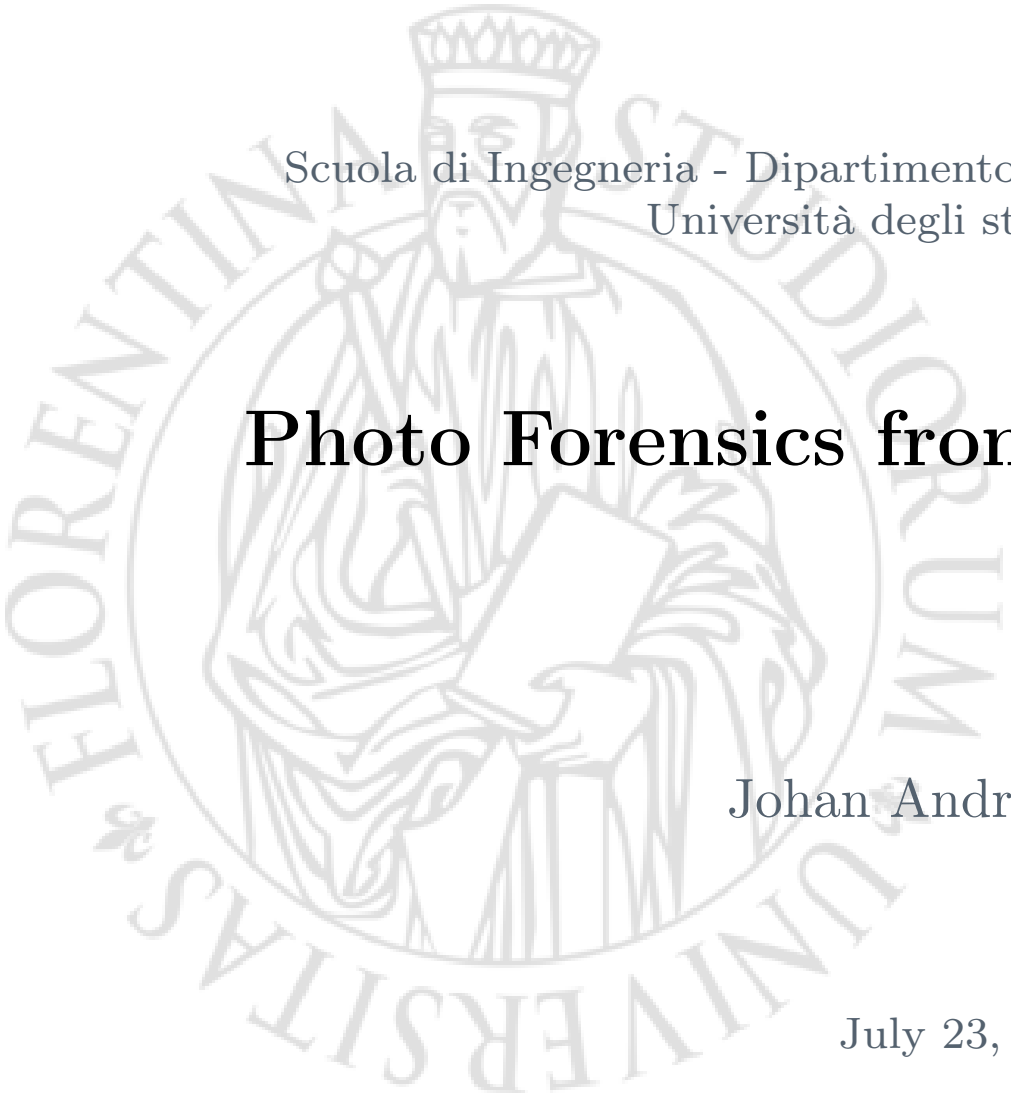

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Photo Forensics from JPEG Dimples

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Introduction

JPEG compression play an important role in forensic study. A large amount of methods based on compression pipeline were developed in order to detect tampering .
We are going to see a method based on an artifact that arises from the choice of the mathematical operator used in DCT coefficients conversion.

