Steganography and its Detection in JPEG Images Obtained with the "Trunc" Quantizer

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ICASSP 2020

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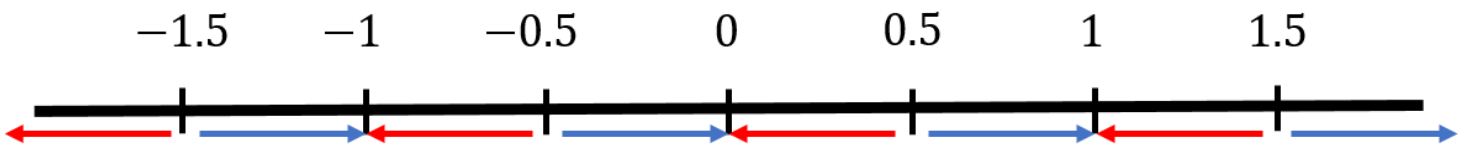
What is Trunc Quantizer?



Round quantizer

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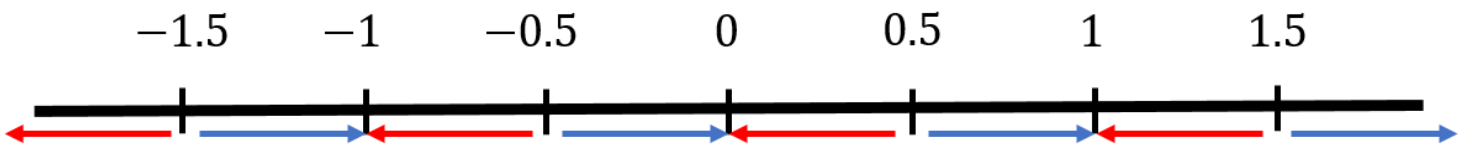

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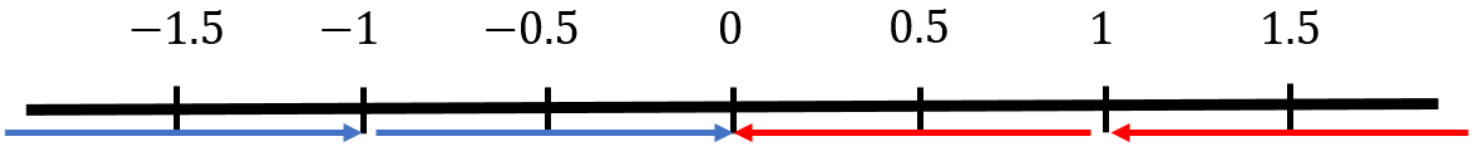
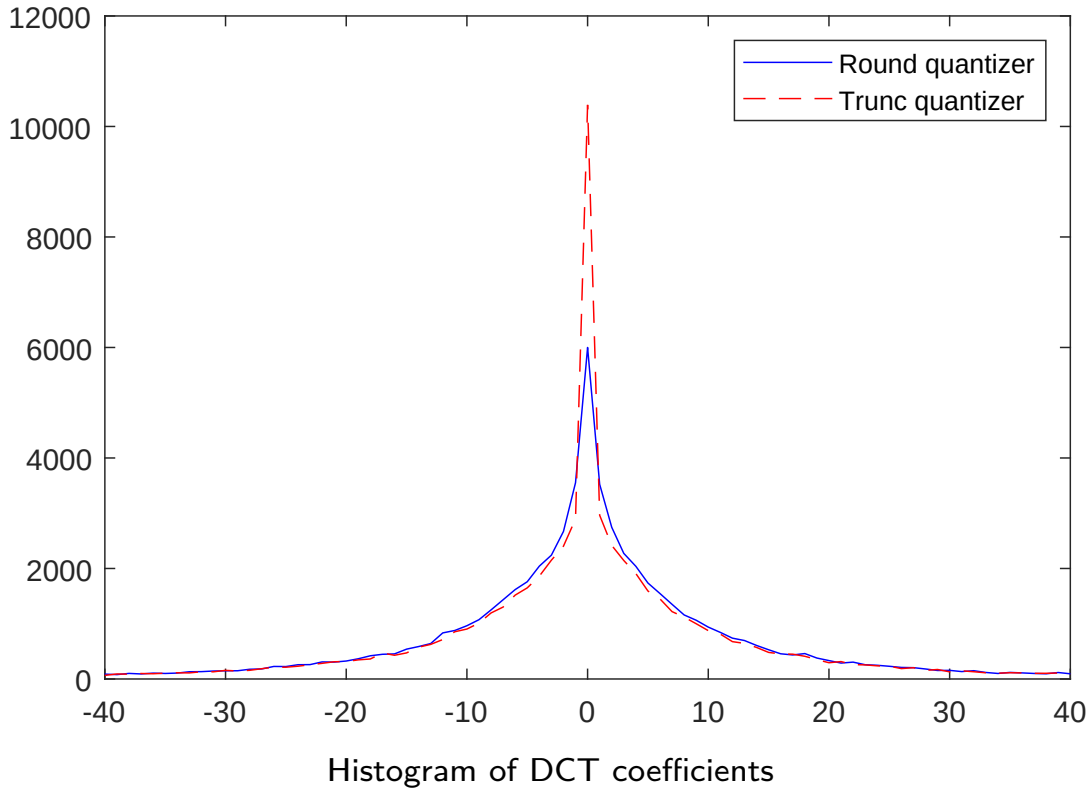


