TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Computer Science Institute of Systems Architecture, Privacy and Data Security Research Group

On Resampling Detection in Re-Compressed Images

WIFS 2009

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Technische Universität Dresden

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Image Forensics and JPEG Compression

Image Forensics

- use image statistics for identification of source device or **detection of manipulations**
- variety of different forensic methods can be found in the literature
- existing schemes work well under laboratory conditions

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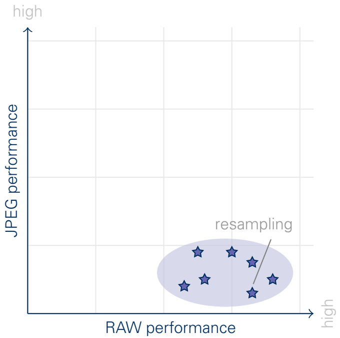

The Curse of JPEG Compression

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- a lot of forensic methods are vulnerable to post-compression

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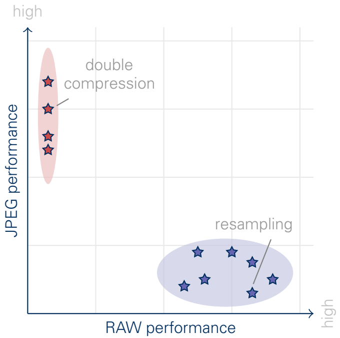

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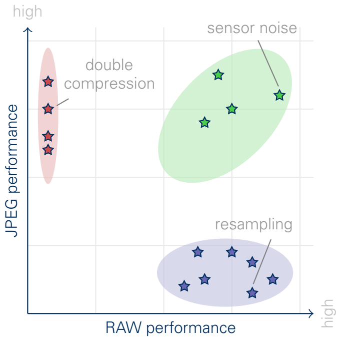

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Resampling Detection

- image manipulations often rely on geometric transformations (scaling, rotation, . . .) of images or parts thereof

Andrea Sommer, Doc Baumann

Resampling Detection

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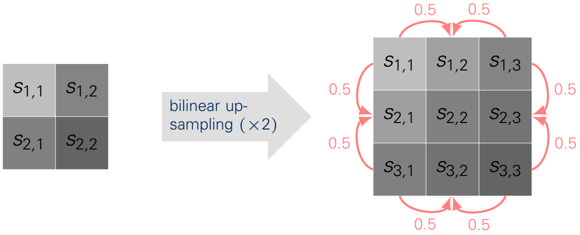
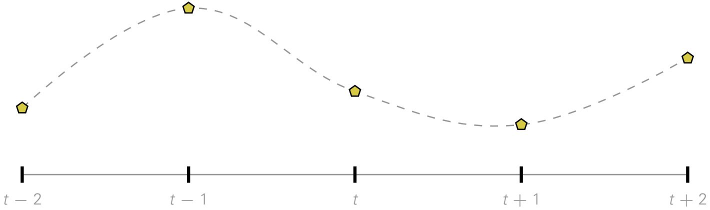
- **resampling** to a new image grid; involves an **interpolation** step
- interpolation introduces **periodic linear correlations** between neighboring pixels



- resampling artifacts can be detected by the analysis of **linear predictor residue** [Popescu & Farid, 2005], [Kirchner, 2008]

Detection Scheme



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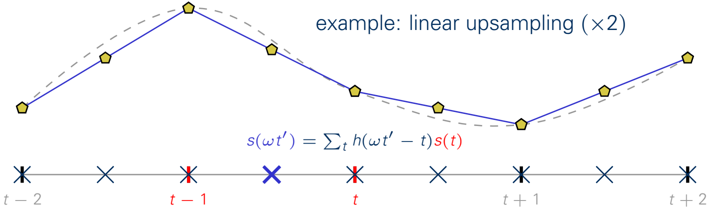

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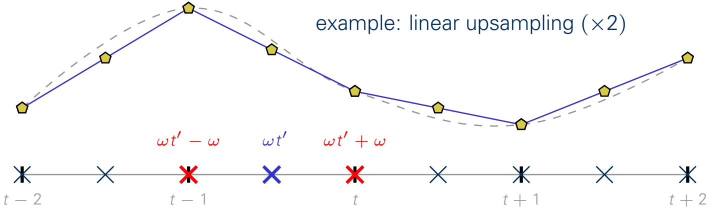

- **predictor residue:** $$e(\omega t') = s(\omega t') - \sum_{k=-K}^{K} \alpha_k s(\omega t' + \omega k) \qquad (\alpha_0 := 0)$$
- large absolute prediction errors indicate minor degree of linear dependence

