Influence of Embedding Strategies on Security of Steganographic Methods in the JPEG Domain

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Three Approaches to JPEG Steganography

- Direct DCT coefficients manipulation
  - Input: JPEG image
  - Embedding operation (how we flip)
  - Selection channel (where we flip)
  - Syndrome coding (matrix embedding, wet paper codes)
- Embedding with side information
  - Input: RAW uncompressed image
  - Selection channel
  - Syndrome coding
- Robust embedding in alternative domain
  - Input: RAW or JPEG image
  - YASS (*Solanki et al. 2007*)

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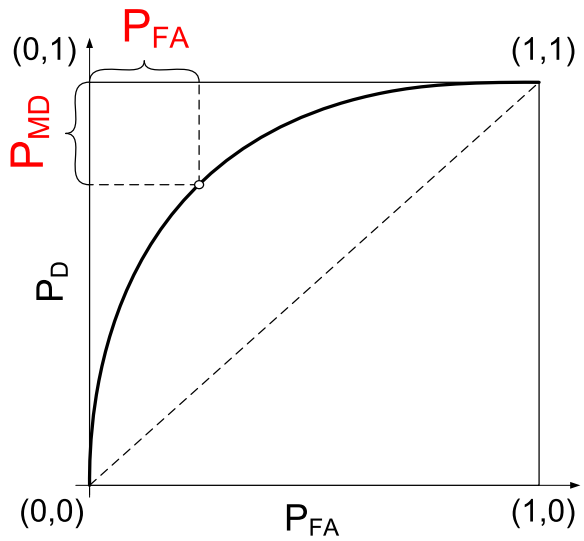
Evaluating Security

- Blind steganalyzer (*Pevný et al., SPIE 2007*)
  - SVM machine with Gaussian kernel
  - 274 merged extended DCT and Markov features
  - 6000 images, single compressed greyscale 80% JPEGs
  - On average 3.2 MPixels, cca 540,000 nz DCT coeffs
  - 3500 training images & 2500 testing images

- Minimal total detection error

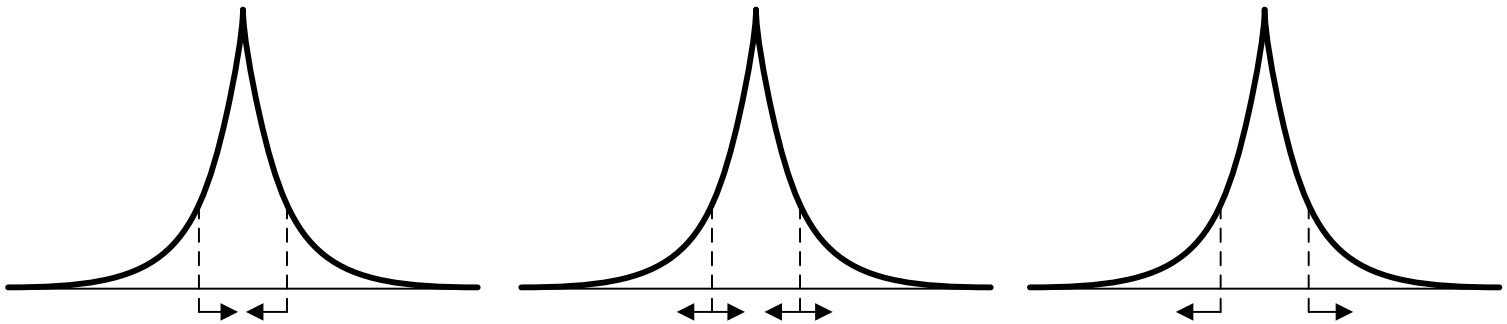
$$P_E = \min \frac{1}{2} \cdot (P_{FA} + P_{MD})$$



Influence of Embedding Operation

Three types of embedding operations involved:

- F5 embedding operation
- ± 1 embedding
- –F5 embedding operation



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distortion budget nsF5 would do when embedding 0.10 bpac

Detection error P_E

nsF5 payload (bpac)	0.05	0.10	0.15	0.20
Change rate β	0.008	0.016	0.028	0.040
F5	26.31	11.17	5.01	2.29
± 1	10.16	2.09	0.46	0.12
–F5	4.01	0.32	0.12	0.06

nsF5 (*Fridrich et al. ACM 2007*)

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Theorem

In the absence of any information about the unquantized DCT coefficients, the F5 embedding operation minimizes the total distortion due to quantization and embedding.