Trunc quantizer

- easier to implement in hardware
- Very common: iPhone 5c, Canon EOS 10D, Samsung Galaxy Tab 3 8.0

Effect of Quantizer on Histogram of DCTs

- One image compressed with quality factor 100 with round and trunc quantizers



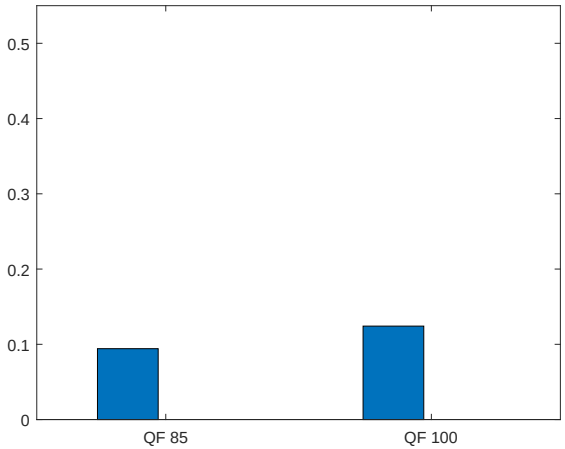
Trunc JPEGs and Steganography

Existence of trunc JPEGs has serious implications both the Steganographer and the Steganalyst:

- Some steganographic schemes (J-UNIWARD, SI-UNIWARD) need to be redesigned to prevent security holes
- Steganalysis also needs to be redesigned for best results

Unaware Steganalyst completely fails

- Training on round JPEGs and testing on trunc JPEGs leads to catastrophic detection failure



Total detection error under equal priors P_{E} of SRNet on J-UNIWARD, 0.4 bpnzac

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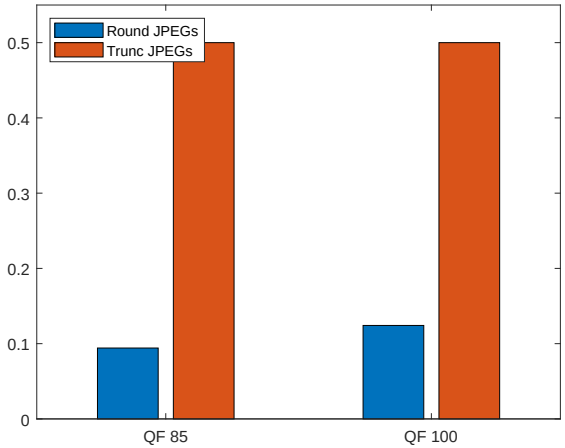