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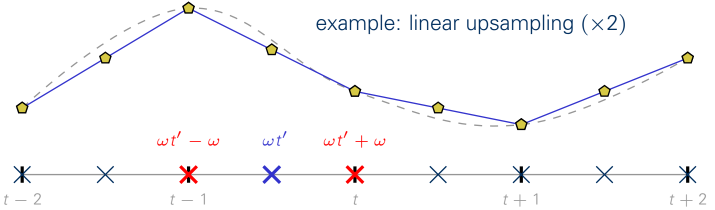

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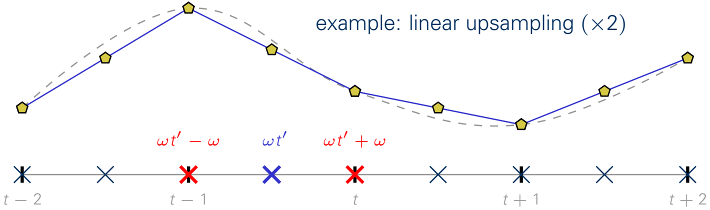
- optimal weights in the example: $\boldsymbol{\alpha} = (0.5, 0, 0.5)$
  - every second sample defaults to 0

Detection Scheme



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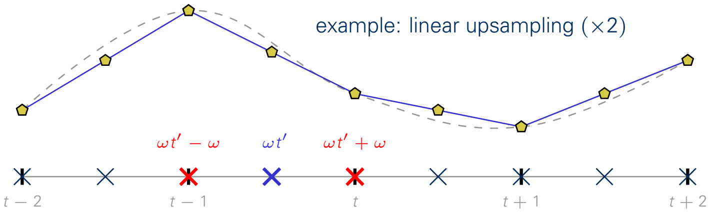

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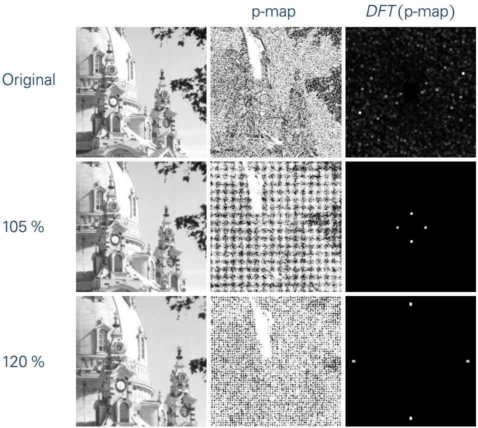
- **p-map:** $p(\omega t') \propto \exp\left(-\sigma |e(\omega t')|^{\tau}\right)$
- measure for the strength of linear dependence

Typical Detection Results



* each spectrum graph has been individually normalized and processed with a maximum filter

- resampling causes **periodic pattern** in the p-map and **distinct peaks** in the p-map's DFT
- peak position is characteristic for resampling parameters

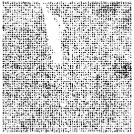
$$f_{\mathrm{re}} = \left| (\mathbf{A}')^{-1} \begin{pmatrix} k \\ l \end{pmatrix} - \left[(\mathbf{A}')^{-1} \begin{pmatrix} k \\ l \end{pmatrix} \right] \right|$$

- typical resampling detectors employ a frequency domain **peak detector**

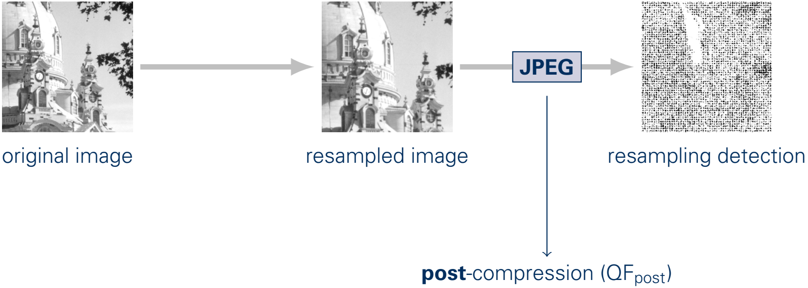
Notation


original image

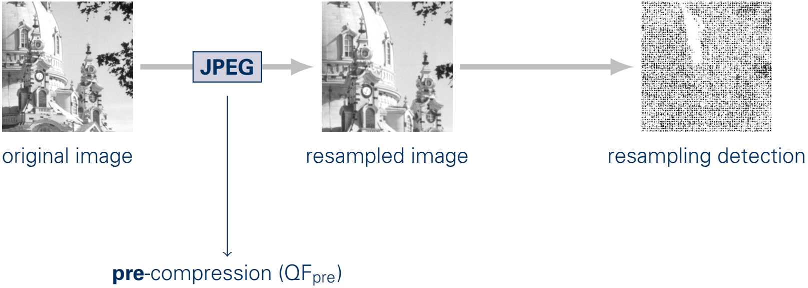

resampled image


resampling detection

Notation


original image
resampled image
JPEG
resampling detection
post-compression (QF_{post})

