

DCT Based Digital Forgery Identification

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Overview

- What is a Forgery?
 - Using Graphical Software
 - The content has been modified
 - The context has been modified
- The JPEG Standard
- Exif Information
 - Thumbnails Analysis
- JPEG DCT Techniques
 - Measuring Inconsistencies of Block Artifact
 - Digital Forgeries From JPEG Ghosts



What is a Forgery?

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

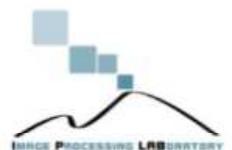


- An **image altered for fun** or someone who has taken a bad photo, but has been altered to improve its appearance cannot be considered a forgery even though it has been altered from its original capture.



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:
 1. Created using **graphical software**
 2. The **content** has been altered
 3. The **context** has been altered



Using graphical software



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



Using graphical software



<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, e.g., a person can be added or removed
- The easiest way is to cut an object from one image and insert it into another image - **copy & paste** - 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.

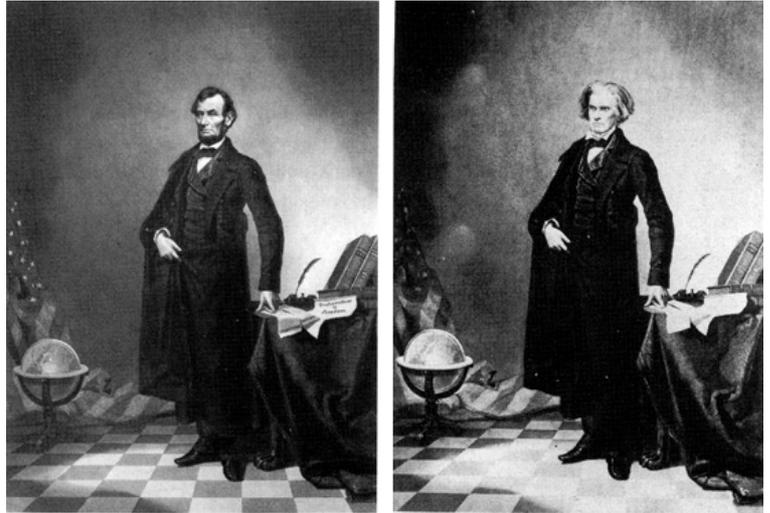
Acting on congressional recommendations to bolster research and development in information technology, intelligence agencies are turning to PCs to develop more sophisticated means of manipulating and delivering digital photos, video clips and recorded sound to portray fictitious events in hopes of provoking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

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.



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 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 length**, **GPS coordinates** etc.
 - **THUMBNAIL PREVIEW** (a small picture which would be equal to the original picture).
- **The ExIF information checking** has demonstrate the possibility of immediate forgery detection.
- In effect if the constructor is known several **ExIF data must match to fixed values**.



File and Attributes	
File Name:	M.Jo2.jpg [12 / 20]
Location:	D:\Giuseppe Messina\My Documents\My Pictures\
Type:	JPEG Bitmap (JPG) YCbCr
Size:	17.6 KB
Date Time:	2005-06-24 10:23:58
Attributes:	150 x 150 (0.02MP) 24bit
Print Size:	1.27 x 1.27 cm , DPI: 300 x 300 DPI
EXIF JPG Comment	
EXIF Metadata	
Make	NIKON CORPORATION
Model	NIKON D70
Software	ACD Systems Digital Imaging
Date/Time	2004-10-17 14:18:17
Exposure Time	1/30 sec
Exposure Program	Aperture priority
Exposure Bias	0 EV
F Number	F 25
Max Aperture	F 4
ISO Speed ratings	
Flash	Flash did not fire
Focal Length	31 mm
35mm Equivalent	
Metering Mode	Multi-segment

Thumbnails Analysis

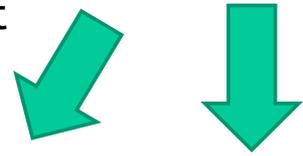
- Using the following image we can extract the thumbnail through simple Exif tools, web sites or open source codes, like:
 - **JPEGSnoop**
(<http://www.impulseadventure.com/photo/jpeg-snoop.html>)
 - **Jhead version 2.82**
(<http://www.sentex.net/~mwandel/jhead/>)
 - **Camera Summary**
(<http://camerasummary.com/>)
 - **Jeffrey's Exif Viewer**
(<http://regex.info/exif.cgi>)
- This tools permit to identify data that **have not been removed by inexperienced users**.