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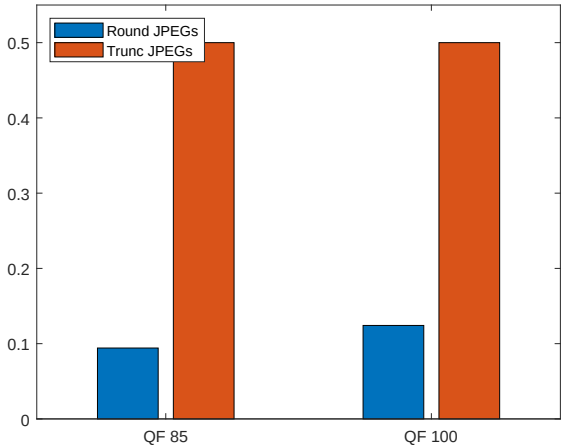

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Failure common across QFs, stego algorithms, detectors

- QFs 75, 76, ..., 100
- SRNet, JRM, GFR
- J-UNIWARD, nsF5, UED
- P_{FA} 99–100%

Experimental Setup

- Dataset: BOSSbase 1.01 + BOWS2, 20,000 grayscale images resized to 256×256
  - Round JPEGs
  - Trunc JPEGs
- TRN / VAL / TST: 10,000BOWS2 + 4,000BOSS / 1,000BOSS / 5,000BOSS
- Stego algorithms: nsF5 (0.2 bpnzac), UED (0.3 bpnzac), J-UNIWARD (0.4 bpnzac)
  - all assumed optimally coded (embedding simulator)

Evaluation Metric

- Accuracy $= 1 - P_{\mathrm{E}}$
  - Total classification error $P_{\mathrm{E}} = \frac{1}{2}(P_{\mathrm{FA}} + P_{\mathrm{MD}})$
  - P_{FA} false alarm rate
  - P_{MD} missed detection
- Detectors
  - SRNet [Boroumand 2018]
  - GFR (Gabor Filter Residual) feature set coupled with ensemble classifier
  - JRM (JPEG Rich Model) feature set coupled with ensemble classifier

Trunc and Round JPEGs can be reliably distinguished

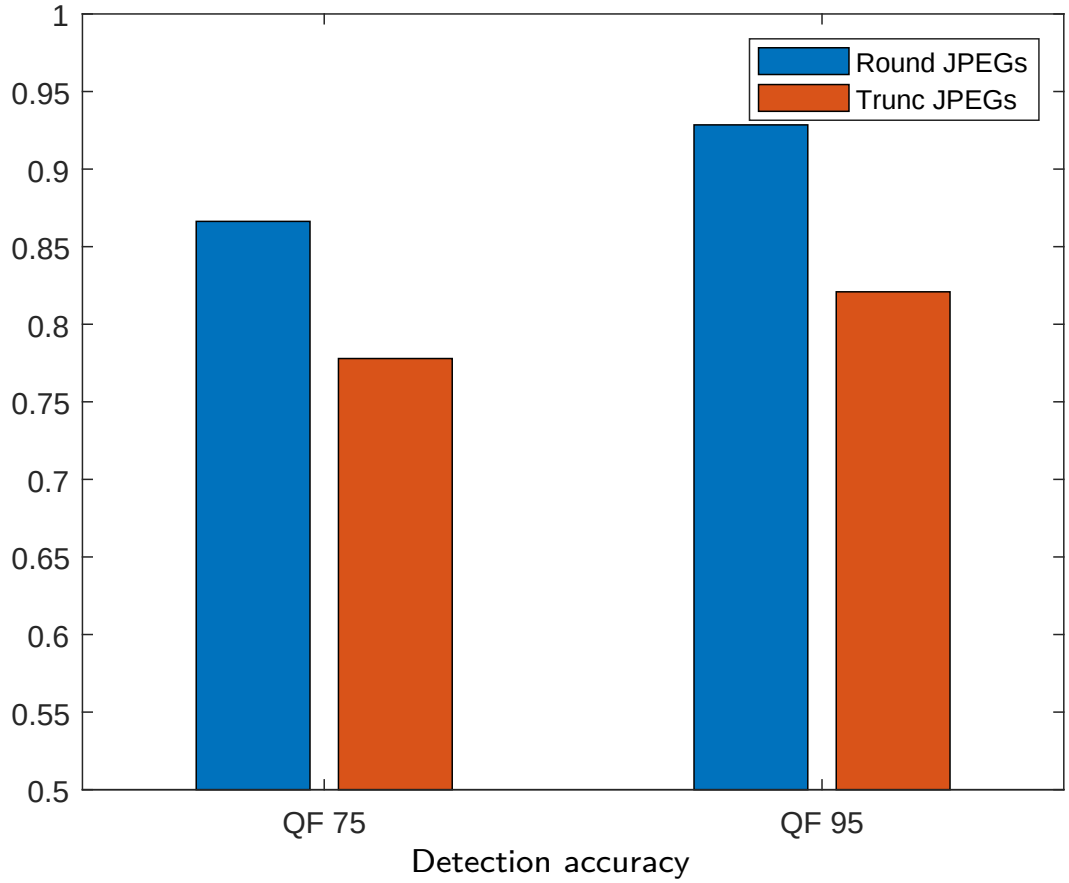
- Train SRNet between Round **covers** and Trunc **covers**
- Accuracy very close to 100%
  - For quality factors 85, 100
  - Even when tested on stego images
- $\Longrightarrow$ one can build separate detectors for each cover source

