Digital Forgery (e non solo…)

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INDIZI: La barba, bocca sono molto sfocati e con una risoluzione molto bassa, mentre i capelli sono più definiti, con risoluzione e contrasto maggiori. Poi al centro della fronte c'è una macchia chiara, che più che un riflesso sembra una pennellata. Identico riflesso del flash (su orecchio destro)

Overview

- What is a Forgery?
  - Using Graphical Software
  - The content has been modified
  - The context has been modified
- Unsupervised method for forgery detection
- Exif Informations
  - Thumbnails Analysis
- The JPEG Standard
- JPEG DCT Techniques
  - Measuring Inconsistencies of Block Artifact
  - Digital Forgeries From JPEG Ghosts
  - Forgery Camera Based

What is a Forgery?

- "Forgery" is a subjective word.
- An image can become a forgery based upon the context in which it is used.

- An image altered for fun or someone who has taken an bad photo, but has been altered to improve its appearance cannot be considered a forgery even though it has been altered from its original capture.

What is a Forgery?

- The other side of forgery are those who perpetuate a forgery for gain and prestige
- They create an image in which to dupe the recipient into believing the image is real and from this be able to gain payment and fame
- Three type of forgery can be identified:
  - An image that is created using **graphical software**
  - An image where the **content** has been altered
  - An image where the **context** has been altered

Computer Forensics A.A. 2010-2011 - Prof. S. Battiato

Using graphical software

Can you to tell which among the array of images are real, and which are CG?

Using graphical software

CG CG REAL CG REAL

CG REAL CG REAL REAL

http://www.autodesk.com/eng/etc/fakeorfoto/about.html

The content has been altered

- Creating an image by altering its content is another method
- Duping the recipient into believing that the objects in an image are something else from what they really are!
- The image itself is not altered, and if examined will be proven as so.

November 1997: After 58 tourists were killed in a terrorist attack at the temple of Hatshepsut in Luxor Egypt, the Swiss tabloid Blick digitally altered a puddle of water to appear as blood flowing from the temple.

The context has been altered

- Objects are be removed or added, for example, a person can be added or removed
- The easiest way is to cut an object from one image and insert it into another image – image editing software makes this a simple task
- By manipulating the content of an image the message can drastically change its meaning.
- An example is this altered image which could be used to influence events in foreign countries which are not aware of manipulation.

INTERNET

Spies turn to high-tech info ops

PCs, Internet used for manipulating images, public opinion

ALTERED IMAGE

BY DANIEL VERTON

Federal intelligence agencies are studying ways to use computers and the Internet, rather than just leaflets and radio broadcasts, to shape and disseminate information designed to sway public opinion in the world's hot spots.

As part of its so-called "perception management" program, the intelligence community has for decades created misinformation to trigger political change without direct political or military involvement in countries where the United States has vested interests, such as Iraq and North Korea.

Acting on congressional recommendations to bolster research and development in information technology, intelligence agencies are turning to PCs to develop more sophisticated means of manipulating and delivering digital photos, video clips and recorded sound to portray fictitious events in hopes of provoking desirable outcomes.

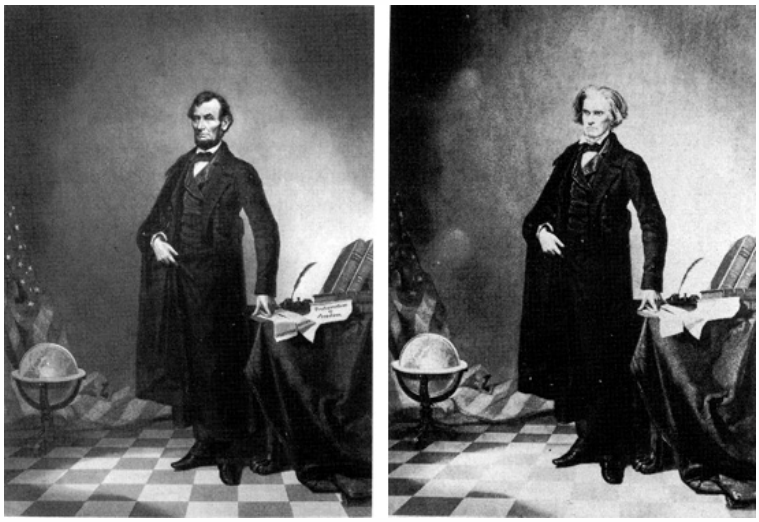
1 2 3

Altered Egos

The top photo, of a fictitious meeting between President Clinton and Saddam Hussein, was generated by digitally altering and combining elements from three photos, shown below the altered image. Intelligence agencies plan to use similar techniques to create images and then disseminate them via the Internet in their efforts to influence events in foreign countries, such as Iraq.

Altering Images

- Altering images is not new – it has been around since the early days of photography
- The concepts have moved into the digital world by virtue of digital cameras and the availability of digital image editing software



circa 1860: This nearly iconic portrait of U.S. President Abraham Lincoln is a composite of Lincoln's head and the Southern politician John Calhoun's body.

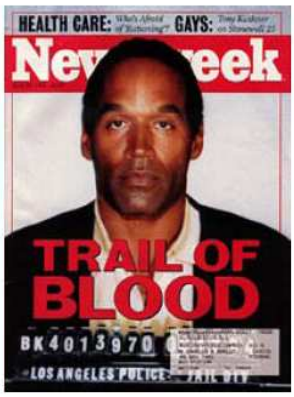
- The ease of use of digital image editing software, which does not require any special skills, makes image manipulation **easy** to achieve.

1930 circa: Stalin ricorreva abitualmente all'aerografo al fine di rimuovere i suoi nemici dalle fotografie. In questa fotografia un commissario venne rimosso dal documento originale.

1937: Nella seguente fotografia Adolf Hitler fece rimuovere Joseph Goebbels (il secondo a destra).

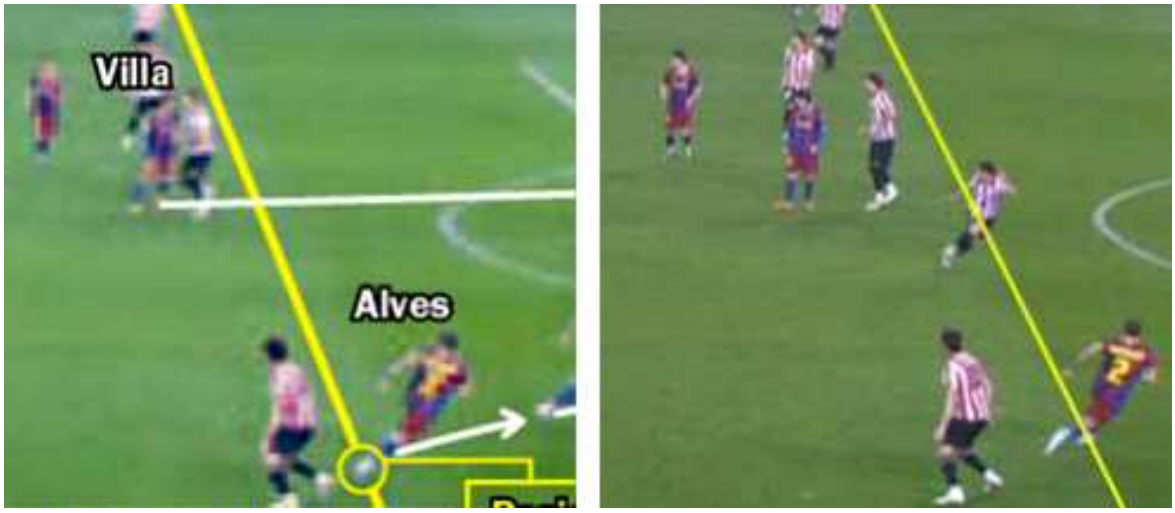

1942: Benito Mussolini fece rimuovere dalla illustrazione originale il soldato che domava il suo cavallo, al fine di rendere più epica la scena che lo ritraeva.

Giugno 1994: Questa fotografia alterata di OJ Simpson venne pubblicata sulla copertina della rivista Time Magazine, subito dopo il suo arresto per omicidio. In effetti la fotografia risultò alterata rispetto all'immagine originale che comparve sulla copertina della rivista Newsweek. La rivista Time venne accusata di aver manipolatolo fotografia al fine di rendere la figura di Simpson più scura e minacciosa.



Aprile 2003: Questa composizione di un soldato Inglese a Basra, che gesticola verso un civile iracheno indicandogli di restare coperto, è apparsa sulla copertina del Los Angeles Times, subito dopo l'invasione dell'Iraq. Brian Walski, un fotografo dello staff del Los Angeles Times e un veterano della notizia con trenta anni di esperienza alle spalle, è stato licenziato in tronco dal suo editore per aver fuso due dei suoi scatti al fine di migliorare la composizione.

Off-side (Febbraio 2011)



Altri esempi famosi
www.cs.dartmouth.edu/farid/research/digitaltampering

Nel vecchio mondo della fotografia analogica, un'immagine era, in genere, considerata una prova d'evidenza attendibile.

E' possibile utilizzare tecniche per la detection automatica di eventuali manipolazioni "**maliziose**" delle immagini digitali?

Allo stato attuale non esistono tecniche **automatiche "perfette"** che permettono l'esatta individuazione di manomissioni delle immagini digitali. Per questo motivo le fotografie digitali non sono, in genere, attendibili ai fini di prove d'evidenza, se non con i dovuti accorgimenti "formali" e "procedurali".

Obiettivo della ricerca scientifica in questo settore è quello di individuare tecniche automatiche o quantomeno semi-automatiche in grado di scovare opportunamente tali problemi.

Digital Forgery

- E' stato coniato il termine "*Photoshopping*" per denotare l'azione volta a falsificare digitalmente medicine, scene di guerra, ed in generale immagini digitali di qualsiasi natura ("Photoshop Forensic", Cynthia Baron 2008).

Digital Forgery

(a) Original

(b) Forgery

(d) Tampered region, TIFF

(f) Tampered region, JPEG 90

Digital Forgery

G2 Original

G2 Forgery

Regions detected as forged

How does it work?