Notation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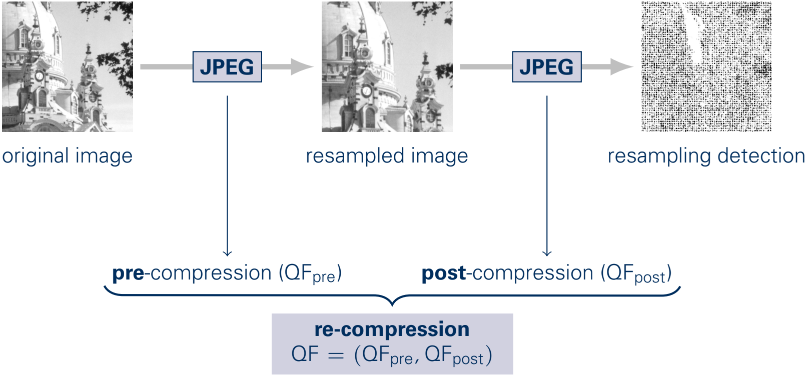
JPEG
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pre-compression (QF_{pre})
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re-compression
$QF = (QF_{pre}, QF_{post})$

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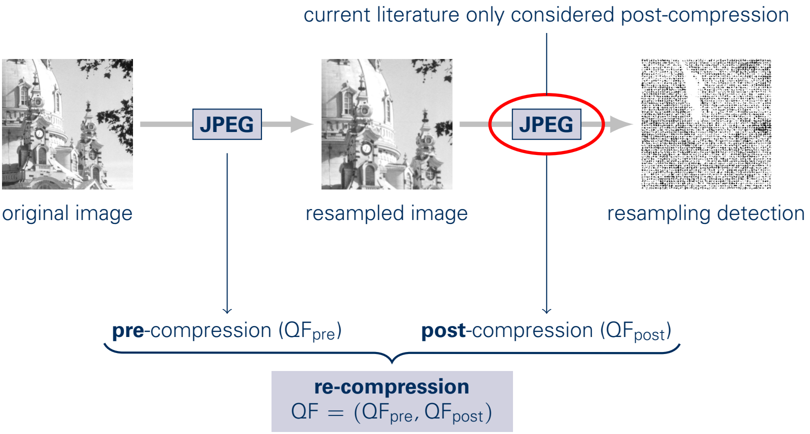

current literature only considered post-compression
JPEG
JPEG
original image
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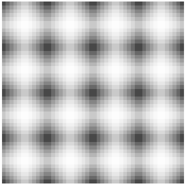
JPEG post-compression

- resampling detectors suffer from **severe performance loss** after post-compression



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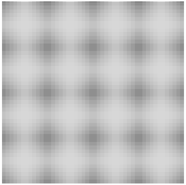

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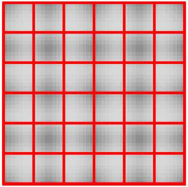
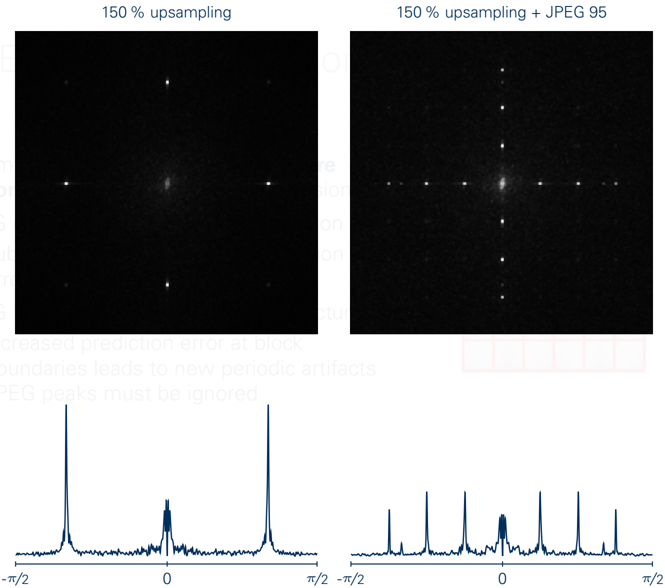
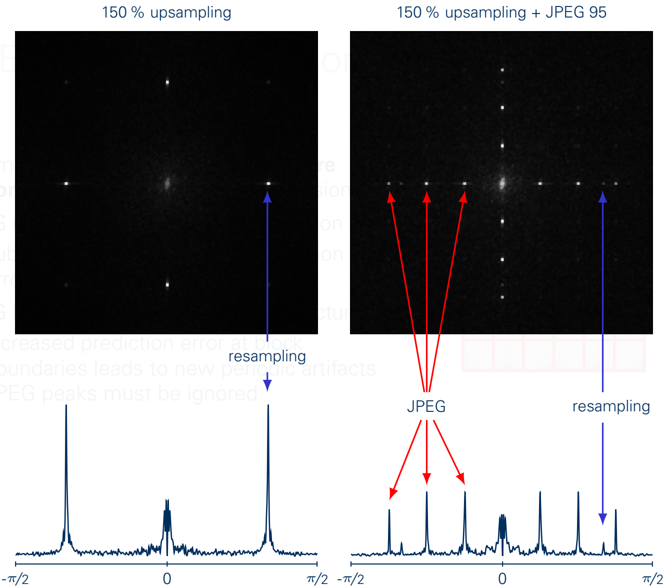
  - JPEG peaks must be ignored




