

Security of Multimedia Information

by Xiangwei Kong, Yanqin Guo, Bo Wang

Chapter 6. Forensics of Digital Media

Lecturer: Jin HUANG

Digital Forensics

*Some content are from Research and slides of **Alessandro Piva** (Dept. of Information Engineering University of Florence (Italy)).*

People should be sensitive to the following problems:

- Is that true?
- Where does it come from?
- How much/Where it is modified/distorted?

Importance

- Personal: your money, your feeling.
- Society: united or divided, on the correct/wrong way.
 - Media is a kind a weapon!



Importance

- Personal: your money, your feeling.
- Society: united or divided, on the correct/wrong way.
 - Media is a kind a weapon!



Several Typical methods

- Visual analysis of the image content
- Analysis of the image file
- Analysis through processing techniques of the image content

Visual analysis of the image content

Does this image look strange?

- **Ripple**, light direction etc.
- Sometimes, needs experts.

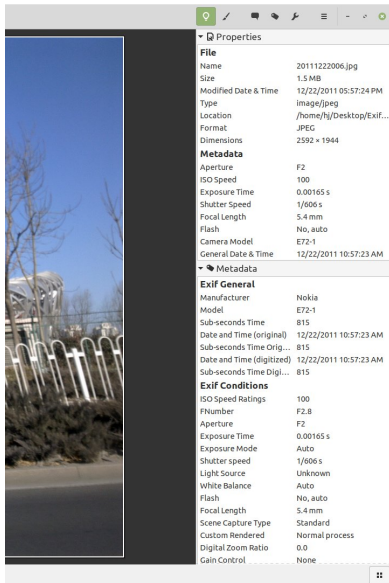


Analysis of the image file

Typically, check EXIF (EXchangeable Image File Format), a metadata.

- Camera brand and model
- Image Processing Software used
- Date/time of last modification
- ...

Example of image metadata



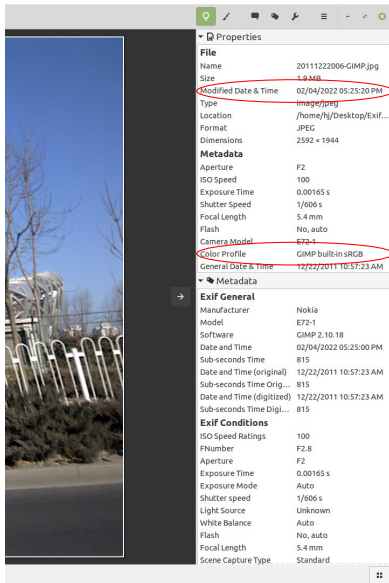
The screenshot shows the GIMP Properties window for the file 20111222006.jpg. The window is divided into three sections: File, Metadata, and Exif. The File section shows the file name, size (1.5 MB), modified date and time (12/22/2011 05:57:24 PM), type (image/jpeg), location (/home/hj/Desktop/Exif...), format (JPEG), and dimensions (2592 x 1944). The Metadata section shows aperture (F2), ISO speed (100), exposure time (0.00165 s), shutter speed (1/606 s), focal length (5.4 mm), flash (No, auto), camera model (E72-1), and general date and time (12/22/2011 10:57:23 AM). The Exif section shows manufacturer (Nokia), model (E72-1), sub-seconds time (815), date and time (original) (12/22/2011 10:57:23 AM), date and time (digitized) (12/22/2011 10:57:23 AM), ISO speed ratings (100), F-number (F2.8), aperture (F2), exposure time (0.00165 s), exposure mode (Auto), shutter speed (1/606 s), light source (Unknown), white balance (Auto), flash (No, auto), focal length (5.4 mm), scene capture type (Standard), custom rendered (Normal process), digital zoom ratio (0.0), and gain control (None).

File	
Name	20111222006.jpg
Size	1.5 MB
Modified Date & Time	12/22/2011 05:57:24 PM
Type	image/jpeg
Location	/home/hj/Desktop/Exif...
Format	JPEG
Dimensions	2592 x 1944

Metadata	
Aperture	F2
ISO Speed	100
Exposure Time	0.00165 s
Shutter Speed	1/606 s
Focal Length	5.4 mm
Flash	No, auto
Camera Model	E72-1
General Date & Time	12/22/2011 10:57:23 AM

Exif General	
Manufacturer	Nokia
Model	E72-1
Sub-seconds Time	815
Date and Time (original)	12/22/2011 10:57:23 AM
Sub-seconds Time Orig...	815
Date and Time (digitized)	12/22/2011 10:57:23 AM
Sub-seconds Time Digi...	815