- Pixel-based
  - Cloning, Resampling, Splicing
  - Statistical
- **Camera Based**
  - Chromatic Aberration
  - ***Color Filter Array***
  - ***Camera Response***
  - ***Sensor Noise***
- **Format Based (JPEG,)**
- Physics based
  - Light Direction, Light Environment
- Geometric Based
  - Principal Point

Copy-Paste Forgery

The Copy and Paste forgery detection is mainly based on the research of blocks which looks like repeated into the image. If the amount of adjacent repeated blocks are higher than an heuristic threshold the region is likely to be altered.

Original

Forgery

Result

Resampling

Al fine di generare una contraffazione convincente, molto spesso si ricorre ad operazioni di ***ridimensionamento***, ***rotazioni***, ***oppure deformazioni di porzioni di immagini***. Per esempio quando si crea un fotomontaggio con due persone, una delle due deve essere manipolata per raggiungere dimensioni compatibili con la risoluzione dell'altra.

Questo procedimento richiede di **ricampionare** l'immagine di partenza in una nuova griglia di destinazione, generando in questo modo delle correlazioni periodiche nei dintorni dei pixel manomessi. La presenza di queste ***correlazioni***, normalmente **inesistenti**, è utilizzata per individuare questo tipo di manomissione

Un esempio reale (2006)

Camera-based

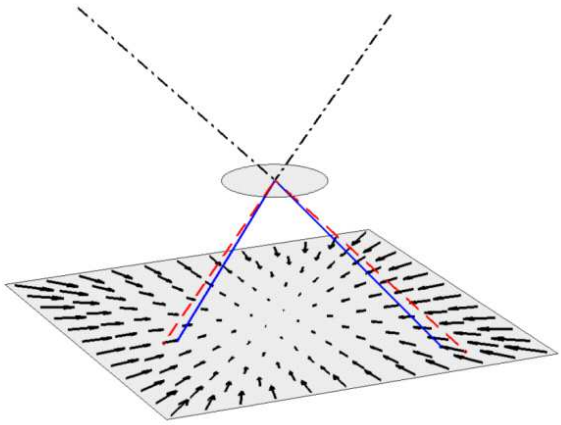
Le scanalature impresse dalle canne delle pistole sui proiettili collegano, con un certo grado di confidenza, una pallottola ad una ben determinata arma da fuoco.

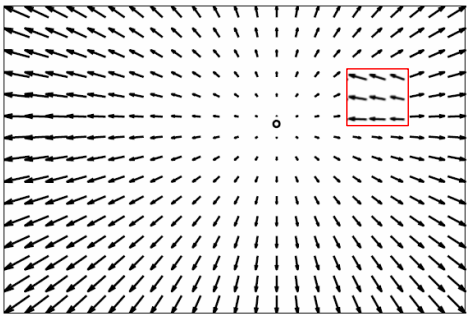
Sfruttando la stessa filosofia, sono state sviluppate delle tecniche di digital forensics che, basandosi su determinati ***artefatti*** introdotti dai vari stadi dell'elaborazione dell'immagine all'interno delle fotocamere, determinano un collegamento **univoco** tra fotocamera e immagine.

Chromatic Aberration

The refraction of light in two dimensions. Polychromatic light enters the lens and emerges at an angle which depends on wavelength.

As a result, different wavelengths of light, two of which are represented as the red (dashed) and the blue (solid) rays, will be imaged at different points. The vector field shows the amount of deviation across the image.





Light Direction

- Shown on the left are three forgeries: the ducks, swans, and football coach were each added into their respective images.
- Shown on the right are the analyzed regions superimposed in white, and spheres rendered from the estimated lighting coefficients.

Format Based:JPEG

La prima regola fondamentale dell'indagine forense è ovviamente quella della conservazione dei dati originali. Per questo motivo la compressione lossy delle immagini JPEG può essere considerata il peggior nemico dell'analista forense.

Il caso vuole che proprio questa caratteristica, di "perdita dei dati", sia utilizzata come ottimo strumento per l'individuazione delle manomissioni.

The JPEG Standard

- JPEG stands for an image compression stream of bytes;
- JFIF (JPEG File Interchange Format) stands for a standard which define:
  - Component sample registration
  - Resolution and aspect ratio
  - Color Space
- ***ExIF*** allows to integrate further information into the file

EXIF: some Details

Exchangeable image file format (Exif) is a standard that specifies the formats for images, sound, and ancillary tags used by digital cameras (including smartphones), scanners and other systems handling image and sound files recorded by digital cameras.

The specification uses the following existing file formats with the addition of specific metadata tags: JPEG DCT for compressed image files, TIFF for uncompressed image files, and RIFF WAV for audio files. It is not supported in JPEG 2000, PNG, or GIF.

This standard consists of the Exif image file specification and the Exif audio file specification.

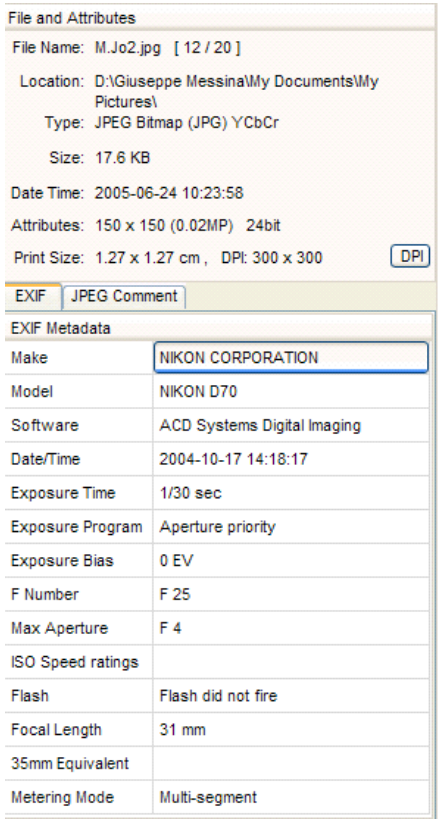
Source Wikipedia

Exif Informations

- ExIF allows to integrate further information into the file.The information usually contained into a standard ExIF are:
  - Dimensions of the image
  - Date and Time of Acquisition
  - Features about acquisition:
    - Exposure-time , Exposure Bias, F-Number, Aperture, ISO, Focal lenght, GPS coordinates etc.
  - Thumbnail preview (a small picture which would be equal to the original picture).

- ***The ExIF information checking has demonstrated the possibility of immediate forgery detection.***

- If the camera maker is known several ExIF data **must** match to fixed values.



Thumbnail

La maggior parte delle fotocamere memorizza negli EXiF data un thumbnail (in JPEG) dell'intera immagine ad utilizzare per preview veloci.

Che succede in caso di forgery (malizioso o meno)?

Thumbnails Analysis

Thumbnail
Original
Size

- Using the following image we can extract the thumbnail through simple ExiF tools, web sites or open source codes, like:
  - **Opanda IExif** (http://www.opanda.com)
  - **Camera Summary** (http://camerasummary.com/)
  - **Jeffrey's Exif Viewer** (http://regex.info/exif.cgi)
  - **JPEGSnoop** (http://www.impulseadventure.com/photo/jpeg-snoop.html)
  - **Jhead version** (http://www.sentex.net/~mwandel/jhead/)
- These tools permit to identify data that have not been removed by inexpert users.

Source Camera Identification

On the most obvious and simplest level, one could inspect the **Electronic File** itself and look for clues in headers or any other attached or associated information. For instance, the **EXIF** header contains information about the digital camera type and the conditions under which the image was taken (exposure, date and time, etc.).

It is important to note that metadata can be easily manipulated ;(

See also:

Eric Kee, Micah K. Johnson and Hany Farid -Digital Image Authentication from JPEG Headers (2011) IEEE TIFS to appear

Thumbnails Analysis

- Furthermore the Exif analysis permits to extract (if present) a further detailed preview of the image which is placed at the end of the JPEG file, and is present only in High-end Cameras.
- This preview is much more detailed and permit also to identify persons.

Thumbnail
Original Size

Casi Famosi

Cat Schwartz

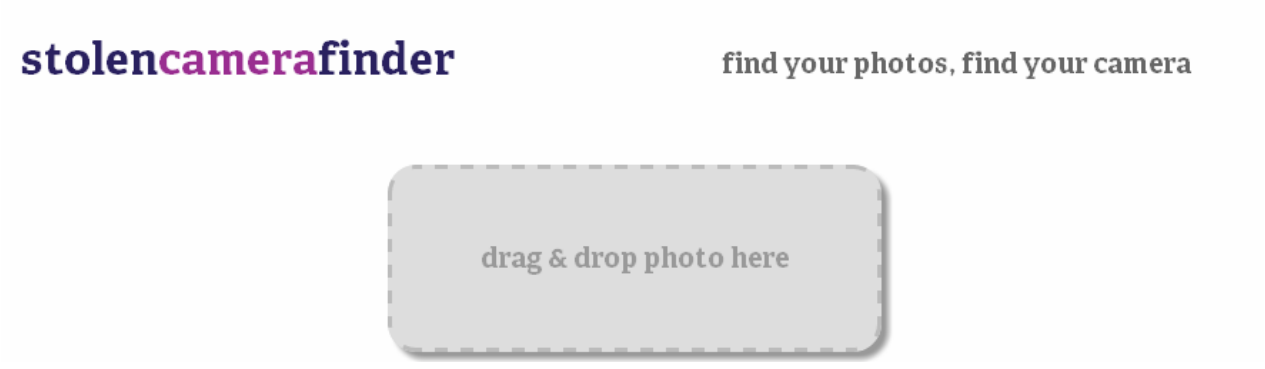
http://www.welcometowallyworld.com/cat-schwartz/

Unsupervised Exif Analyzer

- http://no.spam.ee/~tonu/exif
- EXIF Phun by ascii (www.ush.it)

EXif for Stolen Camera

Many cameras save serial number information in the EXIF data of every photo you take.