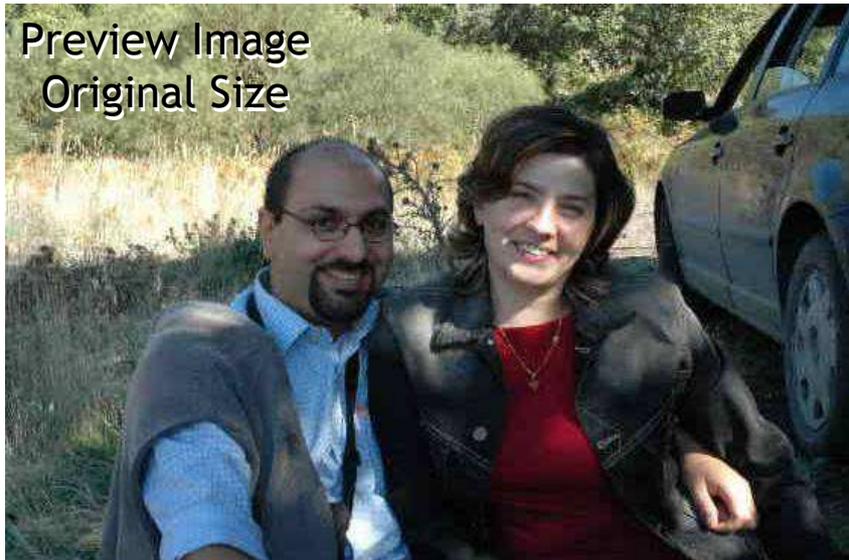
Thumbnail
Original Size

Thumbnails Analysis

- Furthermore the Exif analysis permit 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.

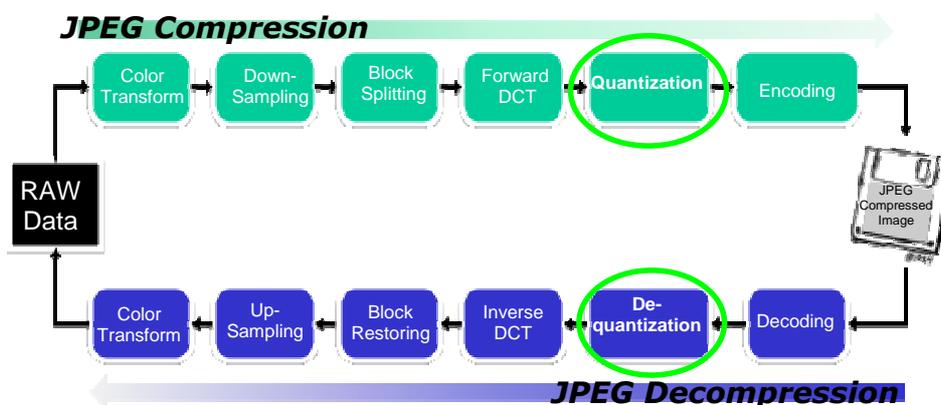


Thumbnail
Original Size



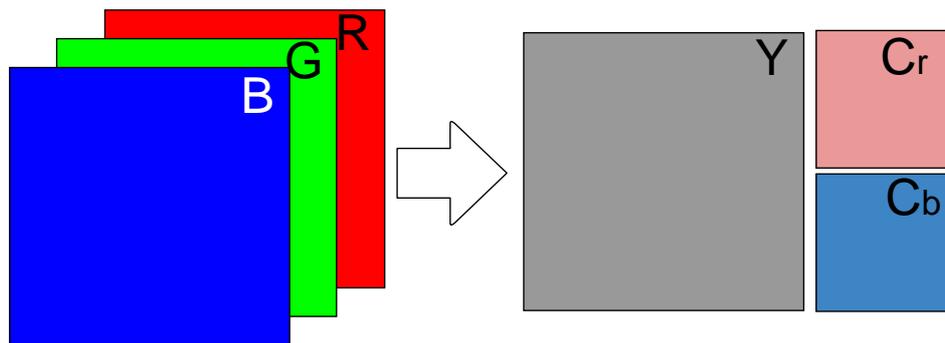
JPEG Compression

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



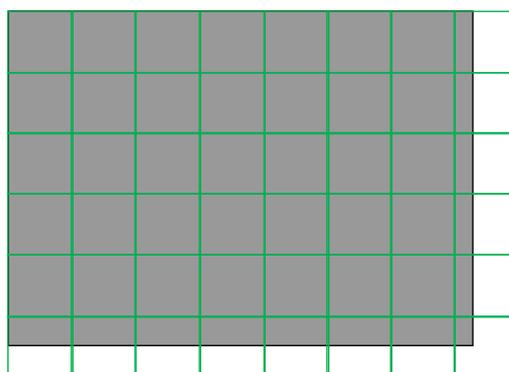
Color Conversion & Downsampling

- 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).