Exif Conditions	
ISO Speed Ratings	100
FNumber	F2.8
Aperture	F2
Exposure Time	0.00165 s
Exposure Mode	Auto
Shutter speed	1/606 s
Light Source	Unknown
White Balance	Auto
Flash	No, auto
Focal Length	5.4 mm
Scene Capture Type	Standard
Custom Rendered	Normal process
Digital Zoom Ratio	0.0
Gain Control	None



The screenshot shows the GIMP Properties window for the file 20111222006-GIMP.jpg. The window is divided into three sections: File, Metadata, and Exif. The File section shows the file name, size (1.9 MB), modified date and time (02/04/2022 05:25:20 PM), type (image/jpeg), location (/home/hj/Desktop/Exif...), format (JPEG), and dimensions (2592 x 1944). The Metadata section shows aperture (F2), ISO speed (100), exposure time (0.00165 s), shutter speed (1/606 s), focal length (5.4 mm), flash (No, auto), camera model (E72-1), color profile (GIMP built-in sRGB), and general date and time (12/22/2011 10:57:23 AM). The Exif section shows manufacturer (Nokia), model (E72-1), software (GIMP 2.10.18), sub-seconds time (815), date and time (original) (12/22/2011 10:57:23 AM), date and time (digitized) (12/22/2011 10:57:23 AM), ISO speed ratings (100), F-number (F2.8), aperture (F2), exposure time (0.00165 s), exposure mode (Auto), shutter speed (1/606 s), light source (Unknown), white balance (Auto), flash (No, auto), focal length (5.4 mm), and scene capture type (Standard).

File	
Name	20111222006-GIMP.jpg
Size	1.9 MB
Modified Date & Time	02/04/2022 05:25:20 PM
Type	image/jpeg
Location	/home/hj/Desktop/Exif...
Format	JPEG
Dimensions	2592 x 1944

Metadata	
Aperture	F2
ISO Speed	100
Exposure Time	0.00165 s
Shutter Speed	1/606 s
Focal Length	5.4 mm
Flash	No, auto
Camera Model	E72-1
Color Profile	GIMP built-in sRGB
General Date & Time	12/22/2011 10:57:23 AM

Exif General	
Manufacturer	Nokia
Model	E72-1
Software	GIMP 2.10.18
Date and Time	02/04/2022 05:25:00 PM
Sub-seconds Time	815
Date and Time (original)	12/22/2011 10:57:23 AM
Sub-seconds Time Orig...	815
Date and Time (digitized)	12/22/2011 10:57:23 AM
Sub-seconds Time Digi...	815

Exif Conditions	
ISO Speed Ratings	100
FNumber	F2.8
Aperture	F2
Exposure Time	0.00165 s
Exposure Mode	Auto
Shutter speed	1/606 s
Light Source	Unknown
White Balance	Auto
Flash	No, auto
Focal Length	5.4 mm
Scene Capture Type	Standard

Can we trust Exif?

It can be

- easily removed and faked
- missing or incomplete

Authentication and integrity verification

- Active techniques: the acquisition device generates some information added to the digital image.
- Passive techniques: just analyze the digital image as it is, without any a prior information.

Active methods

- Cryptographic Digital **Signature**
 - source side: extract features then generating authentication signature.
 - receiver side: verify image integrity by signature.
- Fragile Digital **Watermarking**
 - source side: add a digital watermark.
 - receiver side: verify watermark integrity.

Passive or blind approaches

I.e. Multimedia forensics.

The key observation:

- **Inherent traces** – characteristic artifacts (i.e. digital fingerprints or footprints) are left behind in a digital media during the creation and any other process.
 - Conventionally, footprints are considered as undesired effects.
 - In multimedia forensics, footprints are considered as an asset.

History of a digital content can be reconstructed by analyzing these traces

Typical tasks of multimedia forensics

- source identification
 - Find the origin.
 - Retrieve information on the source device at different levels.
- integrity verification / tampering detection
 - Has it suffered some processing?
 - Digital tracing.

Source identification

Different level of requirement

- Level 1: which kind of device?
 - scanner, digital camera, phone, webcam, ...
- Level 2: which model of such device?
 - Nikon, Cannon, ...
- Level 3: **which one** of this model?
 - SN10273847, SN122794846, , SN238792387, ...

Acquisition footprints

- Distortion of lens
- Color Filter Array
- Noise
-

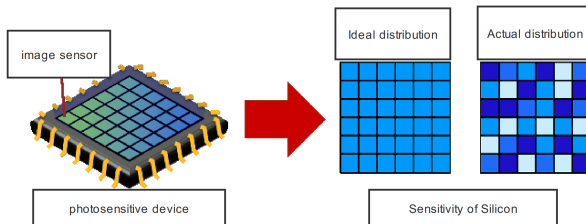
Acquisition footprints

- Distortion of lens
- Color Filter Array
- Noise
-

Noise based source identification

There are many imperfections in the process of acquiring images by a digital camera:

- Random noise.
- Pattern noise.
 - inconsistency of the homogeneity and uniformity of the silicon element of the sensor.