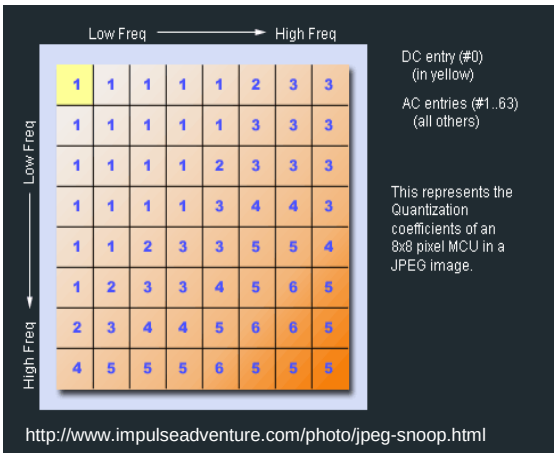


JPEG: La Quantizzazione

- La maggior parte delle macchine fotografiche digitali memorizzano gli scatti in formato JPEG. Questo schema di compressione lossy permette di stabilire, in qualche modo, un "**grado**" di compressione dei dati. Di solito, sono i produttori di fotocamere a stabilire i differenti "**gradi**" di compressione selezionabili, in funzione a statistiche che bilanciano qualità e dimensioni finali dei files.
- Queste differenze possono essere utilizzate per identificare la sorgente (Modello di fotocamera, produttore) di un'immagine.

JPEG as Source Camera Identification

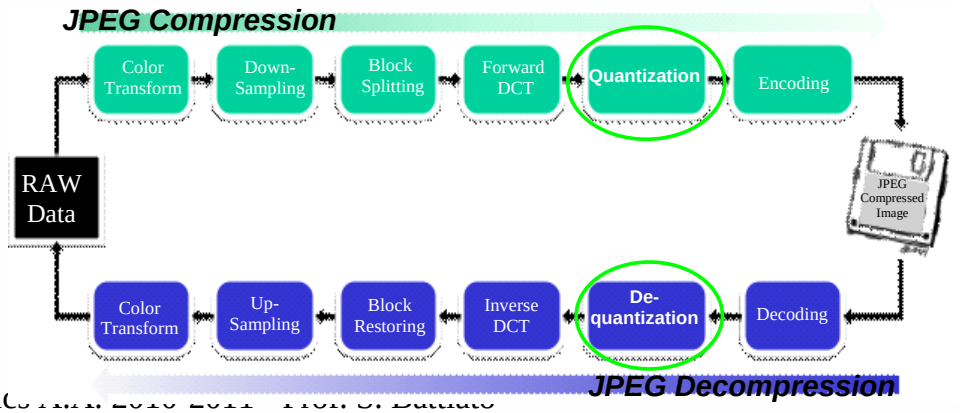
Additional information can be obtained from the **Quantization Table** in the **JPEG** header. This header data, however, may **not be available** if the image is **Resaved** in a different format or recompressed.



Another problem is the **Credibility** of information that can be easily replaced.

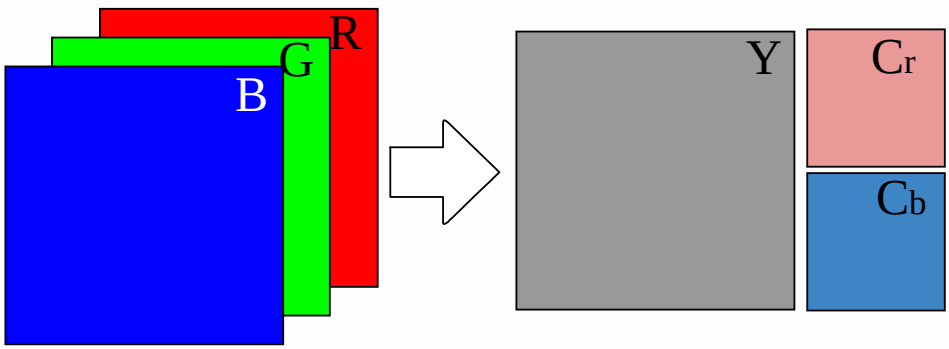
JPEG Compression

- Converting an image into JPEG is a six step process:
  - The image is converted from raw **RGB data into YCbCr**;
  - A **downsampling** is performed on chrominance channels;
  - The channels are splitted into **8x8 blocks**;
  - A **Discrete Cosine Transform** is applied;
  - The DCT coefficient are **Quantized** (lossy) using fixed tables;
  - Finally an entropy coding (lossless **compression**) is applied and the image is said to be JPEG compressed

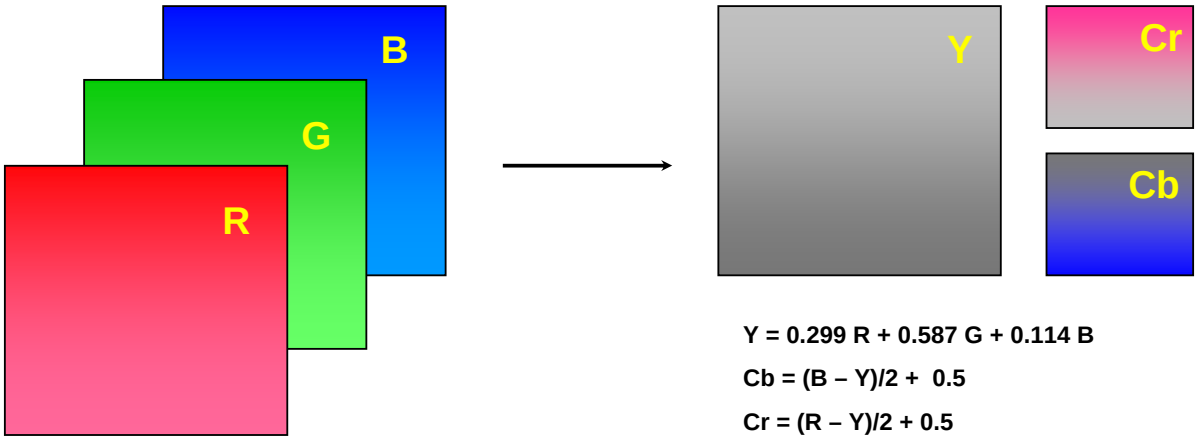


Color Conversion & Downsampling

- First, the image is converted from **RGB** into a different colors pace called **YCbCr**.
- The Y component represents the brightness of a pixel, the Cb and Cr components represent the chrominance (split into blue and red components).
- The Cr and Cb components are usually downsampled because, due to the densities of color- and brightness-sensitive receptors in the human eye, humans can see considerably more fine detail in the brightness of an image (the Y component) than in the color of an image (the Cb and Cr components).



Color Transform



$Y = 0.299\ R + 0.587\ G + 0.114\ B$

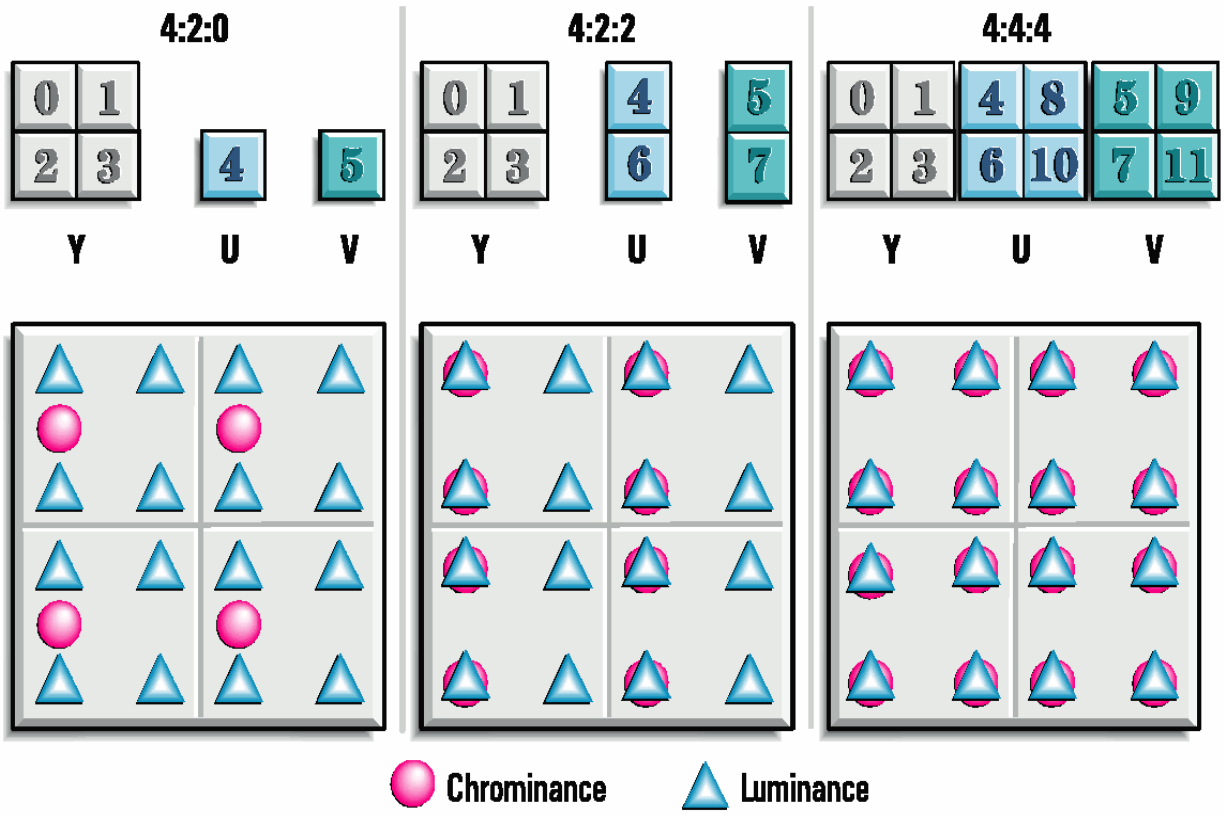
$Cb = (B - Y)/2 + 0.5$

$Cr = (R - Y)/2 + 0.5$

The human eye is more sensitive to luminance than to chrominance. Typically JPEG throw out $^3/_4$ of the chrominance information before any other compression takes place. This reduces the amount of information to be stored about the image by $^1/_2$. With all three components fully stored, 4 pixels needs 3 x 4 = 12 component values. If $^3/_4$ of two components are discarded we need 1 x 4 + 2 x 1 = 6 values.

Example:

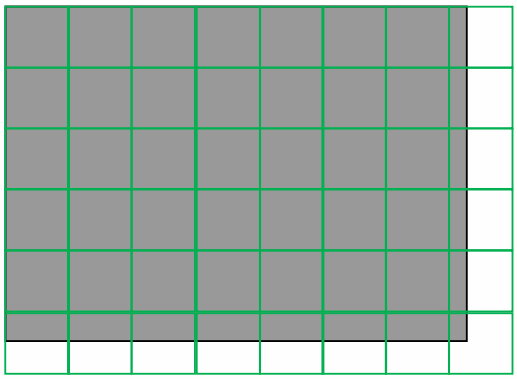
Chrominance subsampling



Blocks 8x8

- After subsampling, each channel must be split into **8x8 blocks** of pixels.