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

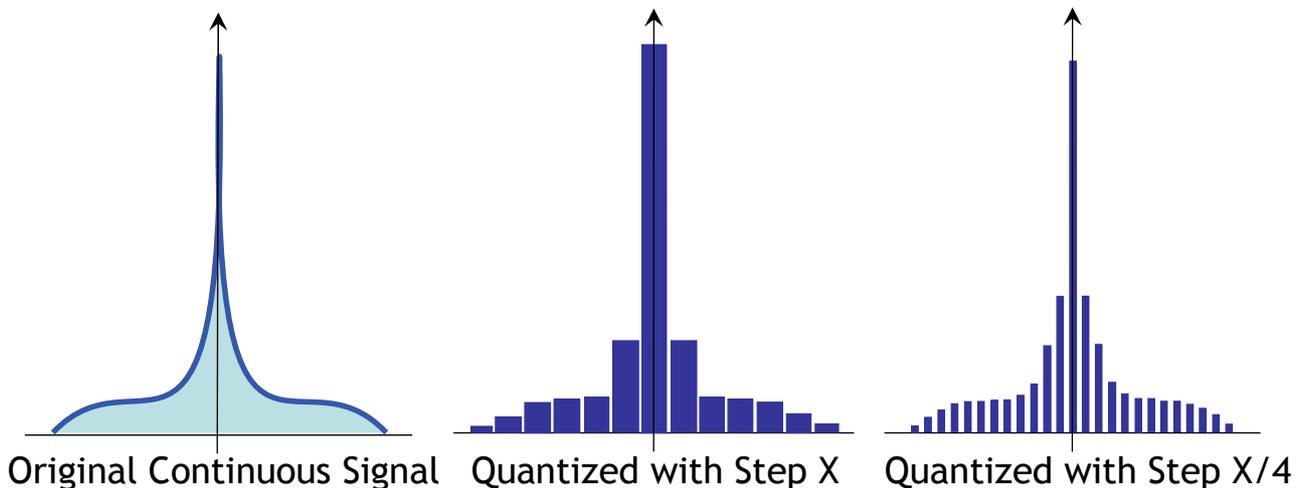
- If we perform this transformation on our matrix above, and then round to the nearest integer, we get

- The top-left corner coefficient is named DC. The remaining 63 coefficients are called the AC coefficients. The advantage of the DCT is its tendency to aggregate most of the signal in one corner of the result, as may be seen above. The quantization step to follow accentuates this effect while simultaneously reducing the overall size of the DCT coefficients, resulting in a signal that is easy to compress efficiently in the entropy stage.

								u
								\rightarrow
-415	-30	-61	27	56	-20	-2	0	v \downarrow
4	-22	-61	10	13	-7	-9	5	
-47	7	77	-25	-29	10	5	-6	
-49	12	34	-15	-10	6	2	2	
12	-7	-13	-4	-2	2	-3	3	
-8	3	2	-6	-2	1	4	2	
-1	0	0	-2	-1	-3	4	-1	
0	0	-1	-4	-1	0	1	2	



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

- The human eye is not so good at distinguishing the exact strength of a high frequency brightness variation.
- This allows one to greatly reduce the amount of information in the high frequency components.
- This is done by simply **dividing each component** in the frequency domain by a constant for that component, and then **rounding to the nearest integer**. As a result of this, it is typically the case that many of the higher frequency components are **rounded to zero**, and many of the rest become small positive or negative numbers, which take many fewer bits to store.
- **THIS IS THE MAIN LOSSY OPERATION IN THE WHOLE JPEG PROCESS.**



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

-415	-30	-61	27	56	-20	-2	0
4	-22	-61	10	13	-7	-9	5
-47	7	77	-25	-29	10	5	-6
-49	12	34	-15	-10	6	2	2
12	-7	-13	-4	-2	2	-3	3
-8	3	2	-6	-2	1	4	2
-1	0	0	-2	-1	-3	4	-1
0	0	-1	-4	-1	0	1	2

- The quantized DCT coefficients are computed with

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

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

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

-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

- The value of Q can range between 0 and 100 and is used to compute the scaling factor, S

$$S = \begin{cases} \frac{5000}{Q} & \text{if } Q < 50 \\ 200 - 2Q & \text{otherwise} \end{cases} \quad (1)$$

- Each element i in the scaled table T_s is computed using the i th element in the base table T_b

$$T_s[i] = \left\lfloor \frac{S * T_b[i] + 50}{100} \right\rfloor \quad (2)$$

- All of these computations are done in integer math; there are no decimals (hence the floor function in the equation). Any value of T_s that computes to zero is set to one.



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.



Forgeries Identification through DCT

- The research activity in such area has started through the analysis of correlations between QT and DCT coefficients.
- Three 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.



Block Artifact Measure

- Block artifact for each 8x8 block is estimated via:

$$B(i) = \sum_{k=1}^{64} \left| D(k) - Q_e(k) \text{round} \left(\frac{D(k)}{Q_e(k)} \right) \right| \quad (3)$$

where $B(i)$ is the estimated blocking artifact for the testing block i , and $D(k)$ is the DCT coefficient at the position k . $Q_e(1:64)$ is the estimated QT.