Effect of Trunc Quantizer on Security

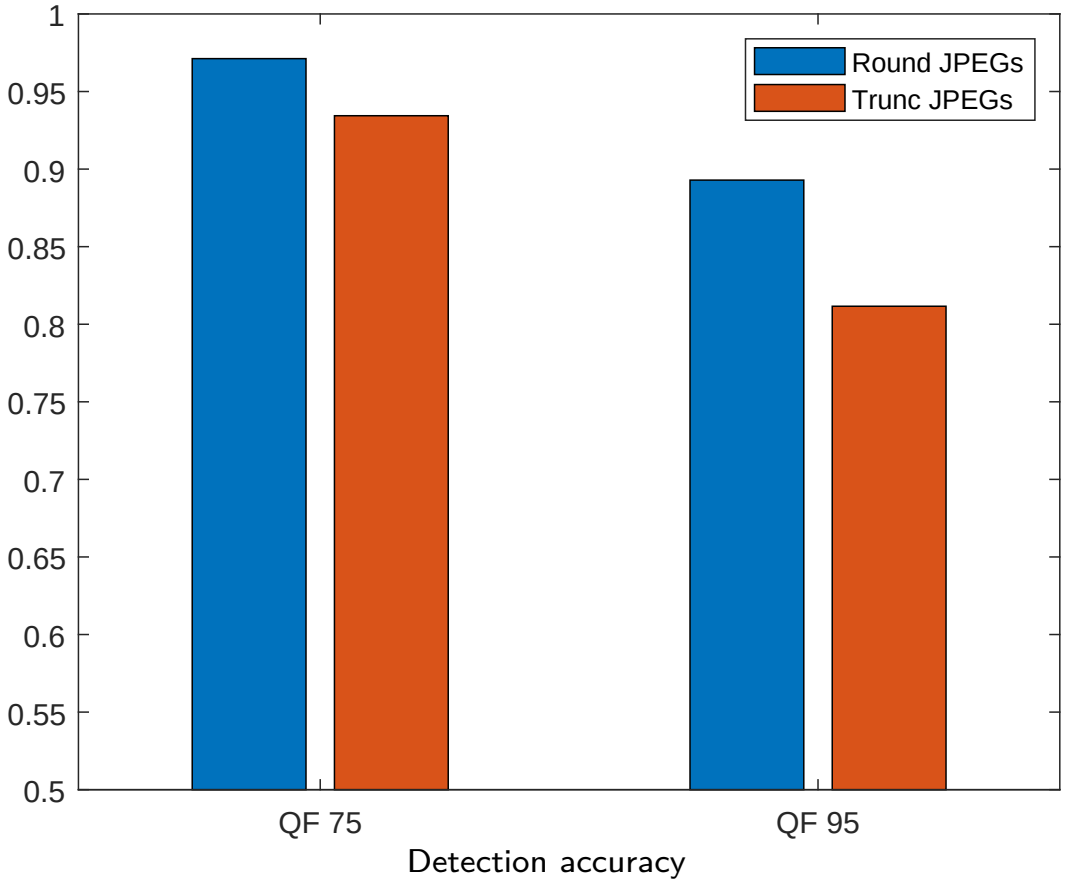
Is it harder or easier to detect stego in round or trunc JPEGs?