- If the data for a channel does not represent an integer number of blocks then the encoder must fill the remaining area of the incomplete blocks with some form of dummy data.



Discrete Cosine Transform

- Next, each component (Y, Cb, Cr) of each 8×8 block is converted to a frequency-domain representation, using a normalized, two-dimensional type-II discrete cosine transform (DCT).

- As an example, one such 8×8 8-bit subimage might be:

52	55	61	66	70	61	64	73
63	59	55	90	109	85	69	72
62	59	68	113	144	104	66	73
63	58	71	122	154	106	70	69
67	61	68	104	126	88	68	70
79	65	60	70	77	68	58	75
85	71	64	59	55	61	65	83
87	79	69	68	65	76	78	94

- Before computing the DCT of the subimage, its gray values are shifted from a positive range to one centered around zero.
- For an 8-bit image each pixel has 256 possible values: [0,255]. To center around zero it is necessary to subtract by half the number of possible values, or 128.

$$\frac{2^{bit}}{2} = \frac{2^8}{2} = 2^7 = 128$$

Discrete Cosine Transform

- Subtracting 128 from each pixel value yields pixel values on [-128,127] and we obtain the following matrix.

$x \rightarrow$

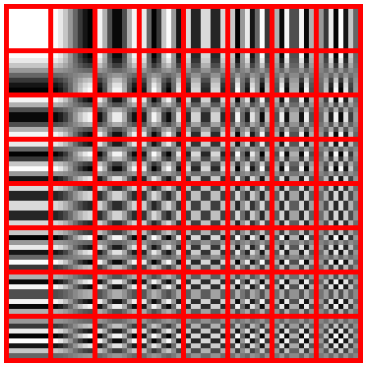
$$\begin{bmatrix} -76 & -73 & -67 & -62 & -58 & -67 & -64 & -55 \\ -65 & -69 & -73 & -38 & -19 & -43 & -59 & -56 \\ -66 & -69 & -60 & -15 & 16 & -24 & -62 & -55 \\ -65 & -70 & -57 & -6 & 26 & -22 & -58 & -59 \\ -61 & -67 & -60 & -24 & -2 & -40 & -60 & -58 \\ -49 & -63 & -68 & -58 & -51 & -60 & -70 & -53 \\ -43 & -57 & -64 & -69 & -73 & -67 & -63 & -45 \\ -41 & -49 & -59 & -60 & -63 & -52 & -50 & -34 \end{bmatrix} \quad y \downarrow$$

- The next step is to take the two-dimensional DCT, which is given by:

$$G_{u,v} = \alpha(u)\alpha(v) \sum_{x=0}^{7} \sum_{y=0}^{7} g_{x,y} \cos\left[\frac{\pi}{8}\left(x + \frac{1}{2}\right) u\right] \cos\left[\frac{\pi}{8}\left(y + \frac{1}{2}\right) v\right]$$

where

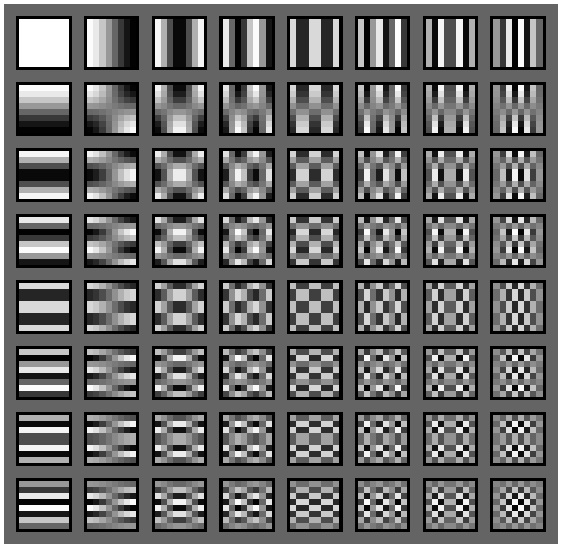
- u is the horizontal spatial frequency, for the integers $0 \leq u < 8$.
- v is the vertical spatial frequency, for the integers $0 \leq v < 8$.
- $\alpha_p(n) = \begin{cases} \sqrt{\frac{1}{8}}, & \text{if } n = 0 \\ \sqrt{\frac{2}{8}}, & \text{otherwise} \end{cases}$ is a normalizing function
- $g_{x,y}$ is the pixel value at coordinates (x, y)
- $G_{u,v}$ is the DCT coefficient at coordinates (u, v)



The DCT transforms 64 pixels to a linear combination of these 64 squares. Horizontally is *u* and vertically is *v*.

DCT basis

The 64 (8 x 8) DCT basis functions:



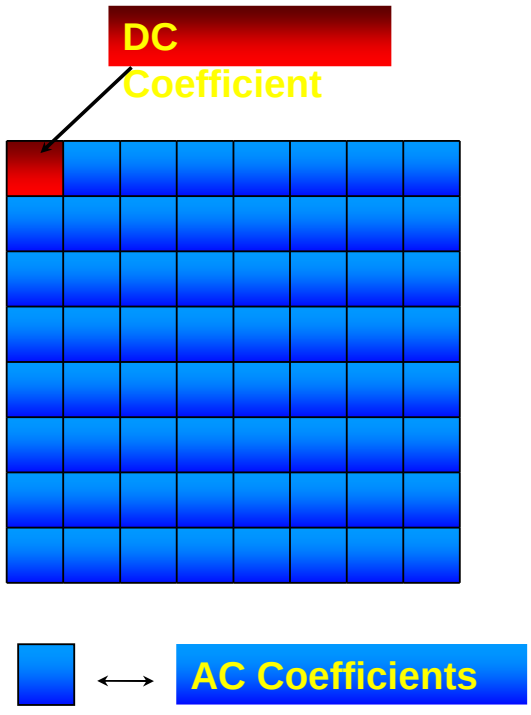
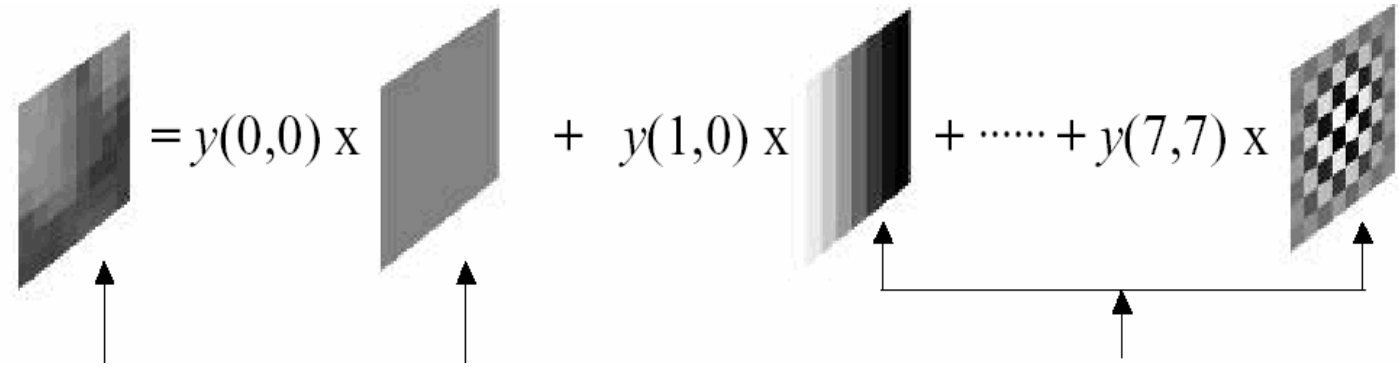


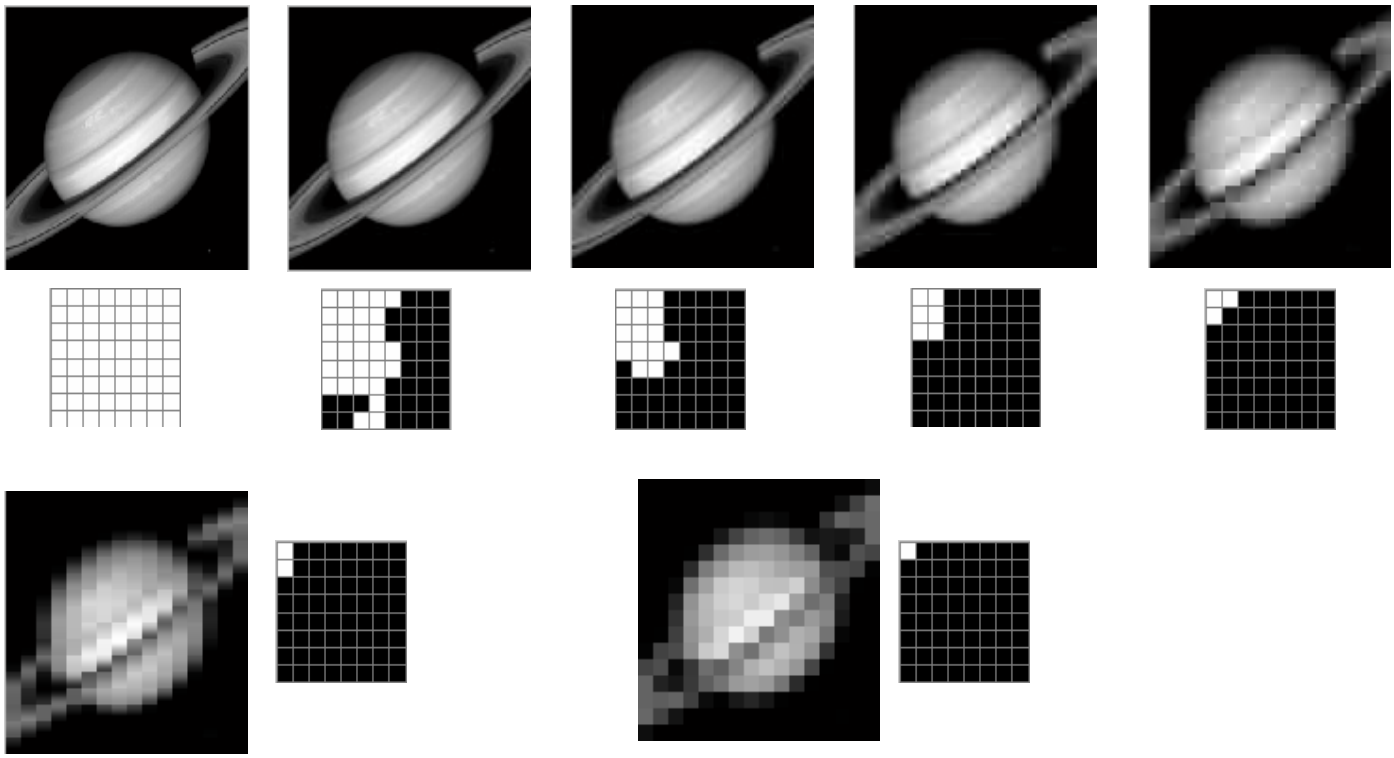
Image Representation with DCT

DCT coefficients can be viewed as weighting functions that, when applied to the 64 cosine basis functions of various spatial frequencies (8 x 8 templates), will reconstruct the original block.