- The block artifact measure (BAM) for the whole image is then calculated based on the blocking artifacts of all blocks:

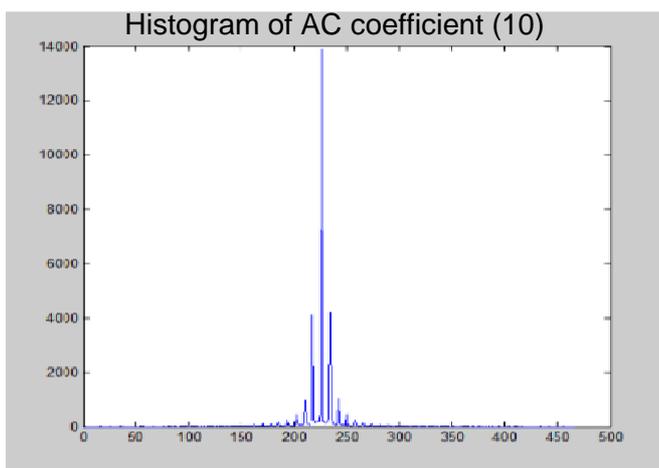
$$BAM = \frac{1}{N} \sum_i B(i) \quad (4)$$

where N is the total number of blocks.

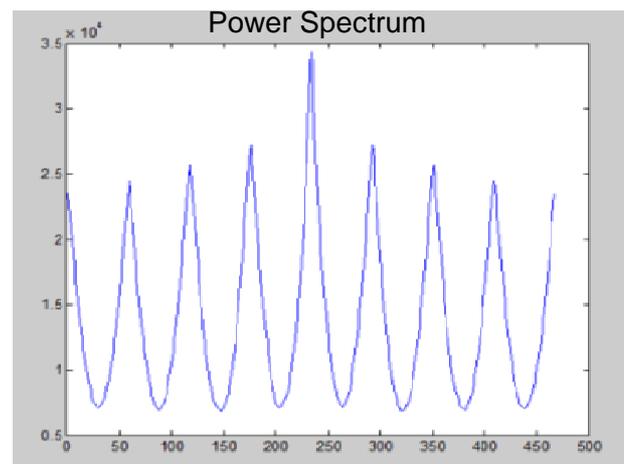


Quantization Table Estimation

- It is observed that if the histogram of a DCT coefficients contain periodic patterns, then the coefficients are very likely to have been quantized with a step of this periodic.
- These periodic artifacts are particularly visible in the Fourier domain as strong peaks in the mid and high frequencies.



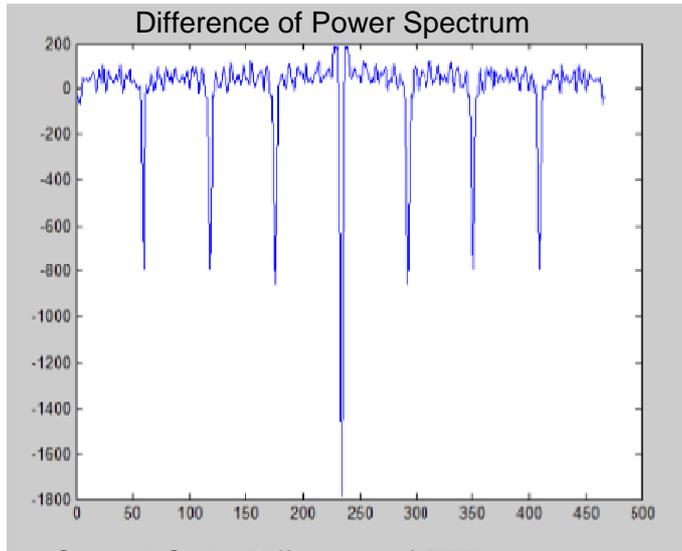
Histogram of AC coefficient (Q(10)=7)



Fast Fourier Transform of the Histogram

Quantization Table Estimation

- Therefore, the derivatives of the histogram power spectrum of DCT coefficients could be used to estimate the quantization table.
- The number of negative local minimum of the filtered second order difference is found to be equal to $Q(i)$.



Second Order Difference of FFT spectrum.



Filtered second Order difference with $th=0$.

