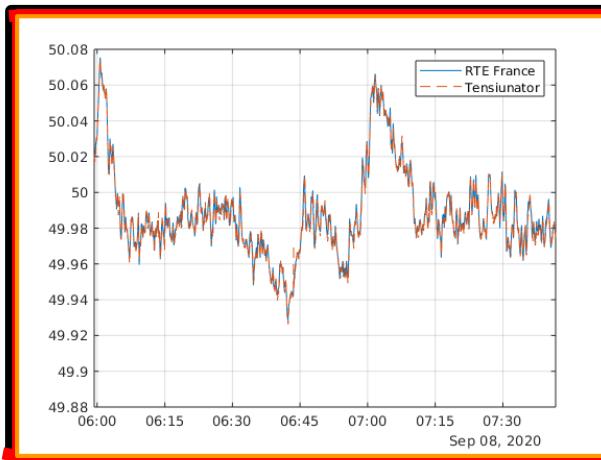
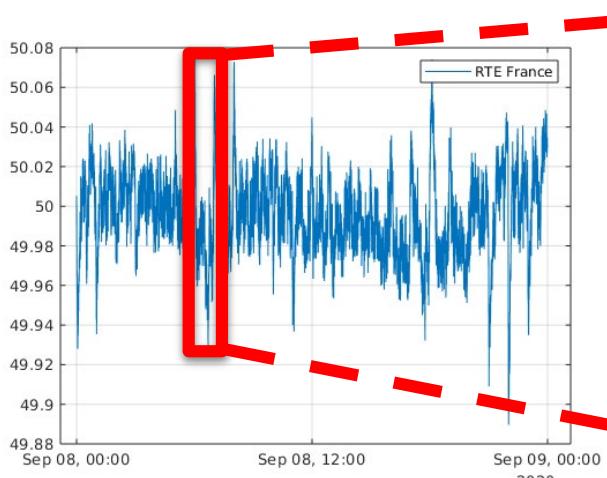
# ENF-based estimation of time of recording

Variations of **ENF (Electric Network Frequency)** provide both temporal and geographical information. They can be extracted from:

- ◆ Any appliance connected to the power network (e.g., microphone)
- ◆ Videos recorded indoors, through analysis of variations of luminance