Original image block **DC** (flat) basis function **AC** basis functions

DCT example



DCT Coefficients Quantization

- **The DCT coefficients are quantized to limited number of possible levels.**
- **The Quantization is needed to reduce the number of bits per sample.**

Example:

101000 = 40 (6 bits precision) ® Truncates to 4 bits = 1000 = 8 (4 bits precision).

i.e. 40/5 = 8, there is a constant N=5, or the *quantization or quality factor* .

Formula:

$$F(u,v) = \text{round}[F(u,v) / Q(u,v)]$$

– Q(u, v) = constant => Uniform Quantization.

– Q(u, v) = variable => Non-uniform Quantization.

Standard Q-tables

Eye is most sensitive to low frequencies (upper left corner), less sensitive to high frequencies (lower right corner)

Luminance Quantization Table Table

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

Chrominance Quantization

17	18	24	47	99	99	99	99
18	21	26	66	99	99	99	99
24	26	56	99	99	99	99	99
47	66	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99

The numbers in the above quantization tables can be scaled up (or down) to adjust the so called **Quality Factor QF.** (i.e. $Q^*(u,v) = QF \times Q(u,v)$)

Custom quantization tables can also be put in image/scan header.

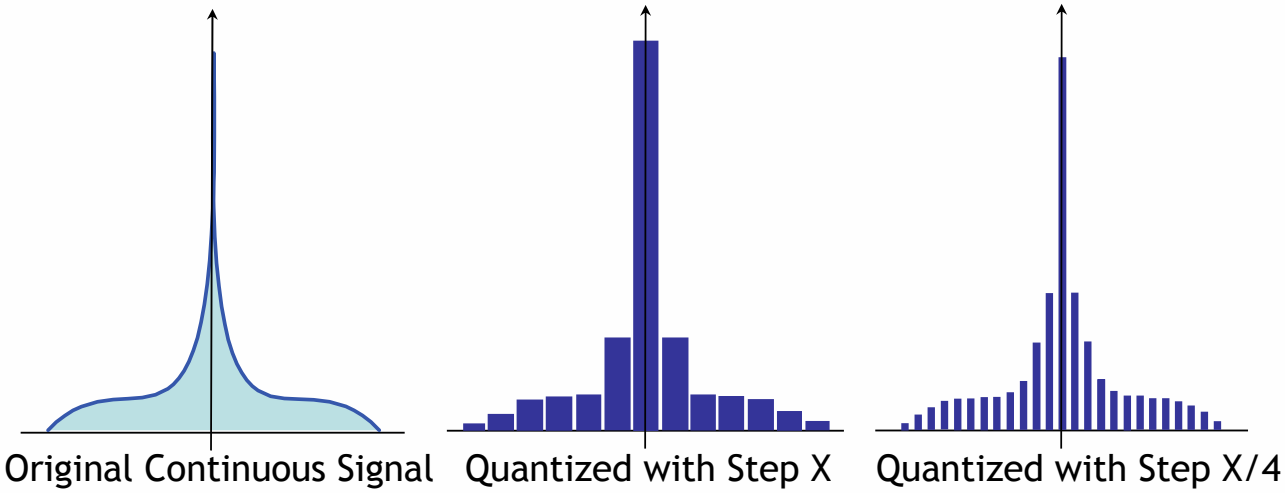
Quantized DCT

$$X = \begin{bmatrix} 168 & 161 & 161 & 150 & 154 & 168 & 164 & 154 \\ 171 & 154 & 161 & 150 & 157 & 171 & 150 & 164 \\ 171 & 168 & 147 & 164 & 164 & 161 & 143 & 154 \\ 164 & 171 & 154 & 161 & 157 & 157 & 147 & 132 \\ 161 & 161 & 157 & 154 & 143 & 161 & 154 & 132 \\ 164 & 161 & 161 & 154 & 150 & 157 & 154 & 140 \\ 161 & 168 & 157 & 154 & 161 & 140 & 140 & 132 \\ 154 & 161 & 157 & 150 & 140 & 132 & 136 & 128 \end{bmatrix} \quad Q = \begin{bmatrix} 16 & 11 & 10 & 16 & 24 & 40 & 51 & 61 \\ 12 & 12 & 14 & 19 & 26 & 58 & 60 & 55 \\ 14 & 13 & 16 & 24 & 40 & 57 & 69 & 56 \\ 14 & 17 & 22 & 29 & 51 & 87 & 80 & 62 \\ 18 & 22 & 37 & 56 & 68 & 109 & 103 & 77 \\ 24 & 35 & 55 & 64 & 81 & 104 & 113 & 92 \\ 49 & 64 & 78 & 87 & 103 & 121 & 120 & 101 \\ 72 & 92 & 95 & 98 & 112 & 100 & 103 & 99 \end{bmatrix}$$

$$Y = \begin{bmatrix} 214 & 49 & -3 & 20 & -10 & -1 & 1 & -6 \\ 34 & -25 & 11 & 13 & 5 & -3 & 15 & -6 \\ -6 & -4 & 8 & -9 & 3 & -3 & 5 & 10 \\ 8 & -10 & 4 & 4 & -15 & 10 & 6 & 6 \\ -12 & 5 & -1 & -2 & -15 & 9 & -5 & -1 \\ 5 & 9 & -8 & 3 & 4 & -7 & -14 & 2 \\ 2 & -2 & 3 & -1 & 1 & 3 & -3 & -4 \\ -1 & 1 & 0 & 2 & 3 & -2 & -4 & -2 \end{bmatrix} \quad Z = \begin{bmatrix} 13 & 4 & 0 & 1 & 0 & 0 & 0 & 0 \\ 3 & -2 & 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}.$$

$$z_{ij} = round(y_{ij} / q_{ij})$$

Quantization



- The Quantization is usually used to convert continuous signal to a discrete space.
- In the example above we have processed a continuous signal , by using a larger quantization step X (thus reducing drastically the numbers of samples), and a smaller step X/4 which introduce more samples and is much more similar to the continuous signal.

Quantization Tables

- A typical quantization matrix, as specified in the original JPEG Standard, is as follows:

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

- The quantized DCT coefficients are computed with

$$B_{j,k} = \text{round}\left(\frac{G_{j,k}}{Q_{j,k}}\right) \quad \text{for } j = 0, 1, 2, \cdots, N_1 - 1; k = 0, 1, 2, \cdots, N_2 - 1$$

where G is the unquantized DCT coefficients; Q is the quantization matrix above; and B is the quantized DCT coefficients.

- Using this quantization matrix with the DCT coefficient matrix from above results in:
  For example, using -415 (the DC coefficient) and rounding to the nearest integer

$$\text{round}\left(\frac{-415}{16}\right) = \text{round}\left(-25.9375\right) = -26$$

−26	−3	−6	2	2	−1	0	0
0	−2	−4	1	1	0	0	0
−3	1	5	−1	−1	0	0	0
−4	1	2	−1	0	0	0	0
1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Quantization Tables

- The standard fixes that each image must have between one and four quantization tables.
- The most commonly used quantization tables are those published by the Independent JPEG Group (IJG) in 1998.
- These tables can be scaled to a quality factor Q.
- The quality factor allows the image creation device to choose between:
  - Larger, higher quality images
  - Smaller, lower quality images.

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

17	18	24	47	99	99	99	99
18	21	26	66	99	99	99	99
24	26	56	99	99	99	99	99
47	66	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99

Quantization Tables

- For example, we can scale the IJG standard table using Q=80 by applying Eq. (2) to each element in the table. The resulting values are the following scaled quantization tables

6	4	4	6	10	16	20	24
5	5	6	8	10	23	24	22
6	5	6	10	16	23	28	22
6	7	9	12	20	35	32	25
7	9	15	22	27	44	41	31
10	14	22	26	32	42	45	37
20	26	31	35	41	48	48	40
29	37	38	39	45	40	41	40

7	7	10	19	40	40	40	40
7	8	10	26	40	40	40	40
10	10	22	40	40	40	40	40
19	26	40	40	40	40	40	40
40	40	40	40	40	40	40	40
40	40	40	40	40	40	40	40
40	40	40	40	40	40	40	40
40	40	40	40	40	40	40	40

- Note that the numbers in this table are lower than in the standard table, indicating an image compressed with these tables will be of higher quality than ones compressed with the standard table. It should be noted that scaling with Q=50 does not change the table.

Quantization Tables

- The different QT could be classified into the following categories:
  - **Standard Tables**:
    Images which use scaled versions of the QT published by Independent JPEG Group (IJG) standard;
  - **Extended Tables**:
    Same as Standard Tables but have three tables instead of two. The third table is a duplicate of the second;
  - **Custom Fixed Tables**:
    Images containing non-IJG QT that do not depend on the image being processed (Adobe Photoshop);
  - **Custom Adaptive Tables**:
    These images do not conform to the IJG standard. In addition, they may change, either in part or as a whole, between images created by the same device using the same settings. They may also have constants in the tables; values that do not change regardless of the quality setting or image being processed.

Quantization Tables For Ballistics

"Considering only QT is not sufficient to discriminate between different source cameras, but it could be useful to clearly indentify altered images."