150 % upsampling
150 % upsampling + JPEG 95
-π/2
0
π/2
-π/2
0
π/2



150 % upsampling
150 % upsampling + JPEG 95
resampling
JPEG
resampling
-π/2
0
π/2
-π/2
0
π/2

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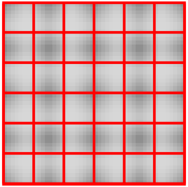
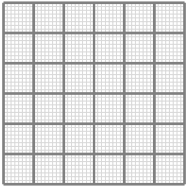


- current literature concludes that resampling detection under moderate JPEG post-compression ($QF_{post} < 95$) is practically **impossible**
  [Popescu & Farid, 2005], [Mahdian & Saic, 2008]

JPEG (p)re-compression

- digital images are often already in JPEG format before being further processed



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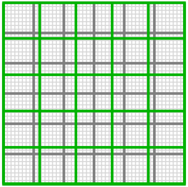

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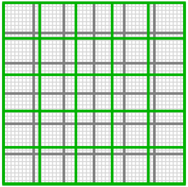
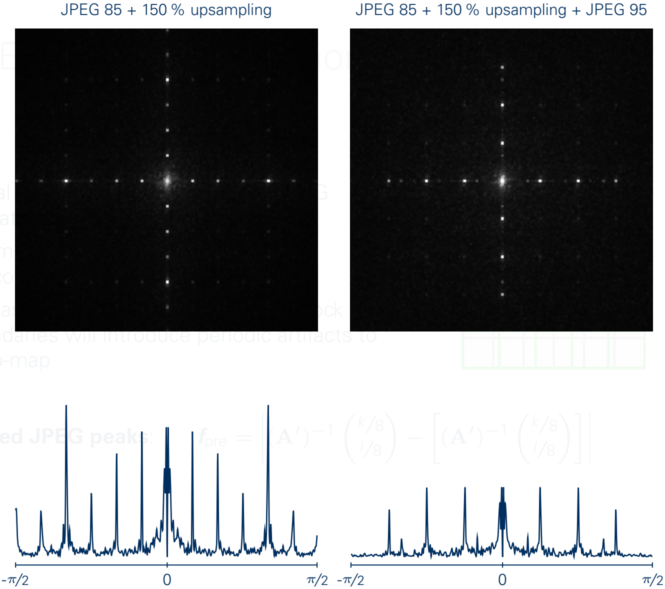
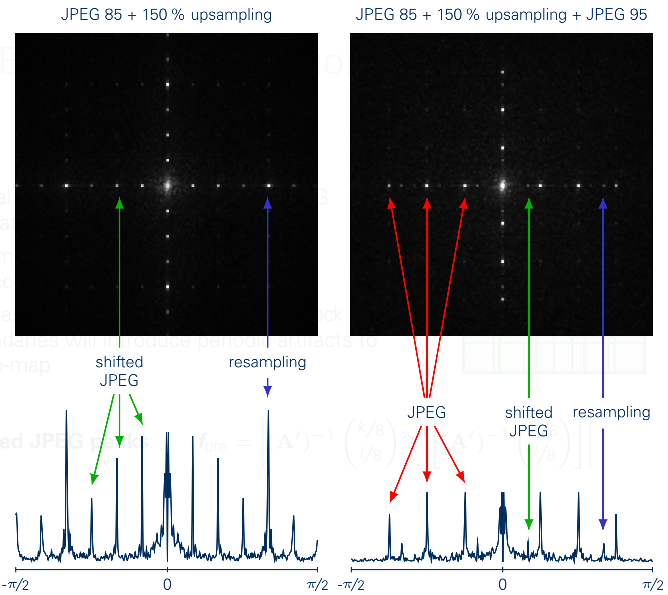