Influence of Texture

Drawbacks of adaptive selection channels:

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- Vulnerability to targeted attacks

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Our block based measure of texture $\rightarrow$ $\boxed{t(B) = \sum_{\Omega}(1 - \delta(z_i, z_j))}$

B ... 8×8 block of pixels
z_i ... pixel value at position i
Ω ... set of all the neighbouring pixel pairs (z_i, z_j)
δ ... indicator function

$$\delta(x, y) = 0 \quad \text{for } x \neq y$$
$$\delta(x, x) = 1$$

Spatial Domain

Influence of Texture

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- Less powerful matrix embedding
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Our block based measure of texture $\longrightarrow$ $t(B) = \sum_{\Omega}(1 - \delta(z_i, z_j))$

Detection error P_E

Change rate β	0.008	0.016	0.028	0.040
10% most textured blocks	26.32	11.57	5.27	3.23
25% most textured blocks	25.34	10.57	4.69	2.65
50% most textured blocks	25.88	11.71	4.63	2.51
Regardless the texture	26.31	12.21	5.01	2.29

Influence of Spatial Frequency

1	2	3	4	5	6		
2	3	4	5	6			
3	4	5	6				
4	5	6					
5	6						
6							

8×8 DCT block

Influence of Spatial Frequency

Detection error P_E

Change rate β	0.008	0.016	0.028	0.040
Diagonals 1-3	26.46	13.59	6.50	3.11
Diagonals 2-4	25.96	11.87	5.19	2.53
Diagonals 3-5	20.45	7.40	2.43	0.92
Diagonals 4-6	14.86	5.81	2.83	0.92

Matrix embedding vs spatial frequency ?

Influence of Spatial Frequency

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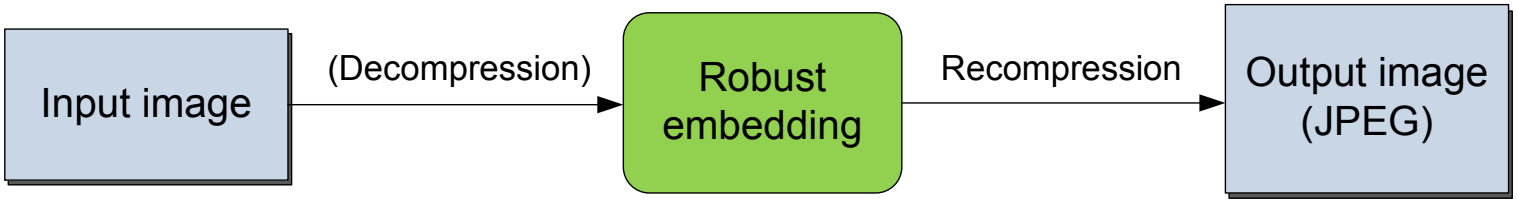
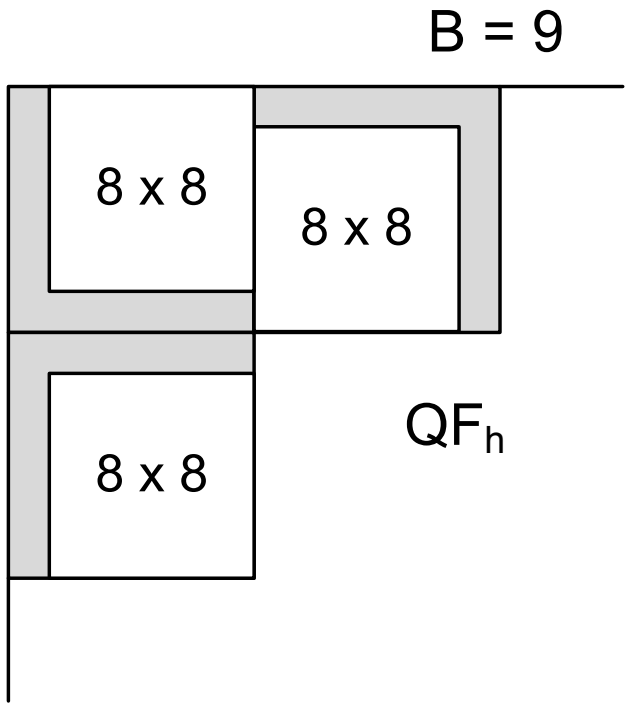
Diagonals 4-6	14.86	5.81	2.83	0.92