Forgeries Indentification through DCT

- The research activity in such area has started through the analysis of correlations between QT and DCT coefficients.
- Two techniques are under investigation regarding such aspect:
  - Detecting Forgeries by **Measuring Inconsistencies of Block Artifact;**
  - Exposing Digital Forgeries From **JPEG Ghosts** (under study);

Measuring Inconsistencies of Block Artifact

- As manufacturers typically use different JPEG QT to balance compression ratio and image quality, the blocking artifact introduced in the images could be different.
- When creating forgeries, the resulted tampered image may inherit different kind of compression artifacts from different sources.
- These inconsistencies, if detected, could be used to check image integrity.

DCT histograms anomalies

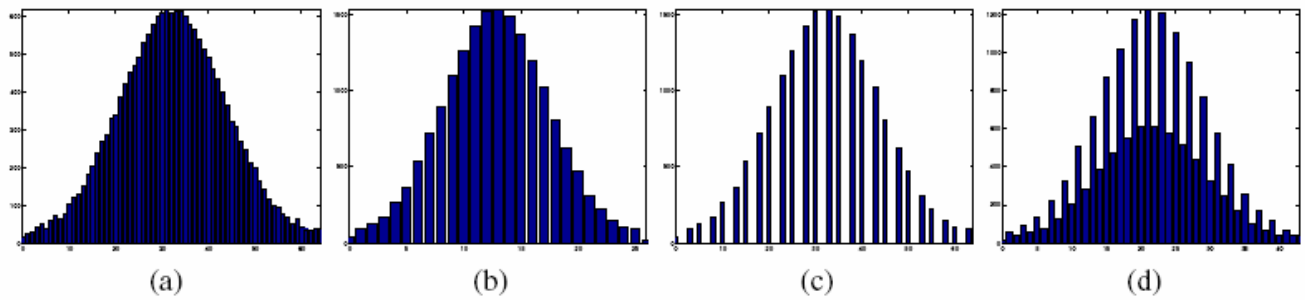


Fig. 4. The left two figures are histograms of single quantized signals with steps 2 (a) and 5 (b). The right two figures are histograms of double quantized signals with steps 5 followed by 2 (c), and 2 followed by 3 (d). Note the periodic artifacts in the histograms of double quantized signals.

Estimated Quantization Table

1	1	1	1	1	1	1	2
1	1	1	1	1	1	1	2
1	1	1	1	1	1	2	2
1	1	1	1	1	2	2	3
1	1	1	1	2	2	3	3
1	1	1	2	2	3	3	3
1	1	2	2	3	3	3	3
2	2	2	3	3	3	3	3

Original QT

2	1	1	1	1	1	3	2
1	1	1	1	1	3	3	1
1	1	1	1	2	3	1	1
1	1	1	1	3	3	3	3
1	1	1	3	1	1	3	3
1	1	3	1	3	4	4	4
1	3	4	3	5	4	6	4
3	1	1	4	4	4	4	4

Estimated QT

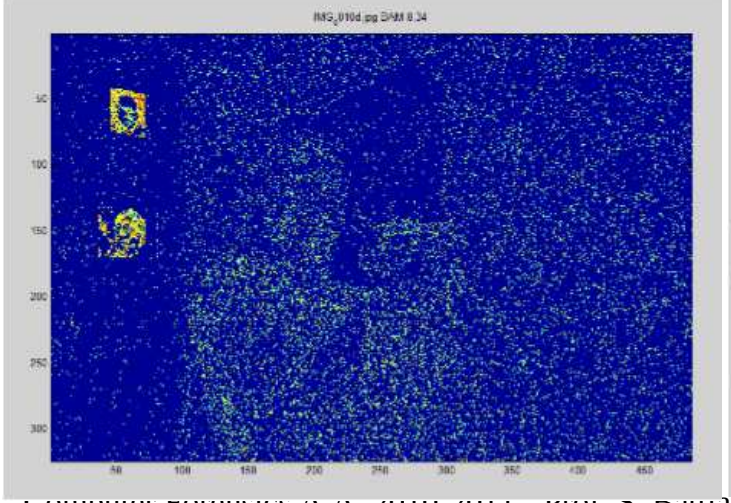
1	0	0	0	0	0	2	0
0	0	0	0	0	2	2	-1
0	0	0	0	1	2	-1	-1
0	0	0	0	2	1	1	0
0	0	0	2	-1	-1	0	0
0	0	2	-1	1	1	1	1
0	2	2	1	2	1	3	1
1	-1	-1	1	1	1	1	1

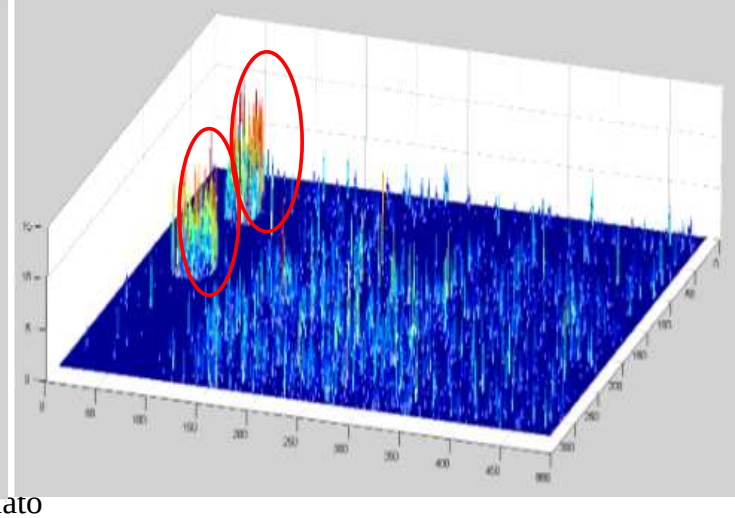
Differences between the two tables.

- Here is an example of estimated quantization table onto a Canon 400D tampered image.
- Some slight differences have been found in the Estimated Q-Table.

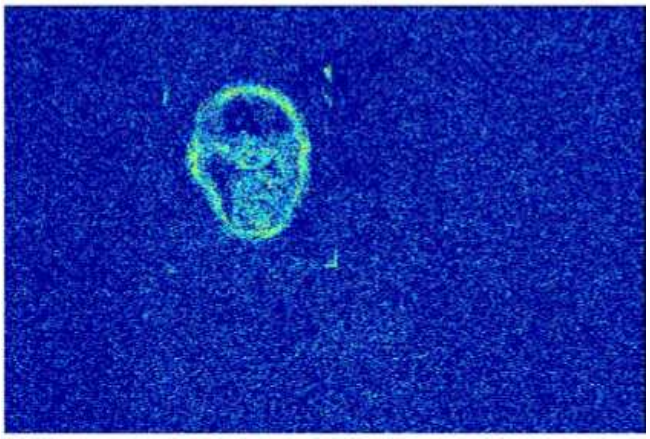
Results 1/4

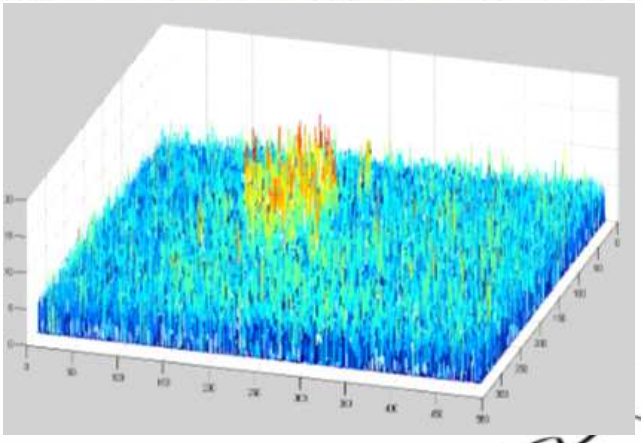
- By taking into account such anomalies the following error map has been generated.
- The map clearly underlined the part of the image that contain forgeries (max value 14.7).





Results 2/4

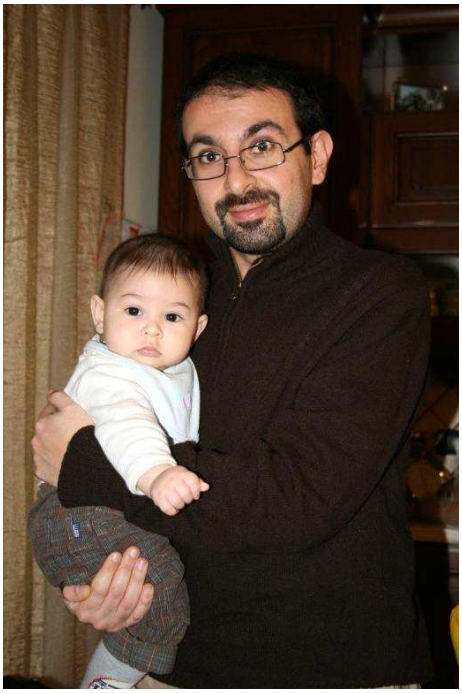




- In this experiment we have taken a face from a different (downsampled image) we have removed the background of the picture and pasted it over the original face.
- During the process of cancelling the background the corners have been coarsely removed, as visible in the error map (max value 18.3).