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

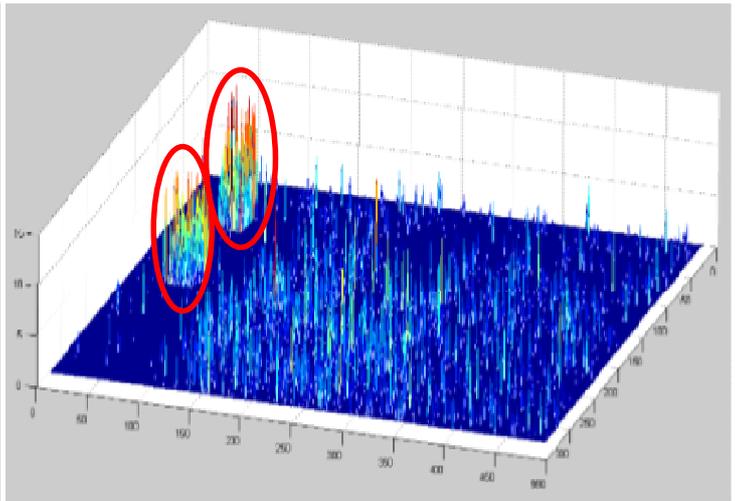
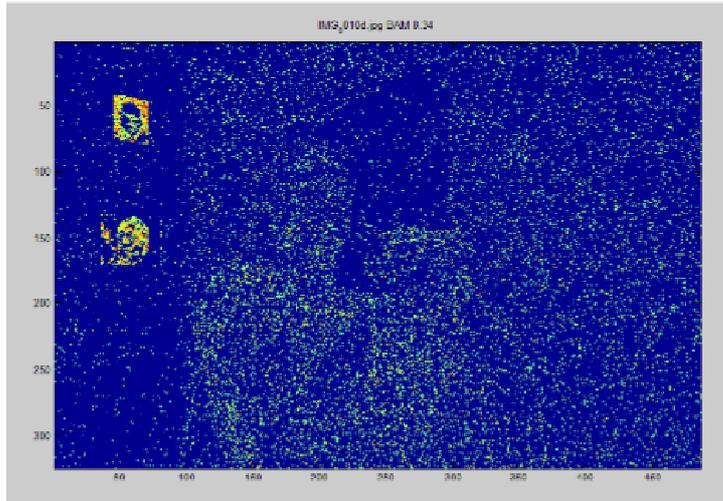
Differences between the two tables.

- 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.

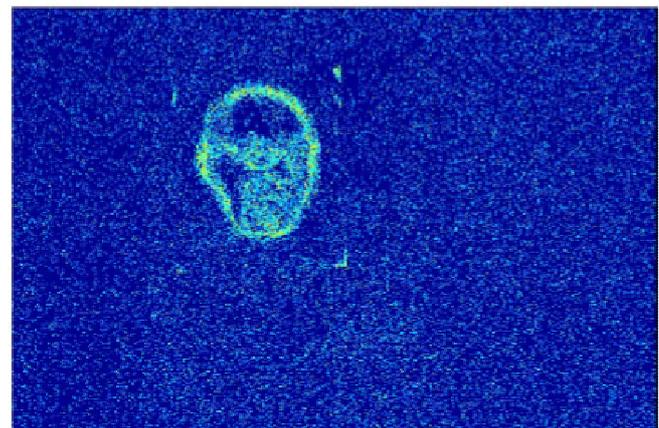


Results 1/4

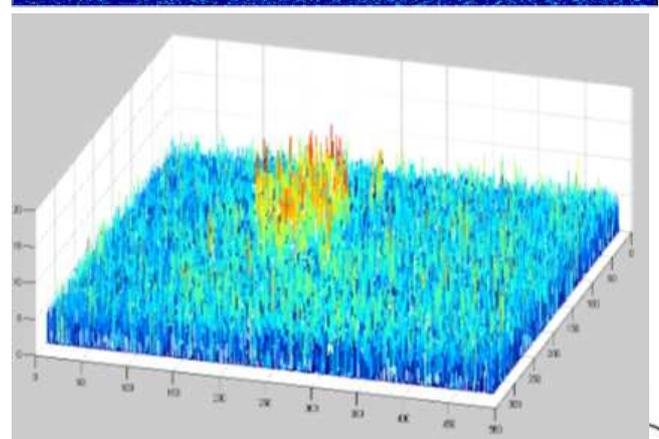
- By taking into account the formula (3) the following error map has been generated.
- The map clearly underlined the part of the image that contain forgeries (max value 14.7).



Results 2/4

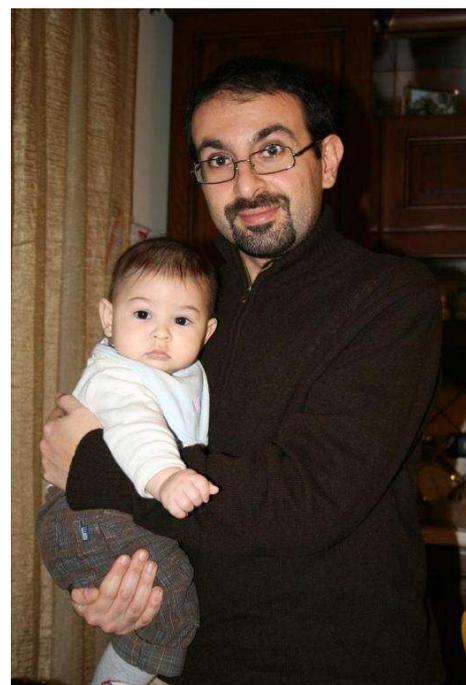


- In this experiment we have taken a face from a different (downsampled image) we have remove the background of the picture and pasted it over the original face.
- During the process of cancelling the background the corners have been coarsely removed, as visible in the error map (max value 18.3).