JPEG Compression Pipeline

1. Convert from RGB to luminance/chrominance
2. Subsample each channel by a factor of two or more
3. Partition each channel into non-overlapping 8x8 pixel blocks
4. Convert the luminance values from unsigned to signed integers
5. Convert each block to the frequency domain using a 2-D DCT
6. Quantize each DCT coefficient c by an amount q where the amount of quantization depends on the spatial frequency.
7. Entropy encode the quantized DCT coefficients

DCT Quantization

Focusing on step six, of particular interest is the operator chosen to convert from a floating-point value to an integer .

$$\vec{s} = (3.7 \;\; 8.3 \;\; 5.9 \;\; 5.1 \;\; 1.6 \;\; 2.4)$$

There are 3 possible operators:

- Floor operator : $\vec{s}_f = (3 \;\; 8 \;\; 5 \;\; 5 \;\; 1 \;\; 2)$
- Ceiling operator: $\vec{s}_c = (4 \;\; 9 \;\; 6 \;\; 6 \;\; 2 \;\; 3)$
- Round operator : $\vec{s}_r = (4 \;\; 8 \;\; 6 \;\; 5 \;\; 2 \;\; 2)$

DCT Quantization
Operators odds

We can easily notice that the 3 operators have a common main effect (convert a floating value in integer) but with 3 difference policy :

- Round operator: return intermittently larger or smaller values than the original $\Delta\vec{s}_r = (0.3 \quad -0.3 \quad 0.1 \quad -0.1 \quad 0.4 \quad -0.4)$
- Floor operator: return consistently smaller values than the originals $\Delta\vec{s}_f = (-0.7 \quad -0.3 \quad -0.9 \quad -0.1 \quad -0.6 \quad -0.4)$
- Ceiling operator: return consistently larger values than the originals $\Delta\vec{s}_c = (0.3 \quad 0.7 \quad 0.1 \quad 0.9 \quad 0.4 \quad 0.6)$

Frequency Domain

Our operators are apply in the frequency domain and leaving out round operator we can express floor and ceiling operators as follow:

$$\vec{s}_f = s - \alpha_f \vec{1}$$

e

$$\vec{s}_c = s + \alpha_c \vec{1}$$

where α_f and α_c are positive vectors.

Spatial Domain

We are working in frequency domain but consider now the result of converting from frequency domain back in spatial domain. Because of the linearity of the DCT we have

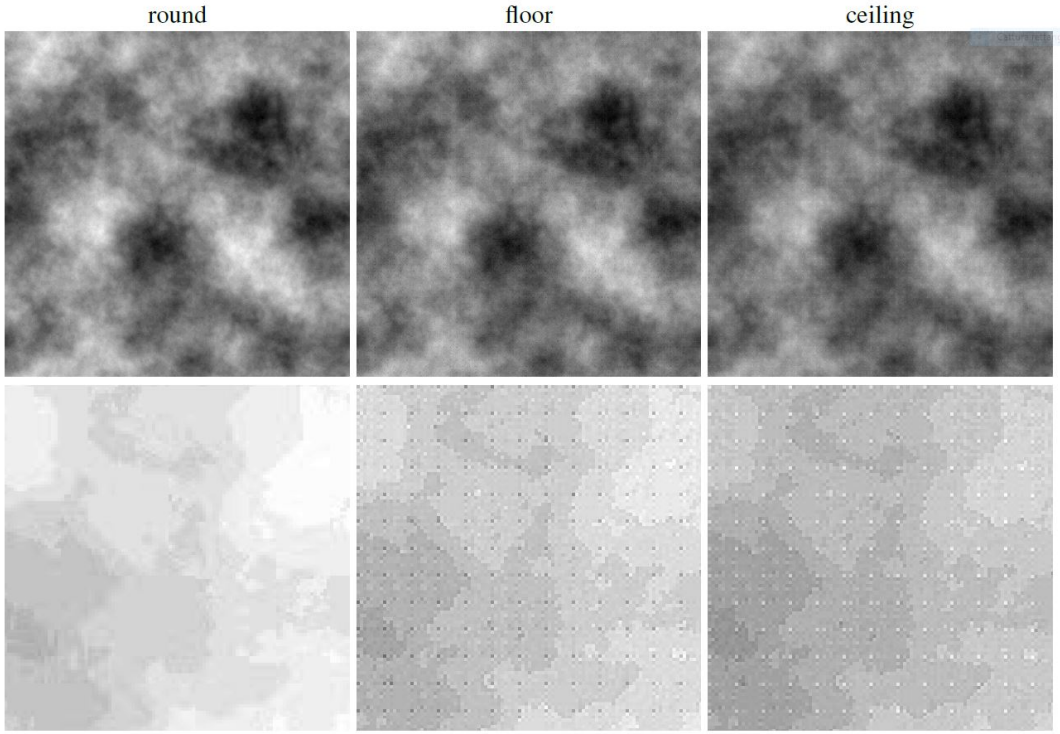
$$D^{-1}(\vec{s}) = D^{-1}(\vec{s}) - \alpha D^{-1}(\vec{1})$$

