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Increasing Trust in Image Analysis by Detecting Trellis Quantization in JPEG Images

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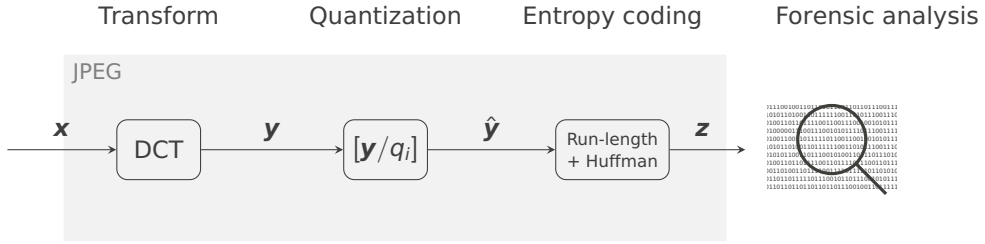
Digital Image Forensics

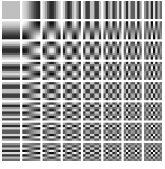
Methods for the verification of **image authenticity**, **source attribution**, and the detection of **traces of manipulation**

Image content

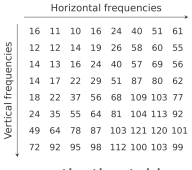
Statistical image properties

The Compression Pipeline

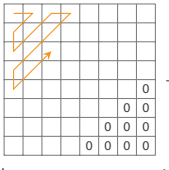




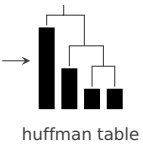
2D base vectors



quantization table

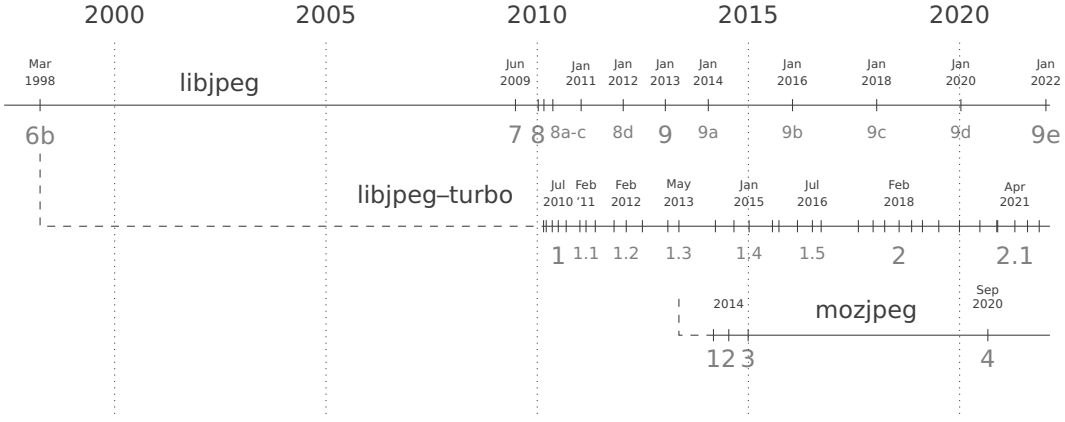


zig–zag arrangement



huffman table

JPEG Compressor Timeline



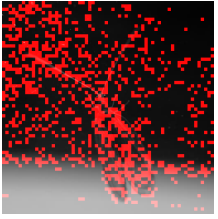
Beneš, M., Hofer, N., and Böhme, R. Know Your Library: How the libjpeg Version Influences Compression and Decompression Results. *IH&MMSEC*. ACM, 2022, pp. 19–25.

Do JPEG Implementations Differ? Yes!

libjpeg v6b

libjpeg-turbo

MozJPEG

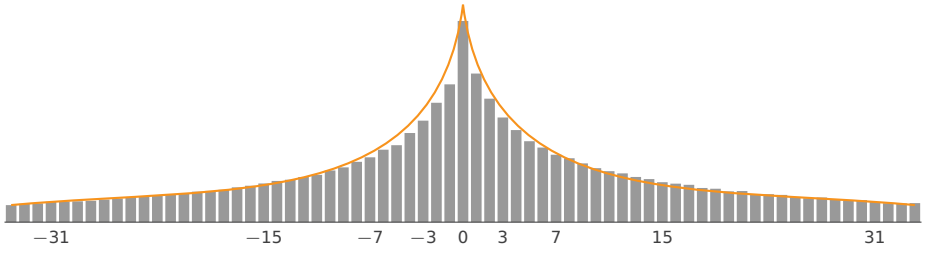


Red highlights: 8×8 pixel blocks containing numerical differences in at least one DCT coefficient.