- Trunc JPEGs have more zero DCT coefficients
- Thus, for fair comparison, payload for trunc JPEGs was scaled according to Square Root Law
- Conclusions similar for fixed bpnzac and bpp

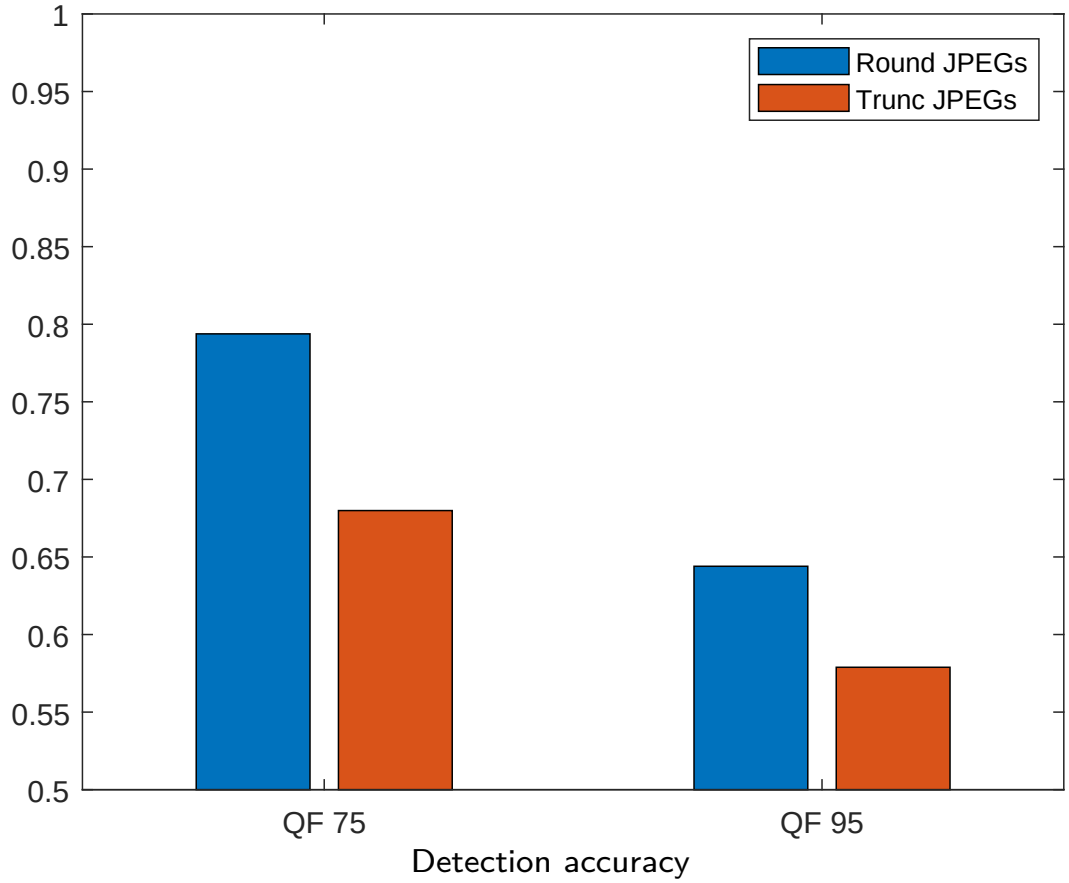