- **shifted JPEG peaks**: $$\boldsymbol{f}_{\text{pre}} = \left| (\mathbf{A}')^{-1} \begin{pmatrix} k/8 \\ l/8 \end{pmatrix} - \left[(\mathbf{A}')^{-1} \begin{pmatrix} k/8 \\ l/8 \end{pmatrix} \right] \right|$$


JPEG 85 + 150 % upsampling
JPEG 85 + 150 % upsampling + JPEG 95
-π/2
0
π/2
-π/2
0
π/2



JPEG 85 + 150 % upsampling
JPEG 85 + 150 % upsampling + JPEG 95
shifted JPEG
resampling
JPEG
shifted JPEG
resampling
-π/2
0
π/2
-π/2
0
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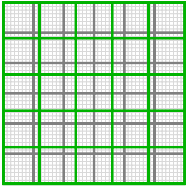

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- depending on the pre-compression quality, shifted JPEG peaks can be more robust to post-compression than resampling peaks
  - resampling detection in re-compressed images **benefits** from additional peaks!

Frequency Domain Detection Procedure

- periodic resampling artifacts can be best measured in the frequency domain

General Procedure

- **pre-processing** to reduce disturbing low-frequency components

- **decision** based on the existence of distinct peaks

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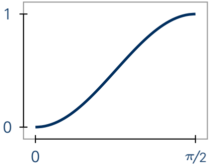

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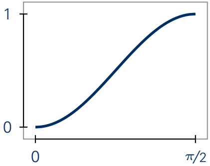

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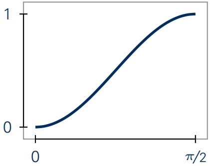

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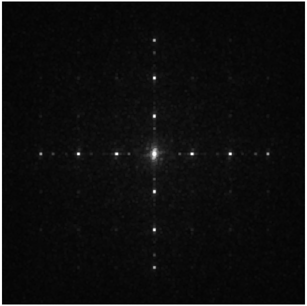
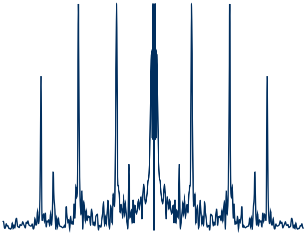
exhaustive search

best for one distinct peak

Pre-processing

- input: DFT of the p-map, $P = \text{DFT}(\text{p-map})$





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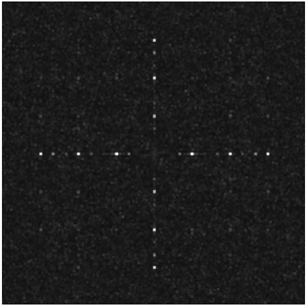

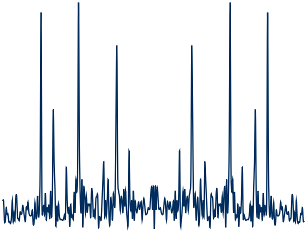

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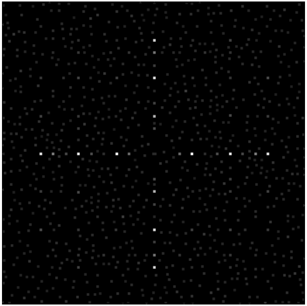

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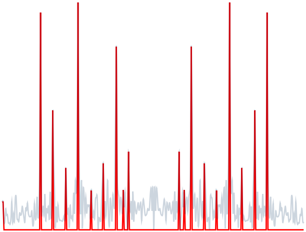
$$P_m(\boldsymbol{f}) = \begin{cases} P_n(\boldsymbol{f}) & \text{if } P_n(\boldsymbol{f}) = \max\limits_{\boldsymbol{w}\in\{-W,\dots,W\}^2} P_n(\boldsymbol{f}+\boldsymbol{w}) \\ 0 & \text{else.} \end{cases}$$



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- **remove JPEG post-compression peaks**