Outline

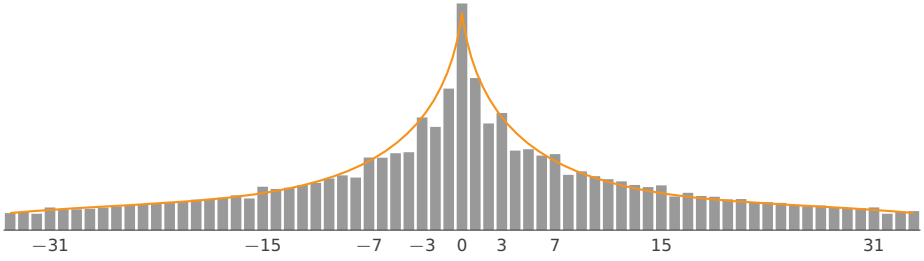
- **Forensic implications of JPEG optimizations**
- Detection of artifacts from JPEG optimizations

Histogram of DCT Coefficients



First AC subband of 100 **baseline** grayscale images (QF 99).

Histogram of DCT Coefficients



First AC subband of 100 **trellis quantized** grayscale images (QF 99).

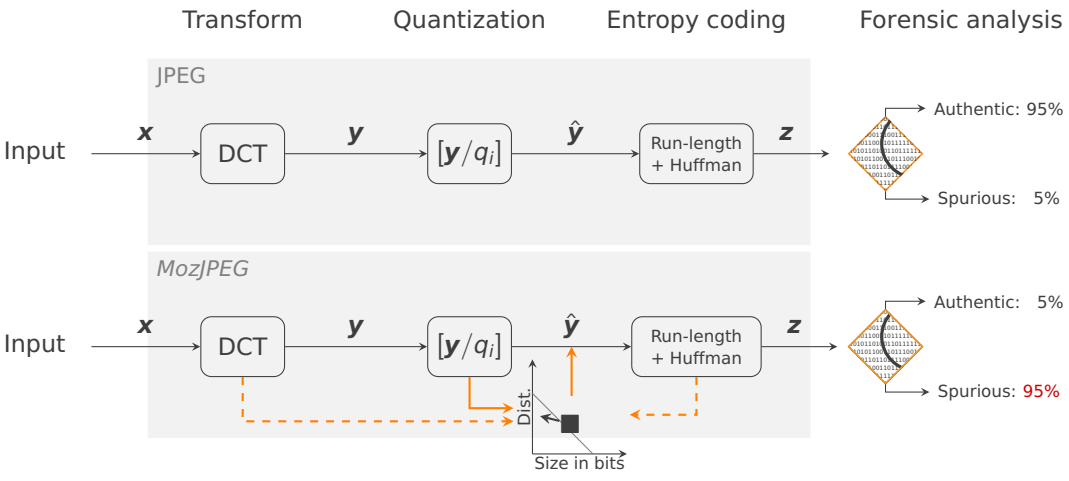
Detection of Steganography in *MozJPEG* Images

Performance of EfficientNet-B0 detectors			
Embedding	*libjpeg-turbo*		*MozJPEG*
	Baseline acc.	FPR	FPR
nsF5 (Fridrich et al., 2007.)	99%	1%	**99%**
UERD (Guo et al., 2015.)	93%	4%	**43%**
J-UNIWARD (Holub et al., 2014.)	91%	8%	**94%**

1 000 ALASKA2 test images of QF 75 and 0.4 bits per non-zero AC coefficients (bpnzAC) embedding.

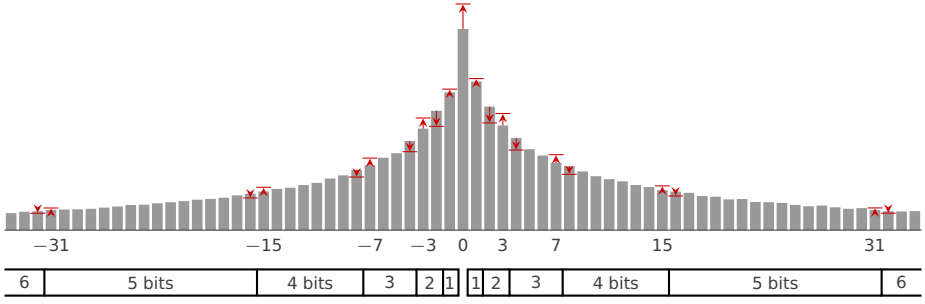
ImageNet-pretrained EfficientNet-B0 models: 32 batch size, 0.25 dropout rate, 0.0001 learning rate, Adam optimizer.