Pattern Noise

Characteristics of pattern noise:

- Not affected by environmental factors, such as temperature and humidity.
- It is a deterministic noise for each camera.

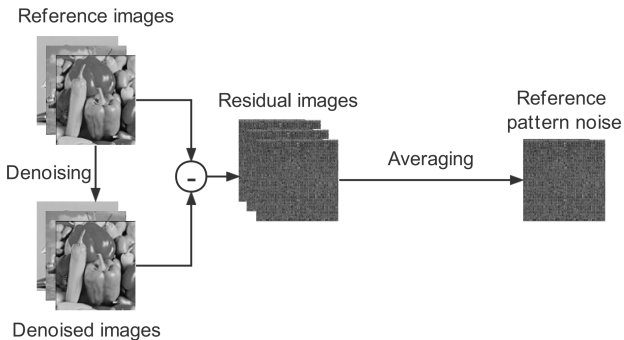
Pattern Noise

Characteristics of pattern noise:

- Not affected by environmental factors, such as temperature and humidity.
- It is a deterministic noise for each camera.

Use it for source identification!

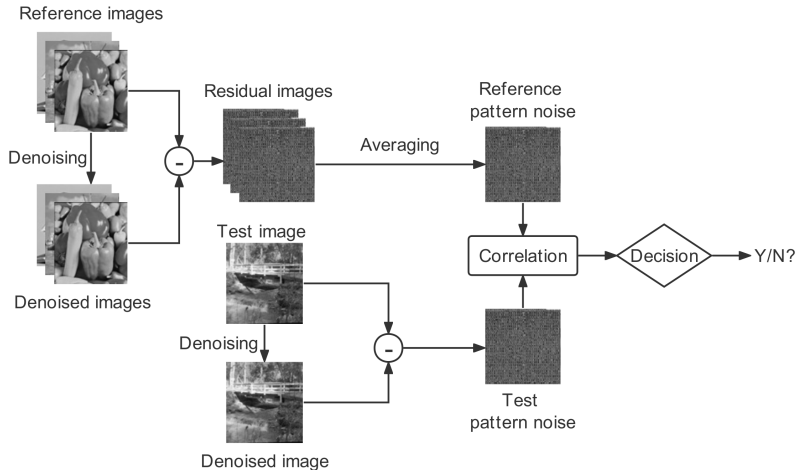
Generate Reference Pattern Noise



Extract reference pattern noise for camera \mathcal{C} :

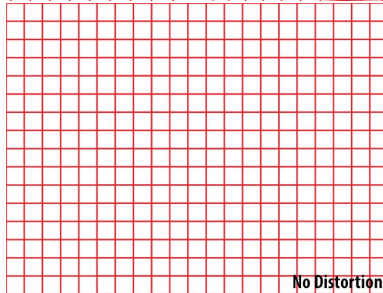
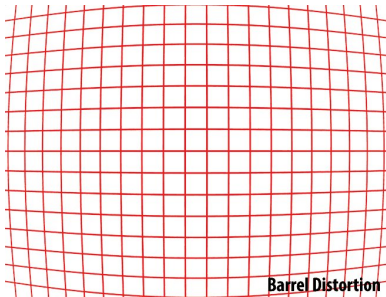
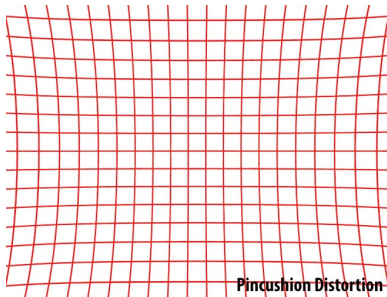
$$N_{ref}^{\mathcal{C}} = \frac{1}{M} \sum_{k=1}^M N_k^{\mathcal{C}}$$