Real embedding schemes

Payload (bpac)	0.05	0.10	0.15	0.20
nsF5 in 1-3	25.18	11.93	6.26	5.25
nsF5 in 1-4	27.77	13.85	7.22	3.25
nsF5 in 1-5	26.68	13.27	6.94	2.93
nsF5 (everywhere)	26.31	11.17	5.01	2.29

How YASS Works





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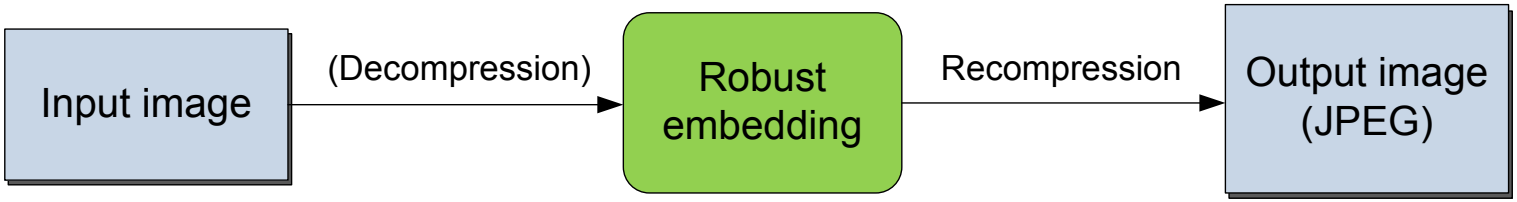
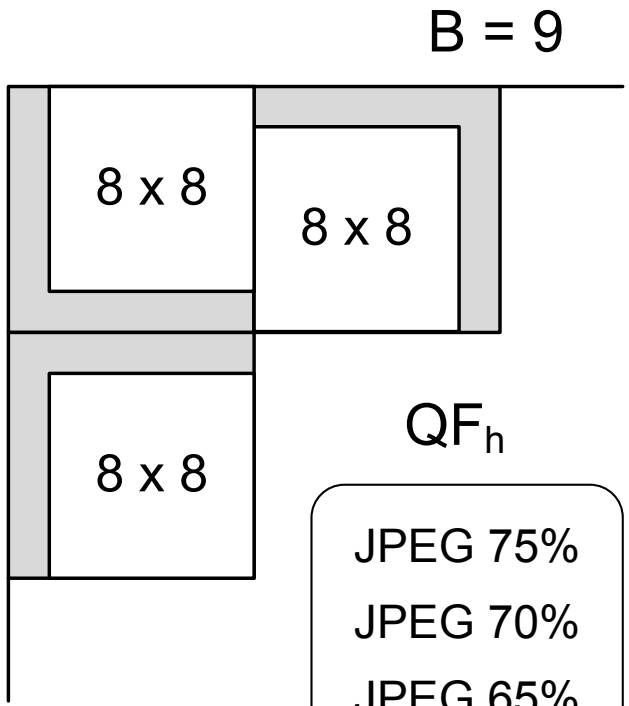