Results 3/4

Original Images



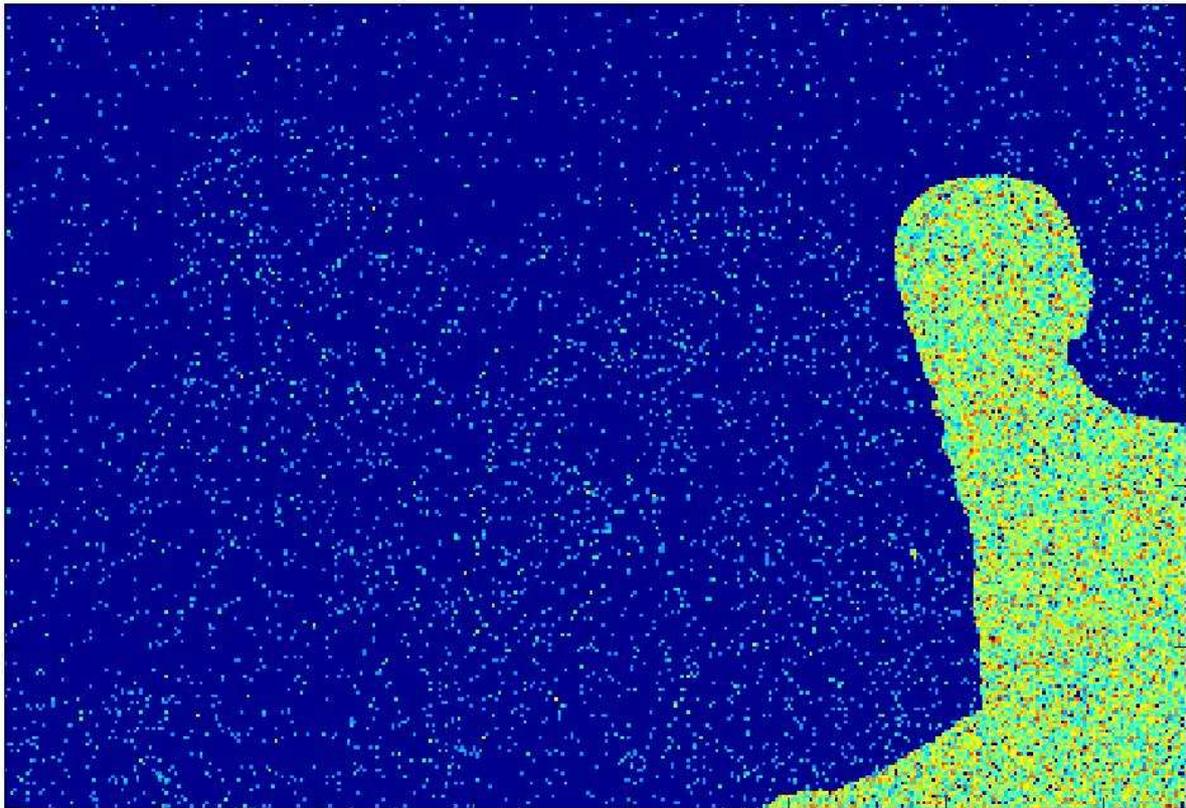
Results 3/4

Tampered Image

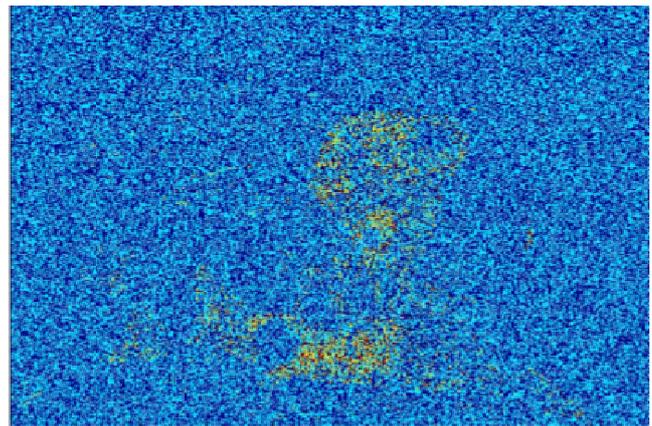


Results 3/4

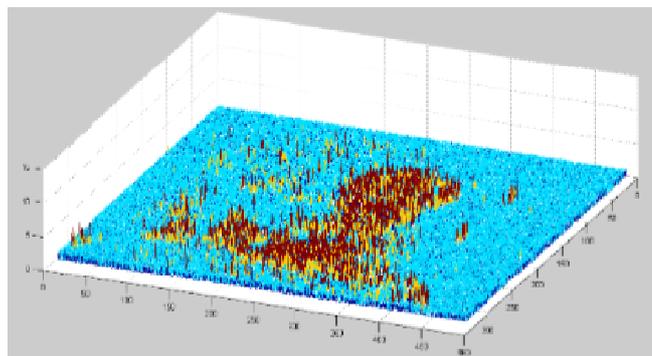
Estimated Map.



Results 4/4



- Here is an example on an unaltered image.
- The global error is very low and there are no relevant peaks (max value 1.8).



Forgeries From JPEG Ghosts

- The following method is based on a simple concept :
 - If a forgery has been introduced into an original image such forgery will probably have a different compression from the whole image.