where the inverse DCT of a constant signal is an impulse

$$D^{-1}(\vec{s}) = D^{-1}(\vec{s}) - \alpha\vec{\delta}$$

JPEG Dimples

Due to the subtraction (floor) and addiction (ceiling) of an impulse, in the 2D case, we can observe a periodic artifact every 8x8 pixel blocks in which the top-left corner of each of them is consistently dark (floor) or light (ceiling).



Automatic Detection

JPEG dimples can be detect with a template based approach: T(x,y) is a template of the same size as the image I(x,y) and is characterised by all zero values except for the upper left corner of every 8x8 block, which is 1. The strength of the JPEG dimples is mesured using the peack to correlation energy:

$$p_I = \frac{F_I^2(\hat{u}, \hat{v})}{\frac{1}{63} \sum_{(u,v) \neq (\hat{u}, \hat{v})} F_I^2(u, v)}$$

where

$$F_I(u, v) = \sum_x \sum_y I(x, y) T(x + u, y + v)$$

PCE respond regardless of where in 8x8 blocks the impulse appears. This allows to handle image rotation and cropping.

Automatic Detection
Image Content Suppress

Image content can sometimes interfere with the detectability of JPEG dimples. To handle this problem we can apply

- 3x3 Wiener filter to each RGB channel and average the resulting noise residual across all the three channels.
- non-overlapping 32x32 blocks are then averaged across the entire image