Results 3/4

Original Images

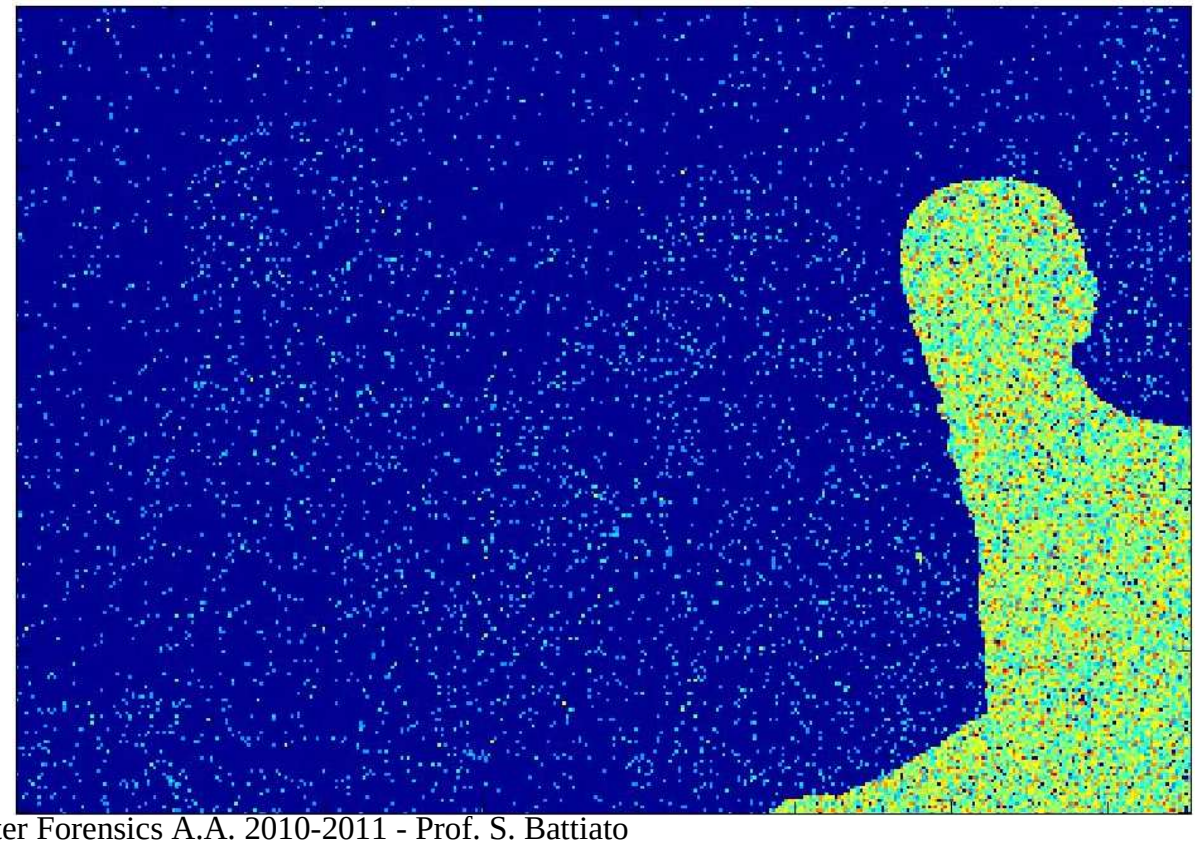


Results 3/4

Tampered Image

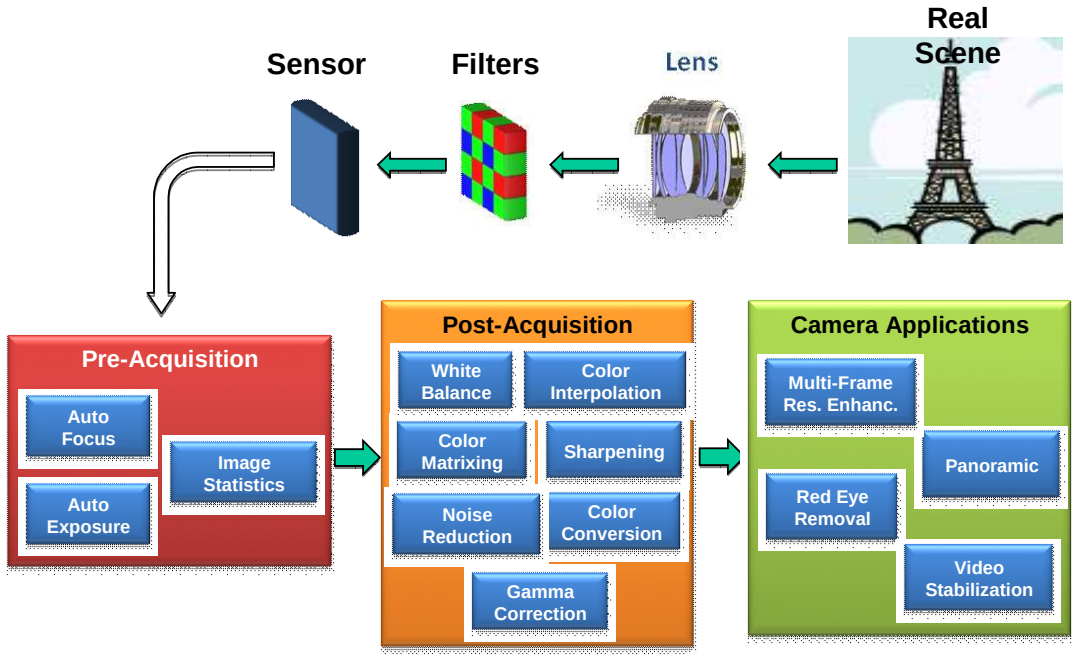
Results 3/4

Estimated Map.



Digital Camera Identification: Camera based methods

Typical Imaging Pipeline



Data coming from the sensor (in Bayer format) are first analyzed to collect useful statistics for parameters setting (pre-acquisition) and then properly processed in order to obtain, at the end of the process, a compressed RGB image of the acquired scene (post-acquisition and camera applications).

Camera identification

Reliable identification of the device used to acquire a particular digital image is especially prove useful in the court for establishing the origin of images presented as evidence.

Forensic methods capable of determining that two clips came from the same camcorder or that two transcoded versions of one movie have a common source will obviously help investigators draw connections between different entities or subjects and may become a crucial piece of evidence in prosecuting the *pirates*.

Reliable, inexpensive, and fast identification of the source of digital video can also help the law enforcement with prosecution of *child pornographers*.

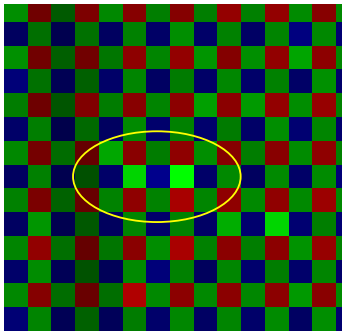
CFA Color Filter Array

- La maggior parte delle macchine fotografiche è invece equipaggiata con un singolo sensore che cattura le immagini attraverso un Color Filter Array (un filtro a griglia dei colori). La pluralità dei filtri CFA è composta da una griglia che alterna i tre colori Rosso, Verde e Blu, posizionata direttamente sul sensore. Poiché, con questo sistema, è possibile catturare solo un canale per pixel, per ottenere un'immagine a colore occorre ricostruire le due componenti mancanti per ogni singolo pixel (Demosaicing).
- Trascurando la metodologia utilizzata al fine di ricreare i tre piani di colore, l'interpolazione, in genere, introduce specifiche correlazioni statistiche tra sottoinsiemi di pixel, in ognuno dei tre canali. Poiché il filtro CFA è una griglia con una tessitura periodica, queste correlazioni avranno un andamento periodico. Sfruttando questa **periodicità** è possibile individuare un tipo di firma digitale associata all'interpolazione del colore.

Existing Approaches (1)

Analisys of the *pixels defect* (spike pixels or dead pixels).

This method represent a reliable camera identification even from lossy JPEG compressed images. Some cameras do not contain any defective pixels or they are eliminated by post-processing algorithms on-board.

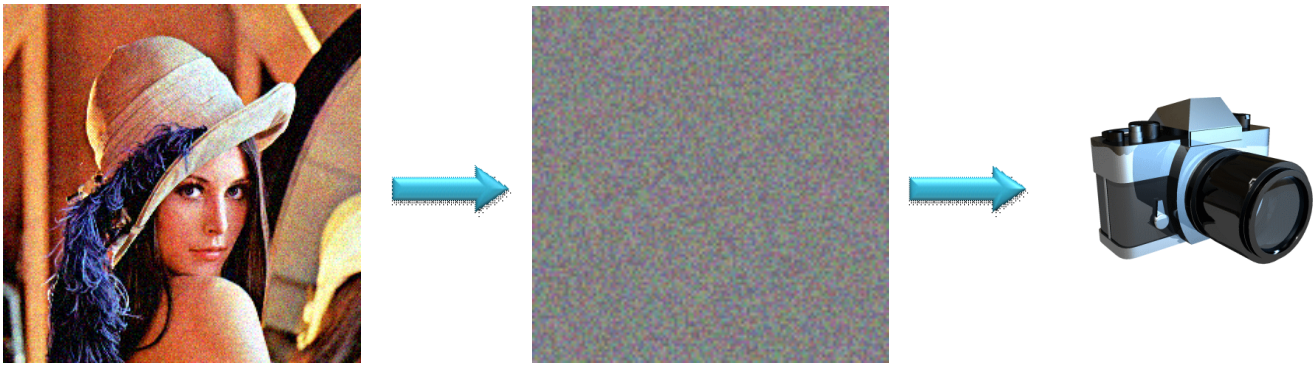


Existing approaches (2)

- Camera identification based on ***supervised learning***.
- Each image is represented using a vector of numerical *features (e.g.,* average pixel values, RGB pairs correlation, wavelet domain statistics, image quality metrics,… *)* extracted from it. This features are then trained by a multi-class SVM classifier (support vector machine) to distinguish images from different cameras

Camera source identification noise based

Sensor output carries not only pure signal but also various noise components. Sensor noise model could be used as a representative feature for cameras.



Noise

Durante tutto il processo di acquisizione ed elaborazione, l'immagine può essere affetta da rumore o imperfezioni di diversa natura.

Il rumore nelle immagini digitali si evidenzia in prevalenza come una certa granulosità o puntinatura monocromatica (luminance noise) e/o come puntini o macchioline colorate (chroma noise) evidenti soprattutto nelle aree uniformi come il cielo, o in aree scure con poco dettaglio. L'effetto è molto simile a quello delle immagini da pellicola ad alta sensibilità.

Image noise

Image noise is a random, unwanted, fluctuation of pixel values in an image. There are numerous sources of imperfections and noise that enter into various stages of the image acquisition process. Main noise sources are:

Photon Shot Noise:

occurring when a finite number of photons is small enough to give rise to detectable statistical fluctuations in a measurement.

Dark Current (Thermal Noise)

this type of noise exists even when the sensor is not exposed to any incident light, and increases as the temperature of the sensor increases.

Readout noise (Bias Noise)

It is the noise generated during the readout of the sensor and does not depend on the shooting conditions

Image noise

Reset Noise

happens when resetting the pixel, prior charge accumulation. Pixel does not exactly reset to zero.

Pattern Noise

A deterministic component that stays approximately the same if multiple pictures of the exact same scene are taken.

Quantization Noise

The analogue to digital converter in each column introduces noise due to the quantization process.