- Thus to identify such artifacts a simple iteration on the original image, changing compression factor by a fixed step, permit to realize a set of maps.
- Such maps are used through the following quadratic difference:

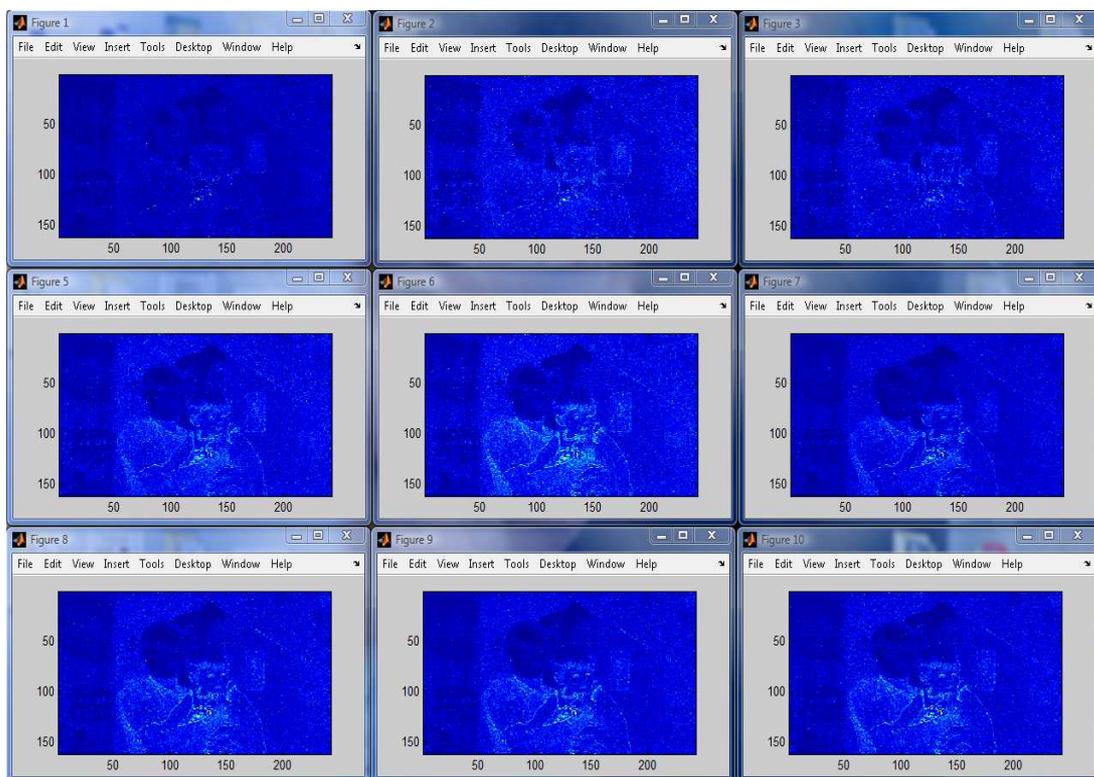
$$\delta(x, y, i) = \frac{1}{3} \sum_{i=1}^3 \frac{1}{b^2} \sum_{b_x=0}^{b-1} \sum_{b_y=0}^{b-1} [f(x + b_x, y + b_y, i) - f_q(x + b_x, y + b_y, i)]^2$$

where $f(x, y, i)$, $i=1,2,4$ denotes each of the three RGB color channels, and $f_q(.)$ is the result of compressing $f(.)$ at quality q , and b is a region block size used to average the values.