The PCE is then computed against this averaged 32x32 blocks

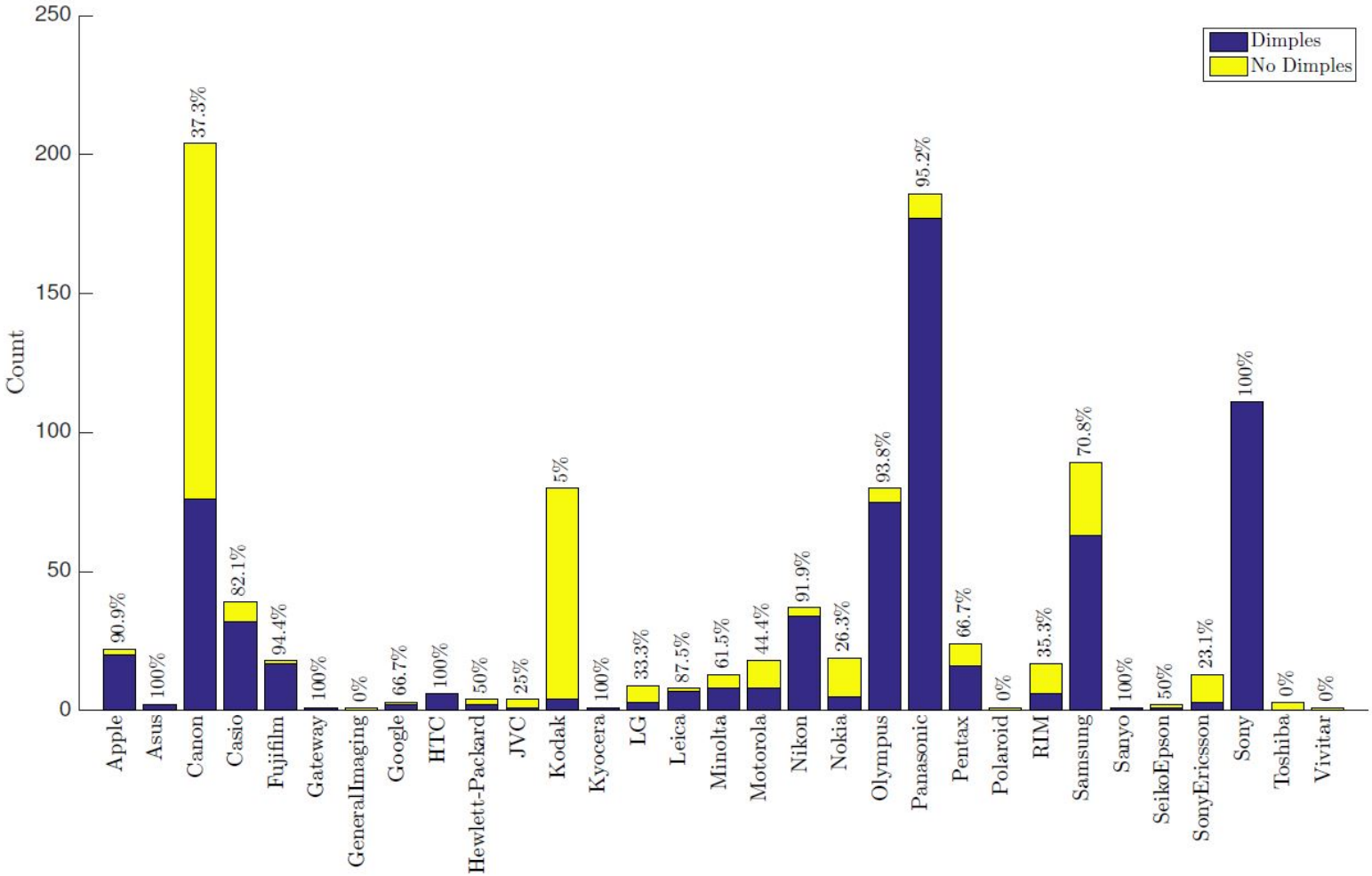
JPEG Dimples in commercial Camera

Dataset collected from Flickr

- 40k of unmodified images.
- 4039 camera configurations.

First analysis: Considering 1017 of 4039 configurations each with 5 to 20 images recorded at the maximum resolution afforded by the camera, the presence of dimples for a camera configuration is determined by averaging the PCE across all available images for the camera configuration with value 13 as threshold.