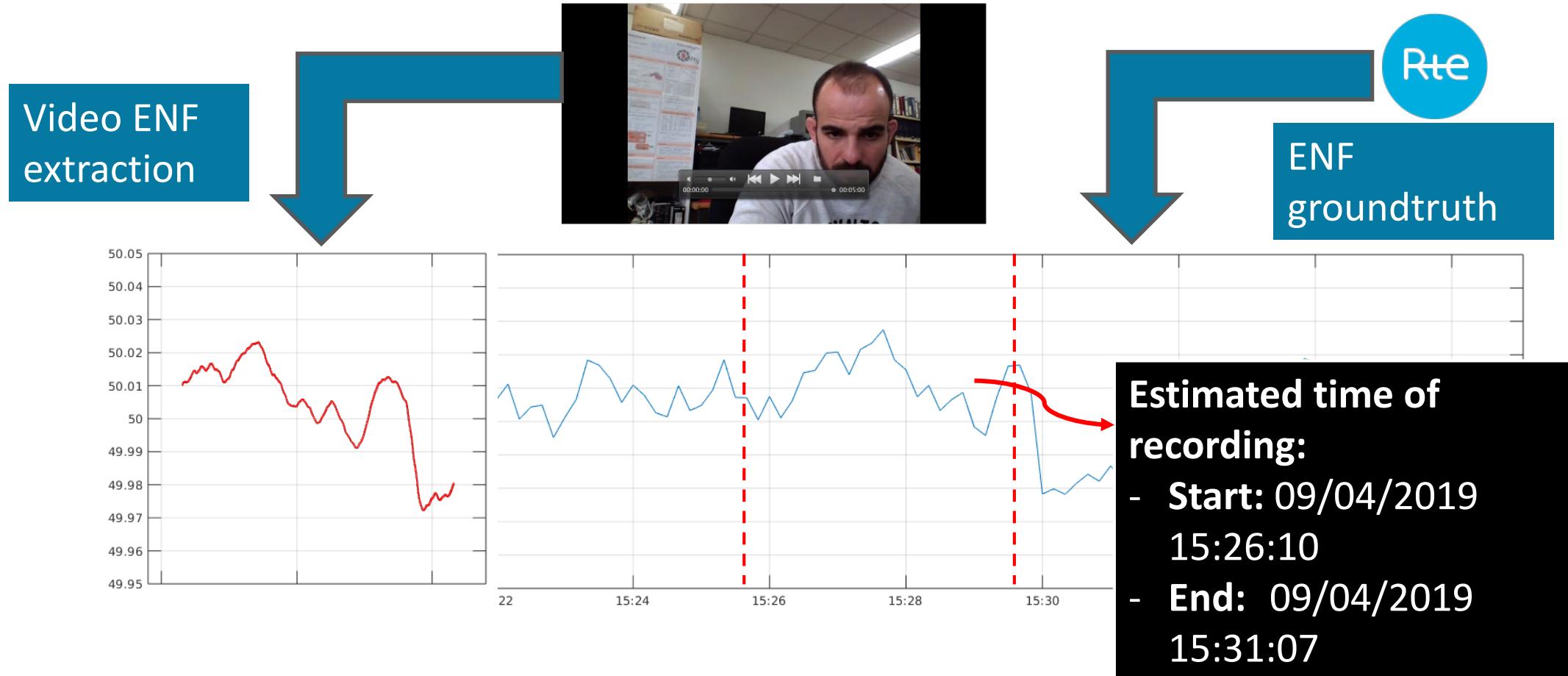
# ENF signal characteristics



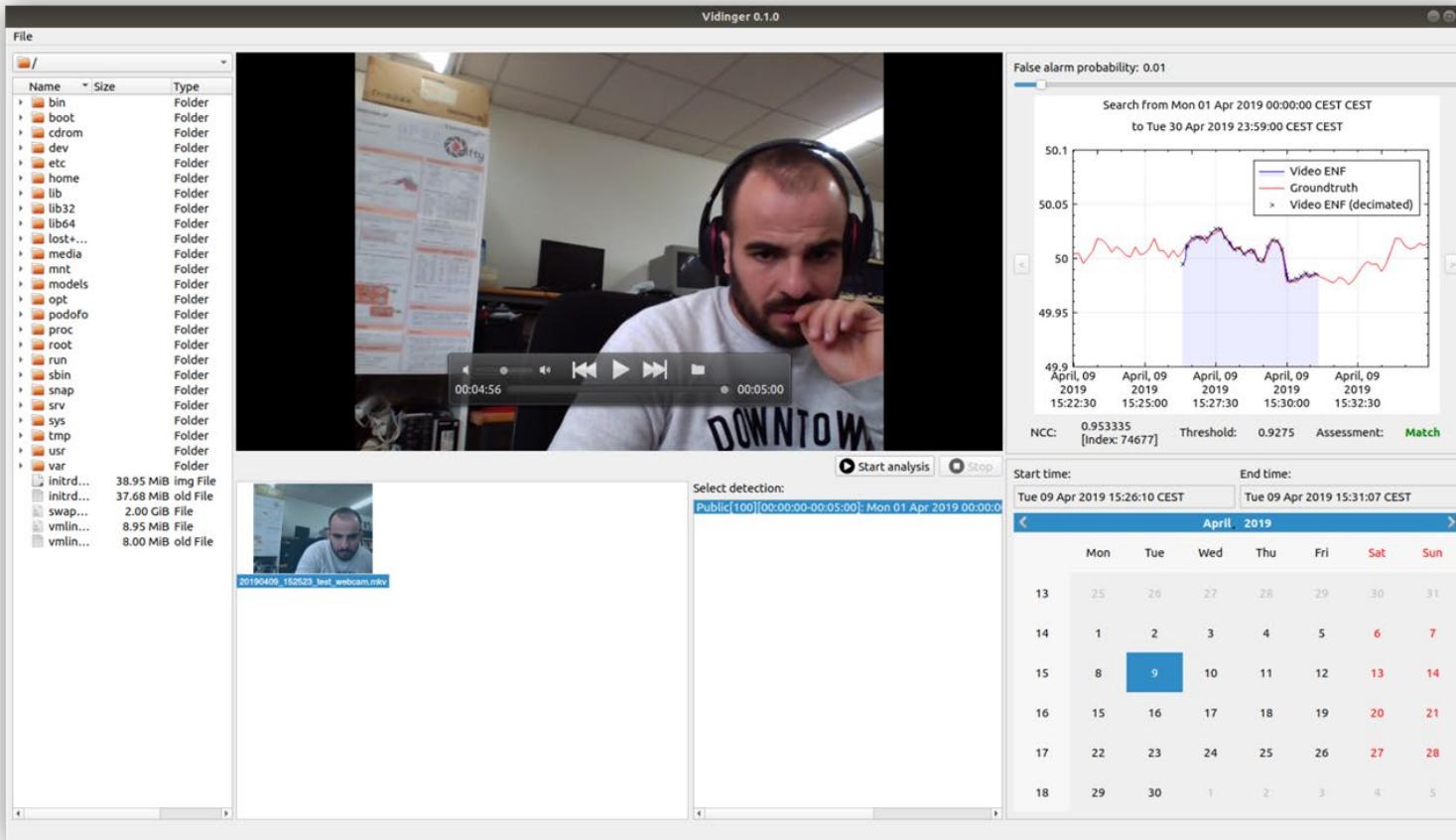
Tensiunator



# Time of recording estimation through ENF



## Vidinger



## Vidinger: two examples





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