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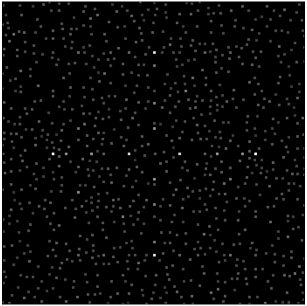
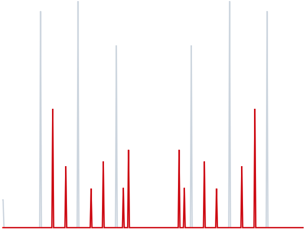
  $({}^{k}/_{8}\,,\ {}^{l}/_{8}),\ (k,l) \in \{-4,\ldots,4\}^2$





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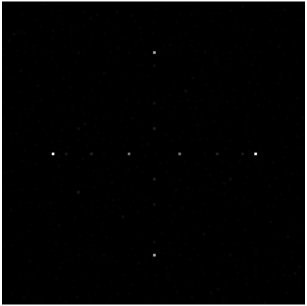
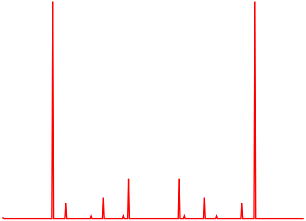
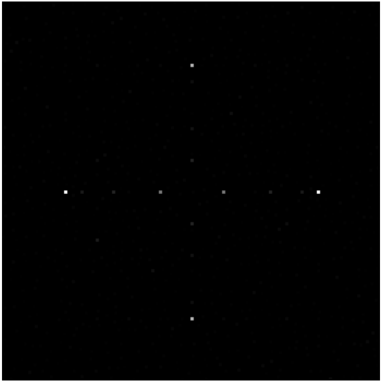
- **gamma correction**

$$P_\gamma = \max(P_m) \cdot \left(\frac{P_m}{\max(P_m)} \right)^\gamma$$





Decision Making



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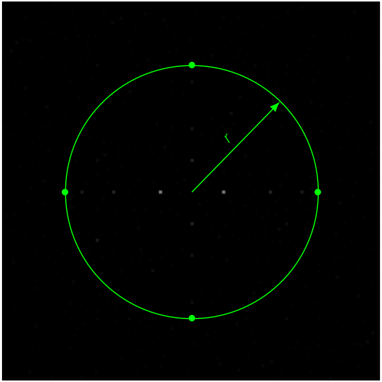
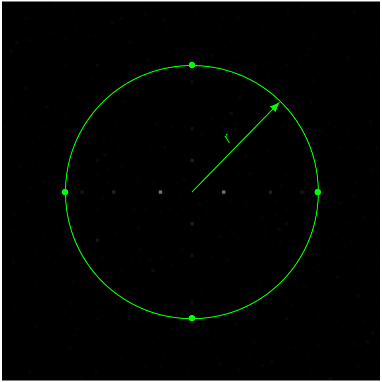


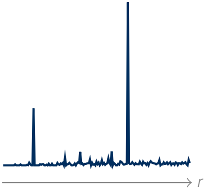
- resampling leads to several resampling and shifted JPEG peaks
- under basic geometric transformations (scale, rotate, shear), these peaks are arranged in groups of at most 4 symmetric peaks with the same distance from the DC frequency
- **decision criterion:** $\delta = \max_{r>r_t} \Sigma_r \Big/ \operatorname{median}_{r>r_t} \Sigma_r$

Decision Making



- resampling leads to several resampling and shifted JPEG peaks
- under basic geometric transformations (scale, rotate, shear), these peaks are arranged in groups of at most 4 symmetric peaks with the same distance from the DC frequency
- **decision criterion:**
  $\delta = \max\limits_{r>r_t} \Sigma_r \,/\, \operatorname*{median}\limits_{r>r_t} \Sigma_r$

sum of the 4 maximum peaks on each radius r



Experimental Setup

- test database consists of 200 never-compressed images (1024×1024) from the **'Dresden Image Database'** [Gloe & Böhme, 2010]
- bilinear resizing, JPEG pre- and post-compression using ImageMagick's `convert`

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21 scaling factors in the range $[0.5, \ldots, 2]$

$\text{QF} = \{40, 50, 70, 75, 80, 90, 95, 98, 100\}^2$

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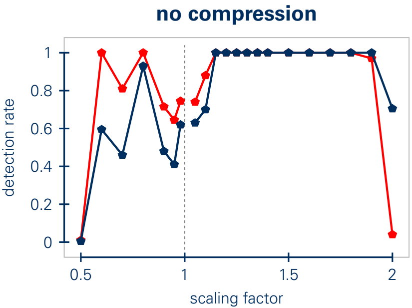
- p-map is calculated from the luminance channel for two fixed linear filter masks [Kirchner, 2008]:

$$\boldsymbol{\alpha}\mathbf{8} = \begin{bmatrix} -1/4 & 1/2 & -1/4 \\ 1/2 & 0 & 1/2 \\ -1/4 & 1/2 & -1/4 \end{bmatrix}, \qquad \boldsymbol{\alpha}\mathbf{4} = \begin{bmatrix} 0 & 1/4 & 0 \\ 1/4 & 0 & 1/4 \\ 0 & 1/4 & 0 \end{bmatrix}$$