nsF5, 0.2 bpnzac - JRM



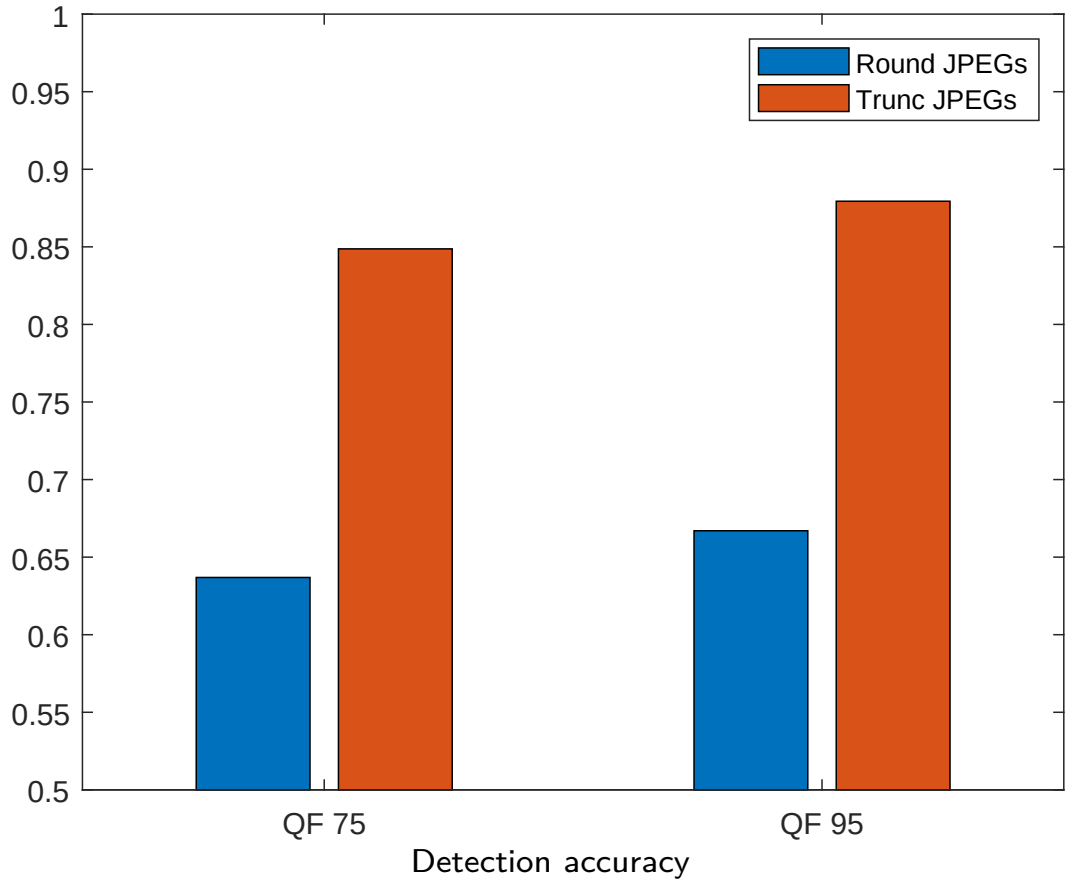
UED, 0.3 bpnzac - SRNet



J-UNIWARD, 0.4 bpnzac - GFR



J-UNIWARD, 0.4 bpnzac - JRM



Wait, what??

Why is J-UNIWARD so detectable in Trunc JPEGs with JRM?