The Compression Pipeline – Trellis Quantization



Histogram of DCT Coefficients

Trellis quantization amplifies **zeros** and **maximum values** of shorter encoding.



Cost of encoding a DCT block when replacing non-zero coefficients with the *highest* value of every lower size group.

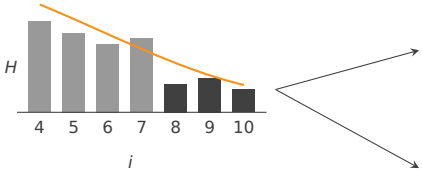
First AC subband of 100 grayscale images (QF 99).

Outline

- Forensic implications of JPEG optimizations
- **Detection of artifacts from JPEG optimizations**

Detection of Trellis Artifacts

Methods



Analytical modelling

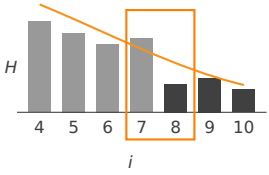
- Calibration
- “Vampire” neighborhoods

Statistical learning

- Cartesian calibration
- Vampire neighborhoods
- JRM features

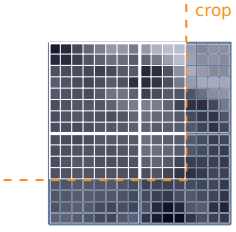
Analytical Detection of Trellis Artifacts

Calibration



$$\alpha_i = \frac{H_i - \hat{H}_i}{\hat{H}_{i+1}}$$

$$\alpha_{\mathcal{C}} = \sum_{i \in \mathcal{C}} (\alpha_i - \alpha_{i+1})$$



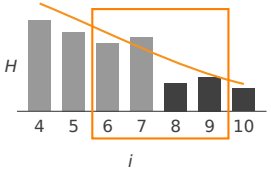
Calibration

- Estimate the histogram of DCT coefficients before trellis quantization.
- α: relative frequency of coefficients being changed to inner neighbors.

Fridrich, J., Goljan, M., and Hogea, D. Steganalysis of JPEG Images: Breaking the F5 Algorithm. *IH*. Springer, 2003, pp. 310–323.

Analytical Detection of Trellis Artifacts

Vampire neighborhoods



$$\beta_i = H_i - \frac{H_{i-1}+H_{i+2}}{2} + H_{i+1} - \frac{H_{i-1}+H_{i+2}}{2}$$

$$\beta_{\mathcal{C}} = \sum_{i \in \mathcal{C}} \left(H_i - H_{i-1} + H_{i+1} - H_{i+2} \right)$$

Vampire neighborhoods

- Measure deviation of monotonous histogram at candidate pairs . . .
- . . . with regard to candidate neighborhoods.

Statistical Detection of Trellis Artifacts

Ensemble of Fisher linear discriminant base learners

Calibration

- candidate neighborhood features of calibrated and input images
- feature dimensions: $4 \times 8 \times 10 \times 2 = 640$

Vampire neighborhoods

- candidate neighborhood features of input images
- feature dimensions: $4 \times 8 \times 10 = 320$

JRM features

- JRMs model dependencies between adjacent subbands
- features from an ensemble of JPEG Rich Models of 11 255 dimensions

Fridrich, J., Kodovský, J. Rich Models for Steganalysis of Digital Images. *TIFS*. IEEE, 2012, pp. 868–882.

Detection of Trellis Artifacts

Detection accuracies

	Analytic detectors		Learning detectors		
QF	calibration	vampires	calibration	vampires	JRM
100	95%	99%	100%	100%	100%
95	84%	92%	99%	99%	100%
90	80%	88%	99%	98%	100%
85	75%	82%	99%	97%	100%
80	72%	79%	98%	96%	100%
75	71%	76%	98%	96%	99%
50	72%	75%	97%	93%	98%

Test set of 5 000 ALASKA2 images compressed with *MozJPEG v*4.0.3, default compression settings.

Hofer, N. Increasing Trust in Image Analysis by Detecting Trellis Quantization in JPEG Images. *ICIP*. IEEE, 2024.

Conclusion

- Trellis quantization can **compromise the reliability** of forensic methods.
- To **prevent misclassifications** we can **detect trellis artifacts**.

When methods are applied in forensic investigations, we need to be aware of differences of compression implementations in practice.

Thank You

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UNCOVER

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Thank You

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