- altogether more than **400 000** detector runs (size of analyzed region fixed to 512×512)

filter masks: $\boldsymbol{\alpha_4}$ $\boldsymbol{\alpha_8}$ (FAR = 1 %)

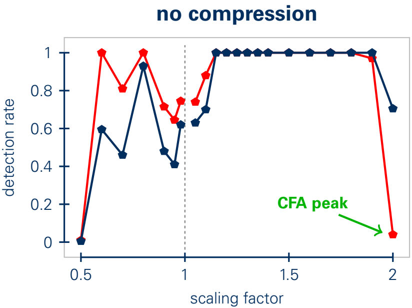
Baseline Detection Results



- reliable detection for a wide range of scaling factors
- upsampling better detectable than downsampling

filter masks:
α_4 α_8
(FAR = 1 %)

Baseline Detection Results



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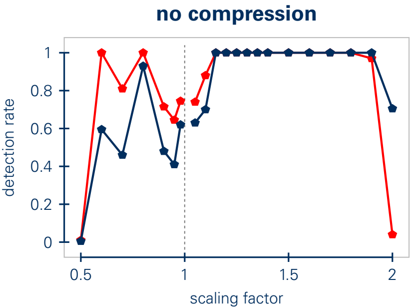

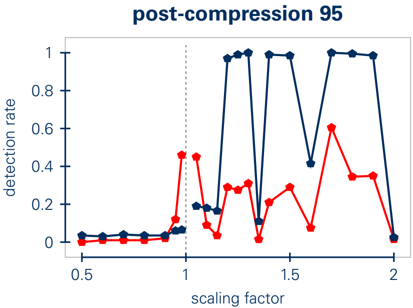

- reliable detection for a wide range of scaling factors
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- JPEG post-compression decreases detectability
- downsampling not detectable

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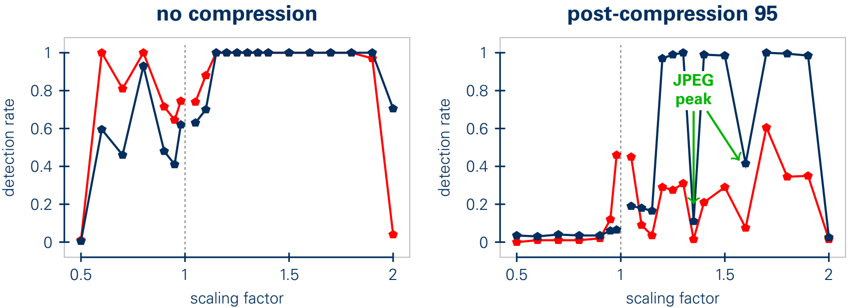

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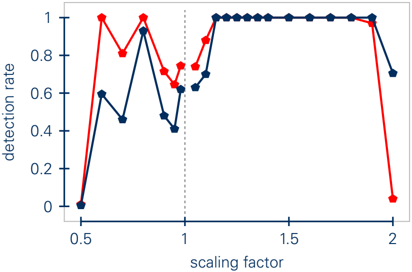
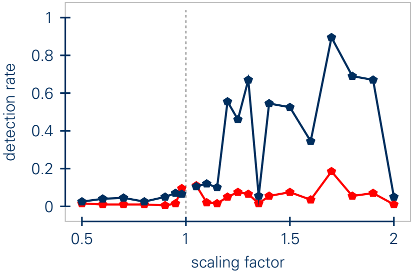


post-compression 90



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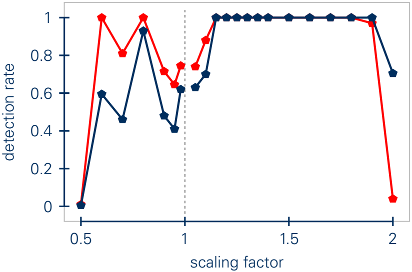

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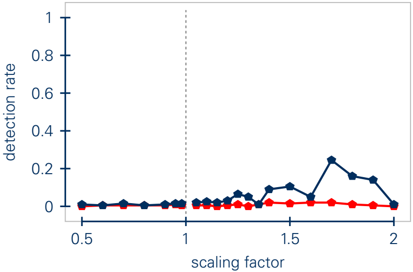