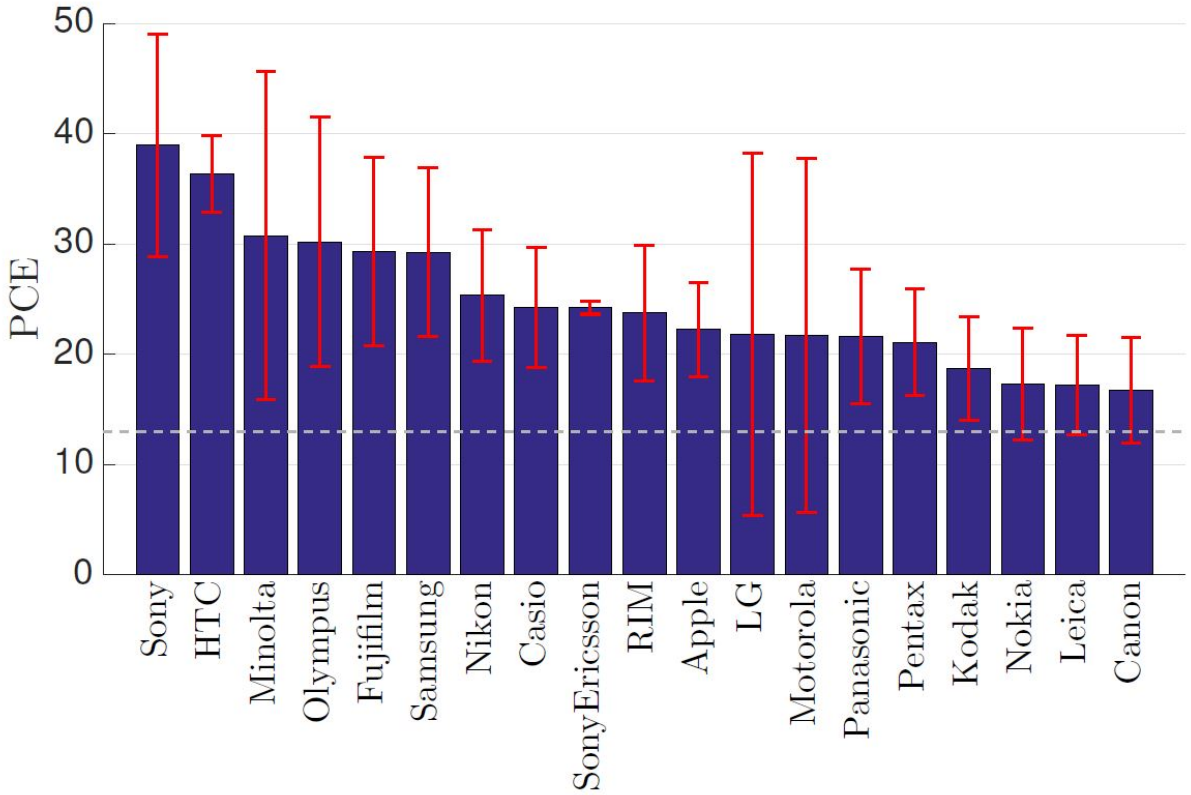
JPEG Dimples in commercial Camera



JPEG Dimples in commercial Camera

Strength of Dimples

The strength of dimples varies across camera manufactures from a maximum of 39 to a minimum of 16. These differences appear to be unrelated to image resolution or quality