Image noise

Considering the presence of many noise sources, it is reasonable to model the overall noise as a zero mean Additive White Gaussian Noise (AWGN)

Each pixel in an image is disturbed by a Gaussian random variable with zero mean and variance σ^2

$$Y(i, j) = X(i, j) + N(i, j)$$

Where

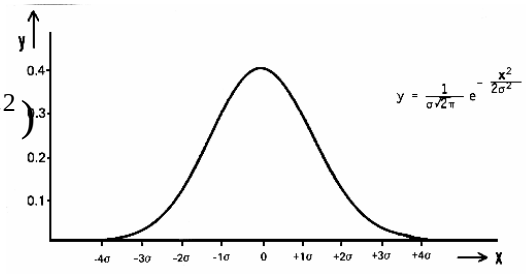
Y = captured image,

X = noise-free image

N= noisy image, with $N(i, j) \sim N(0, \sigma^2)$

$1 \leq i \leq H$

$1 \leq j \leq W$



Quando il sensore acquisisce una scena, anche nelle migliori condizioni di illuminazione, l'immagine digitale mostrerà comunque piccole variazioni di intensità tra i singoli pixel, a causa delle numerose fonti di rumore che intervengono nel processo di formazione dell'immagine.

Come precedentemente accennato, il rumore e' composto da una componente casuale che dipende dal photon shot noise, rumore termico, ecc., e una componente fissa, dovuta al pattern noise, che **lascia una traccia pressoché identica** su tutte le immagini acquisite con lo stesso sensore.

In particolare, ogni fotocamera digitale possiede un sensore lievemente differente dalle altre dello stesso modello, per via di un "disturbo" univoco e riconoscibile, ciò permette di identificare il sensore a partire dalle immagini, sfruttando la stessa idea che ci consente di distinguere le tracce univoche lasciate dalle canne delle armi da fuoco sui proiettili.

Il disturbo generato nelle immagini è legato sia al sensore in sé, che alle minuzie nella costruzione e nell'assemblaggio di ogni dispositivo. Questo assicura una differenza tra singoli dispositivi sufficiente a rendere improbabile la presenza di due camere che generino il medesimo disturbo, proprio come avviene per le impronte digitali.

Sensor identification using pattern noise

Between the different noise source presented, pattern noise differs from the other because of its deterministic properties, thus can be used for camera identification. Pattern noise consists of two main components which are:

Fixed Pattern Noise (FPN) and

Photo Response Non-Uniformity Noise (PRNU)

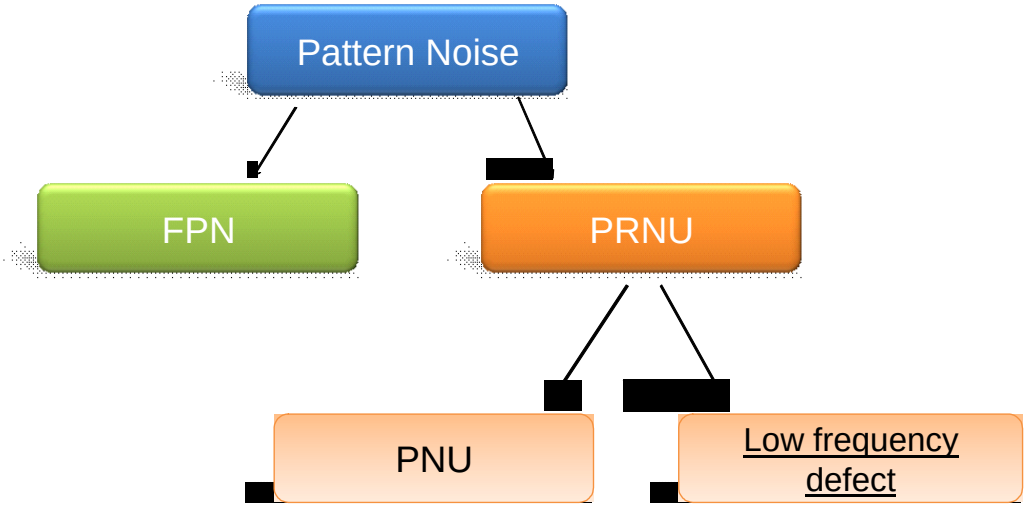
Pattern noise

Main component of the fixed pattern noise (FPN) is due to dark currents which refers to pixel-to-pixel differences when the sensor array is not exposed to light.

Photo-response nonuniformity noise (PRNU), is composed by:

pixel non-uniformity (PNU), which is defined as by sensitivity of pixels to light and it is primarily caused by the imperfections in the sensor manufacturing process.

low frequency defect, due to light refraction on dust particles and optical surfaces and zoom settings.



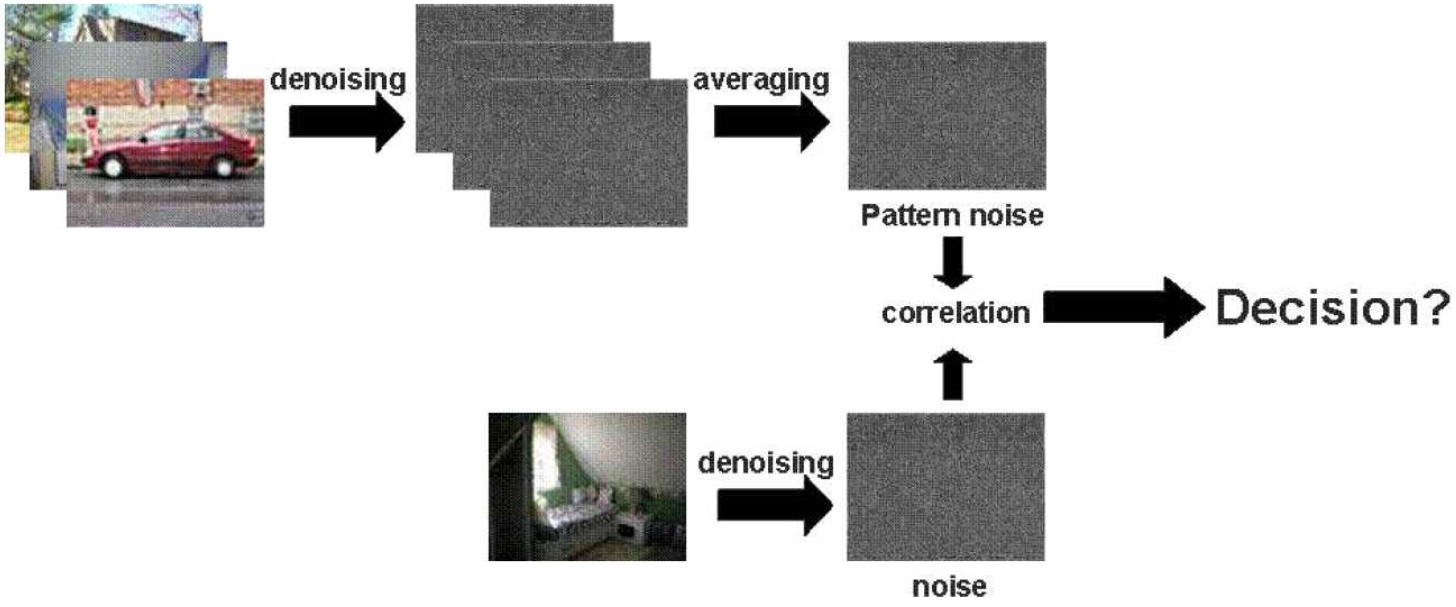
Sensor identification using pattern noise

Pixel non-uniformity noise (PNU) associated with a sensor can be used for source identification in the following way:

Extract the *reference pattern* using a denoising algorithm from a set of images captured by the same camera. Reference pattern must be averaged to eliminate random component of the noise.

Determine whether a given image is captured by a digital camera verifying that the noise pattern extracted from the individual image is *correlated* with the reference pattern of the digital camera. A decision is made based by comparing the measured correlation statistic to a pre-determined decision threshold.

Sensor identification using pattern noise



Sensor identification using pattern noise

This method provide good results, and is quite reliable also using:

- images with different level of *JPEG compression* (low, medium and high)
- images processed using point-wise operator such as brightness/contrast adjustment or gamma correction.
- images acquired by two cameras of the same brand and model.

La procedura appena descritta è la più semplice e nota. Recentemente sono state proposte diverse migliorie e piccole varianti che rendono l'algoritmo di identificazione ancora più affidabile. Alcuni autori hanno presentato delle tecniche attraverso le quali e' possibile migliorare la stima del reference pattern, che fanno uso di piccoli training set e utilizzano particolari procedure di classificazione.

Una implementazione open source di questa tecnica è disponibile su

http://sourceforge.net/projects/prnucompare/

Operazioni di post-processing applicate ai reference pattern stimati, inoltre, possono ridurre la correlazione tra reference pattern di fotocamere della stessa marca e modello, riducendo quindi ulteriormente il numero di errori della procedura.

Forging and malicious processing

Intentionally removing the pattern noise from an image to prevent identification. The easiest way to prevent a simple detection of the reference pattern are slight rotation, possibly combined with other processing that might include resizing, cropping, and filtering.

Extracting the noise and copying it to another image to make it appear as if the image was taken with a particolar camera.This kind of malicious processing is more difficult: requires to remove pattern noise from the image that we want forging and add to it the reference pattern noise of another camera, avoiding to create visible artifacts.

AntiForensics

Fortunatamente l'eliminazione del pattern noise, o la sovrapposizione dello stesso su un' immagine, sono operazioni abbastanza complesse, soprattutto per un non esperto. Se l'alterazione non è ben fatta, infatti, si potrebbe rischiare, di aggiungere artefatti che potrebbero far risaltare il tentativo di manomissione, e comunque di non riuscire ad ingannare l'algoritmo di identificazione.

D'altra parte, purtroppo, operazioni molto elementari sull'immagine, come un crop o una rotazione potrebbero rendere l'immagine irriconoscibile. In rete, ad esempio, è possibile trovare siti come questo: http://www.instructables.com/id/Avoiding-Camera-Noise-Signatures/

Software per il corso (e non solo)

Amped Five

Scaricare l'ultima versione:
http://ampedsoftware.com/download

Seriale (a tempo- scadenza metà Luglio circa)

0POjrqphLAo6gC213bXwFG9yw+xMLVDK31DpSHXkp9g=

Prova in Itinere Image Forensics

Individuale

- Quesito su una o più immagini
- Relazione su un software

Solo per chi supera le prove di Caccavella e Ferrazzano (news a breve)

Materiale di consultazione (Tesi)

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