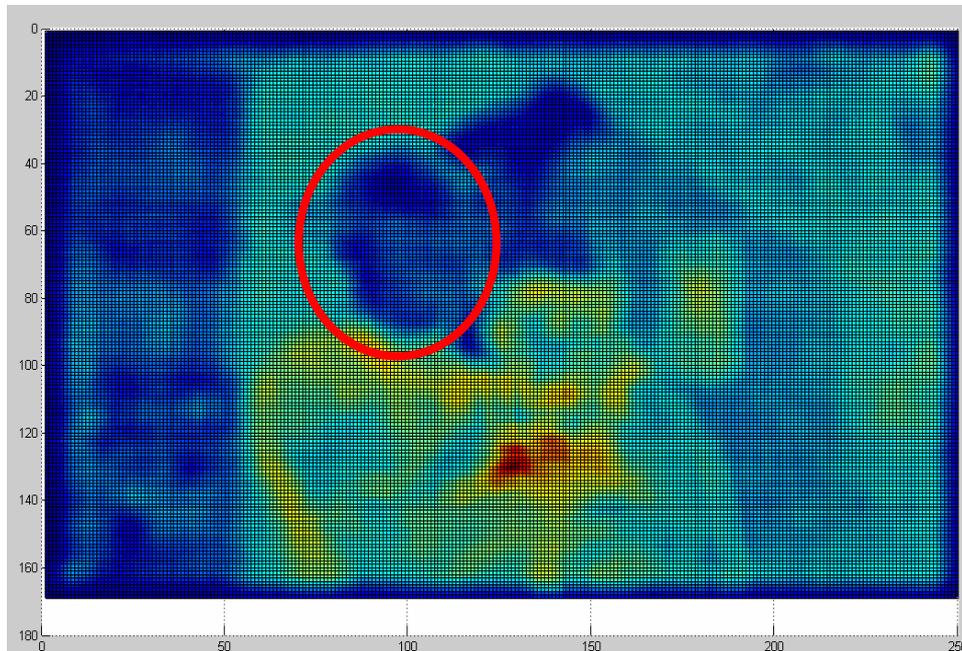
Forgeries From JPEG Ghosts

Example of a succession of differences among several compression steps.



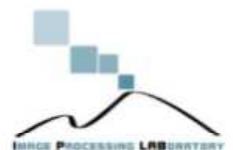
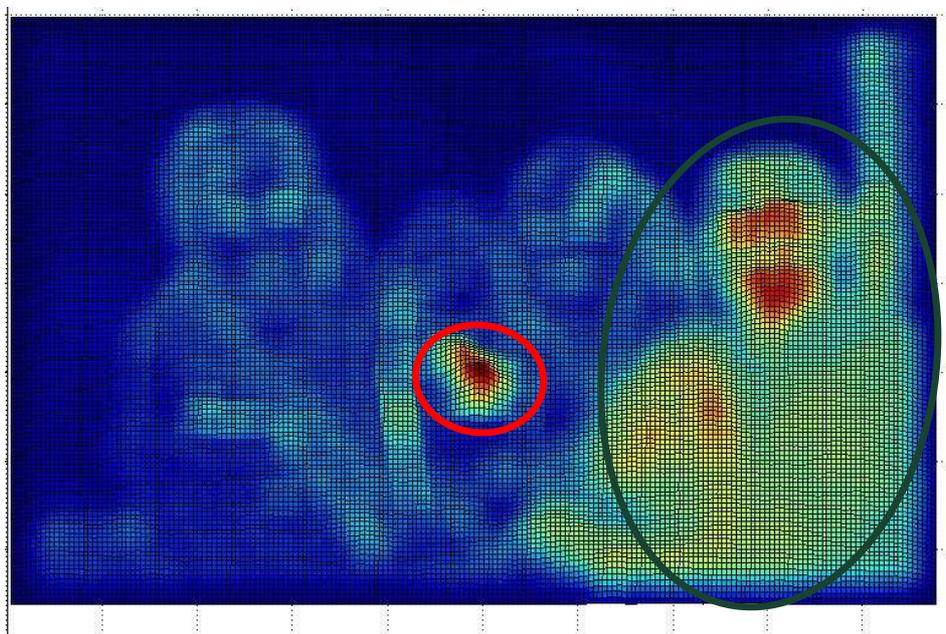
JPEG Ghosts first results

Sum of averaged differences enhances the presence of a “ghost” corresponding to a region which appear clearly different from the rest of the image.



JPEG Ghosts first results

Sum of averaged differences enhance the presence of a “ghost” corresponding to a region which appear clearly different from the rest of the image.



Conclusion & Future Works

- The main aim of such research is to develop a tool, as combination of several techniques, which will be able to detect forgeries taking into account all the collected information.
- The developed methods seems to be promising, further research are ongoing.
- Other techniques DCT based are under investigation
- Furthermore techniques based on Chromatic aberation, light direction, etc. will be investigated.
- Also a further research oriented to Camera Identification is under investigation



Contacts

For further information

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