Pipeline



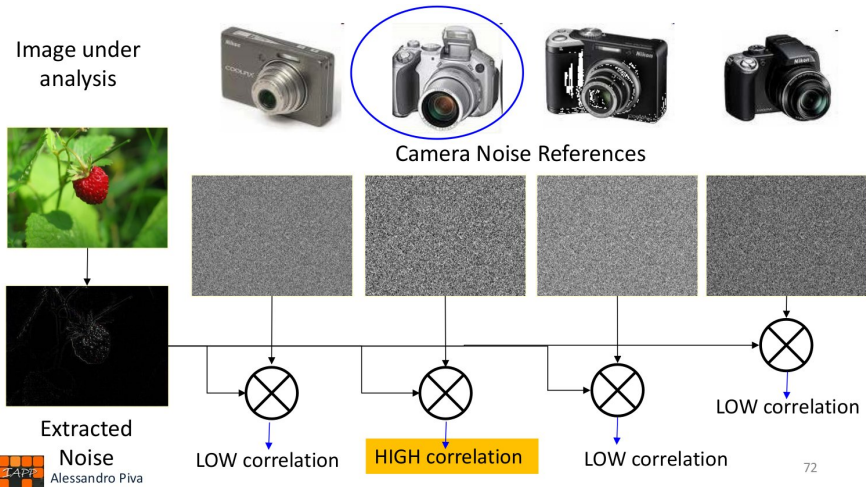
use $z_{cc}(N_{test}, N_{ref}^C)$ to compute their correlation.

Distortion of lens



Noise based source identification

From Alessandro Piva's slides



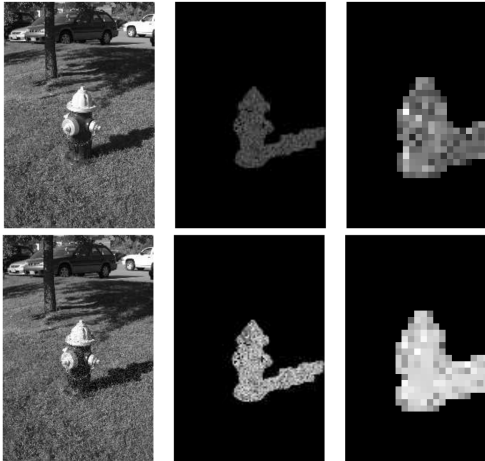
Detection of image splicing

“Statistical Tools for Digital Image Forensics”,
Popescu, 2005.

- copy-paste in a same image
 - by finding similar blocks
- copy-paste between images
 - by consistency of noise

Copy-paste between images

Idea: Noise is different at different regions
Statistical Tools for Digital Image Forensics, Popescu



Noise estimation

Under the additive noise model:

$$y[t] = x[t] + w[t],$$

where the signal x and noise w are independent and zero-mean, and their variances are S and N respectively, i.e.

$$E\{x^2[t]\} = S$$

$$E\{w^2[t]\} = N$$

The moments

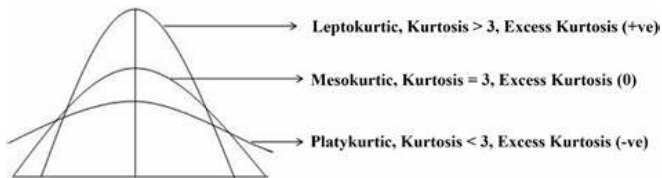
The the second and forth moments:

$$\begin{aligned}M_2 &= E\{y^2[t]\} = \frac{1}{N} \sum_{t=1}^N y^2[t], \\&= E\{x^2[t]\} + 2E\{x[t]w[t]\} + E\{w^2[t]\} \\&= S + N\end{aligned}$$

$$\begin{aligned}M_4 &= E\{y^4[t]\} = \frac{1}{N} \sum_{t=1}^N y^4[t], \\&= E\{x^4[t]\} + 4E\{x^3[t]w[t]\} + 6E\{x^2[t]w^2[t]\} \\&\quad + 4E\{x[t]w^3[t]\} + E\{w^4[t]\} \\&= E\{x^4[t]\} + 6E\{x^2[t]\}E\{w^2[t]\} + E\{w^4[t]\} \\&= \frac{E\{x^4[t]\}}{E\{x^2[t]\}^2} E\{x^2[t]\}^2 + 6E\{x^2[t]\}E\{w^2[t]\} + \frac{E\{w^4[t]\}}{E\{w^2[t]\}^2} E\{w^2[t]\}^2 \\&= k_x S^2 + 6SN + k_w N^2\end{aligned}$$

Kurtosis (peakedness)

$$k_x = \frac{E\{x^4[t]\}}{E\{x^2[t]\}^2}, \quad k_w = \frac{E\{w^4[t]\}}{E\{w^2[t]\}^2}$$



- If x is not Gaussian, i.e. $k_x \neq 3$,
- and $0 \leq (k_y - 3)/(k_x - 3) \leq 1$,

$$\hat{S} = M_2 \sqrt{(k_y - 3)/(k_x - 3)}$$

$$\hat{N} = M_2 \left(1 - \sqrt{(k_y - 3)/(k_x - 3)} \right)$$

Results

From left to right: image, absolute differences (added noise), estimated local noise variance