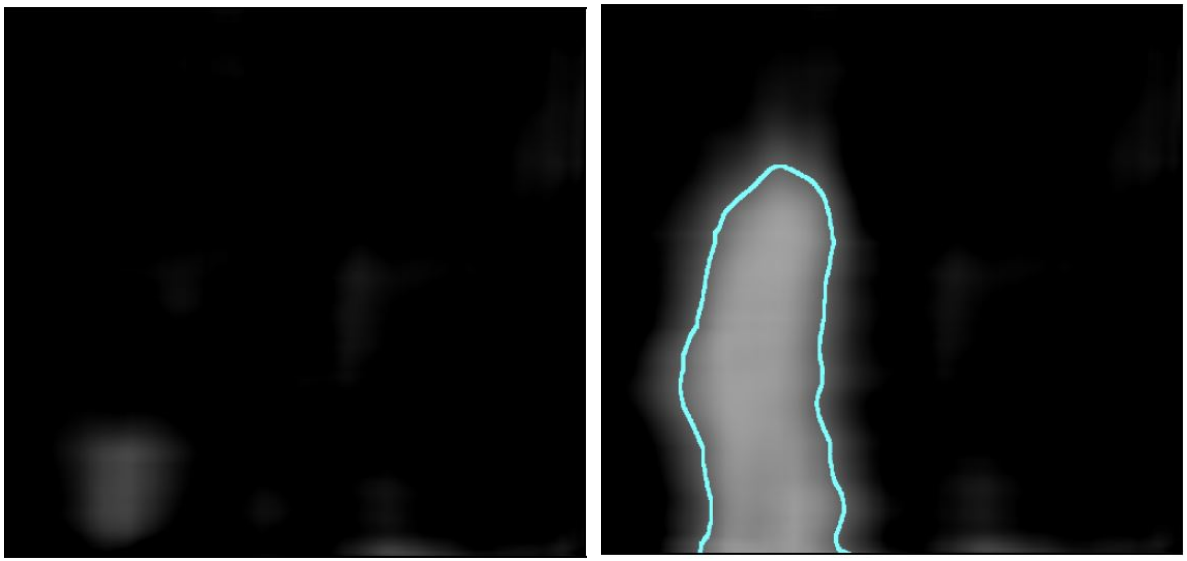
Forensic Application

Now we can see how to take advantage of dimples to discover tampering.

In order to discover the type of local manipulation the measure of JPEG dimples is now applied to overlapping 512x512 windows to yield a prominence map that specifies the per-pixels dimple strength.

Forensic Application
Prominence Map

Observing now the two maps we can clearly identify some areas of interest.



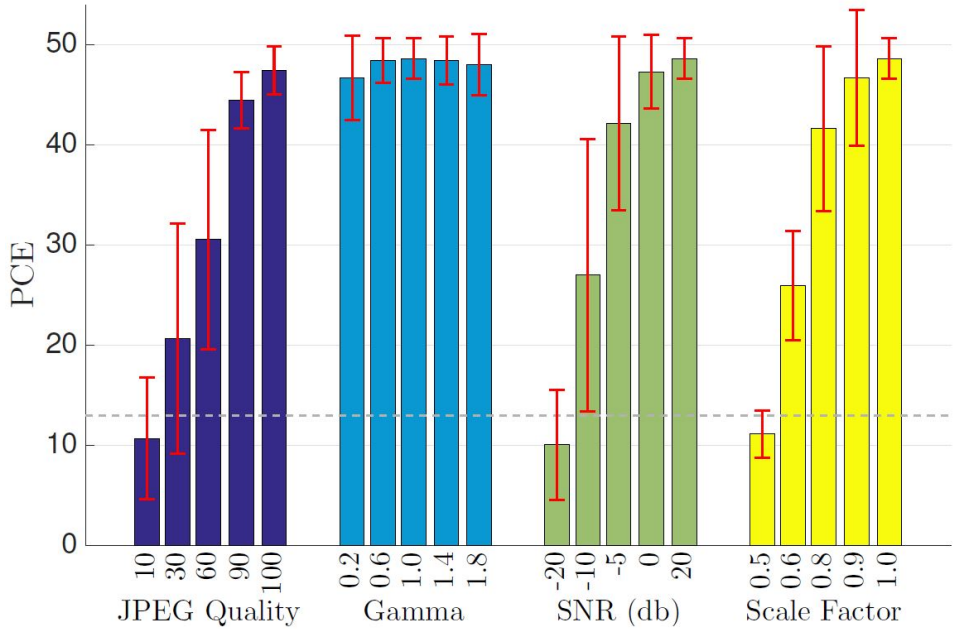
The maps show PCE value per-pixel in the range of 0 (white) to 20 and above (black). The cyan contour lines correspond to a PCE value of 13.

Foresic Application
Parameters

Depending on the size of the manipulation to be identified and on specific knowledge on the dimple's strength we can vary some parameters: In order to discover a smaller tampering we can apply 256x256 windows like in next example that present a small bounding box to discover.

Forensic Application
Resilience to post-processing

A final investigation was conducted to evaluate the impact of post-production on dimples



As we can find out from histogram, except in borderline cases, post-production does not affect dimples and PCE.

References

Graphic, Images and Contents are extracted from
Shruti Agarwal and Hany Farid's Photo Forensics from JPEG Dimples