- reliable detection for a wide range of scaling factors
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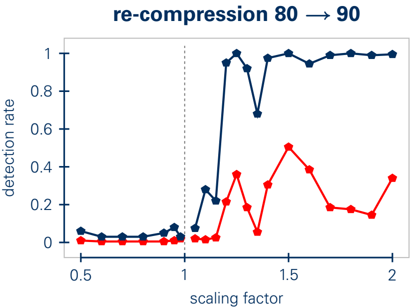
- JPEG post-compression decreases detectability
- downsampling not detectable (as per upsampling for $QF_{post} < 90$)

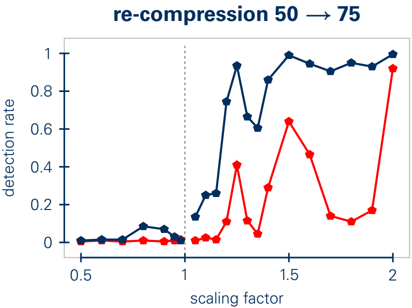
Re-Compression Detection Results

filter masks:
α_4 α_8
(FAR = 1 %)



- JPEG re-compression improves performance for upsampling

Re-Compression Detection Results



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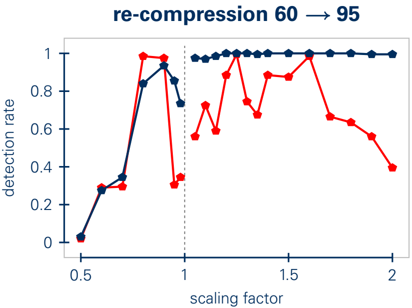
Re-Compression Detection Results

filter masks:
α_4 α_8
(FAR $= 1\,\%$)



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- downsampling only detectable for low pre-compression quality

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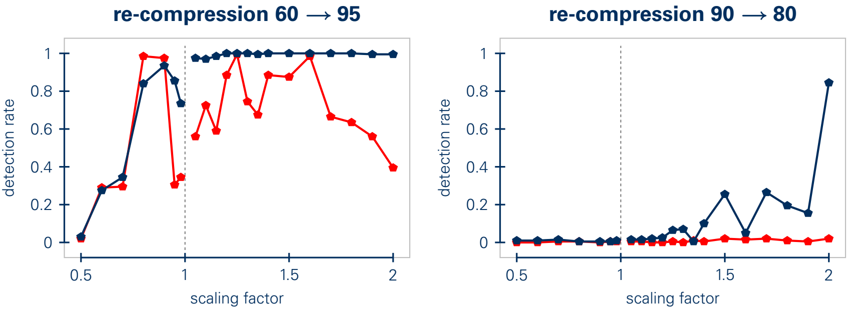

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- downsampling only detectable for low pre-compression quality
- pre-compression should be lower than (at least equal to) post-compression quality

Concluding Remarks

- resampling detection in re-compressed images is of **high practical relevance**
  - images are often already JPEGs before being further processed
- reliable detection after JPEG compression was believed to be a lost cause

but: (p)re-compression introduces additional artifacts in terms of **shifted JPEG peaks** in the p-map's spectrum

- results from 400 000 detector runs show notable **performance gain** for upsampling compared to the post-compression scenario

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- sufficient size of the analyzed image region is critical to distinguish resampling and post-compression peaks

- concept of shifted peaks also applies to CFA interpolation peaks

Thanks for your attention

Questions?

Matthias Kirchner, Thomas Gloe
Technische Universität Dresden

Matthias Kirchner gratefully receives a doctorate scholarship from Deutsche Telekom Stiftung, Bonn, Germany.

Pre- and Post-Compression Quality

- detection rates for 150 % upscaling (FAR = 1 %)

post-compression quality

pre-compression quality	40	50	60	70	75	80	90	95	98	100
40	70	83.5	94.5	99.5	99.5	99	100	100	100	99.5
50	8.5	61	82.5	98	99	99.5	99.5	99	99.5	99.5
60	2	11.5	63	96	100	100	100	100	100	100
70	1.5	2	7	86	98	99.5	100	100	100	100
75	4	3	2.5	55	94	95.5	100	100	100	100
80	3	1.5	1.5	24	71	91.5	100	100	100	100
90	2.5	2.5	1.5	5.5	10	25.5	99.5	100	100	100
95	3	2.5	2	7	11	11.5	87.5	100	100	100
98	2.5	3	2.5	5.5	9	10	56	99.5	100	100
100	2	3	3	5.5	8.5	10	58.0	99	100	100
*	2.5	2	2.5	5	9	10.5	52.5	98.5	100	100