- J-UNIWARD is the only tested algorithm that embeds into zero coefficients
- There are many more zero coefficients in trunc JPEGs

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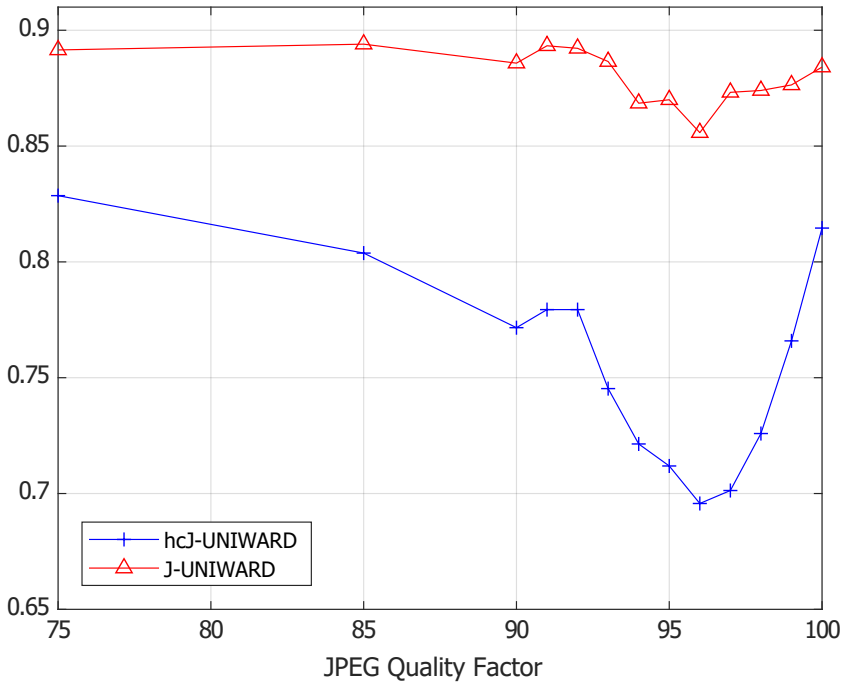
J-UNIWARD embeds **too much** into zero coefficients in trunc JPEGs!

J-UNIWARD for trunc JPEGs

- Change embedding costs of zero coefficients, so that on average the number of zero coefficients is preserved
  - hcJ-UNIWARD (J-UNIWARD with **h**istogram **c**orrection)
- Achieved by increasing the cost of zeros $\rho_0 \to \tilde{\rho}_0 = \eta\rho_0$ by factor $\eta = \frac{\rho_1}{\rho_0} + \frac{1}{\lambda\rho_0} \log\left(\frac{2h[0]}{h[1]+h[-1]}\right)$ (details in the paper)

hcJ-UNIWARD vs J-UNIWARD

- Three detectors: SRNet, JRM, union of SRNet features (512-dim input to IP layer) concatenated with JRM features coupled with ensemble classifier



Accuracy of the best detector in trunc JPEGs at 0.4 bpnzac

Side information

- Heuristic side-informed schemes for round JPEGs cannot be used
- Need to take into account
  - different range of rounding errors, $0 \leq e < 1$ for positive DCTs
  - increased number of zero coefficients

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- Heuristic side-informed schemes for round JPEGs cannot be used
- Need to take into account
  - different range of rounding errors, $0 \leq e < 1$ for positive DCTs
  - increased number of zero coefficients
- Proposed SI-UNIWARD for trunc JPEGs
  - Minimum-perturbation modulation (see paper)
  - No need for histogram correction

bpnzac	1	0.8	0.6	0.4
QF75	0.8164	0.7436	0.6485	0.5653
QF95	0.7984	0.6972	0.6050	0.5420

Detection accuracy with SRNet

Conclusions

- Steganalyst unaware of trunc JPEGs will expereince 100% false alarm
- Easy fix by training a detector for each source (detecting quantizer type is reliable)
- Trunc JPEGs are more friendly for steganographers
  - algorithms that embed into zero coefficients need to be adjusted by increasing the cost of modifying zeros
- Redesigned side-informed schemes to take into account different range of rounding errors