PNG
JPEG 100%
JPEG 90%
JPEG 75%

- 6000 images
- smaller side 512 pixels

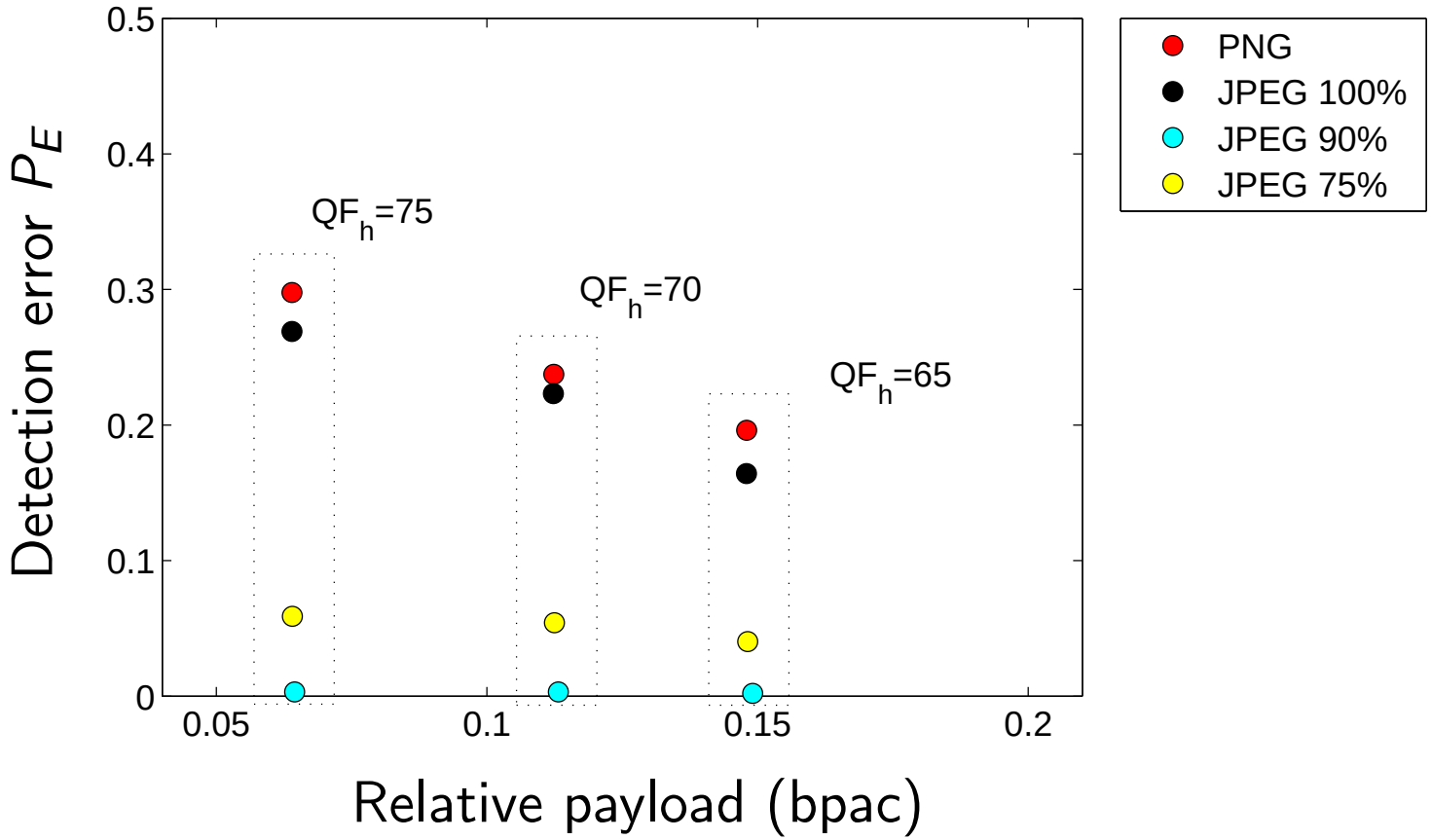


JPEG 75%

QF_h

JPEG 75%
JPEG 70%
JPEG 65%

Experimental Results



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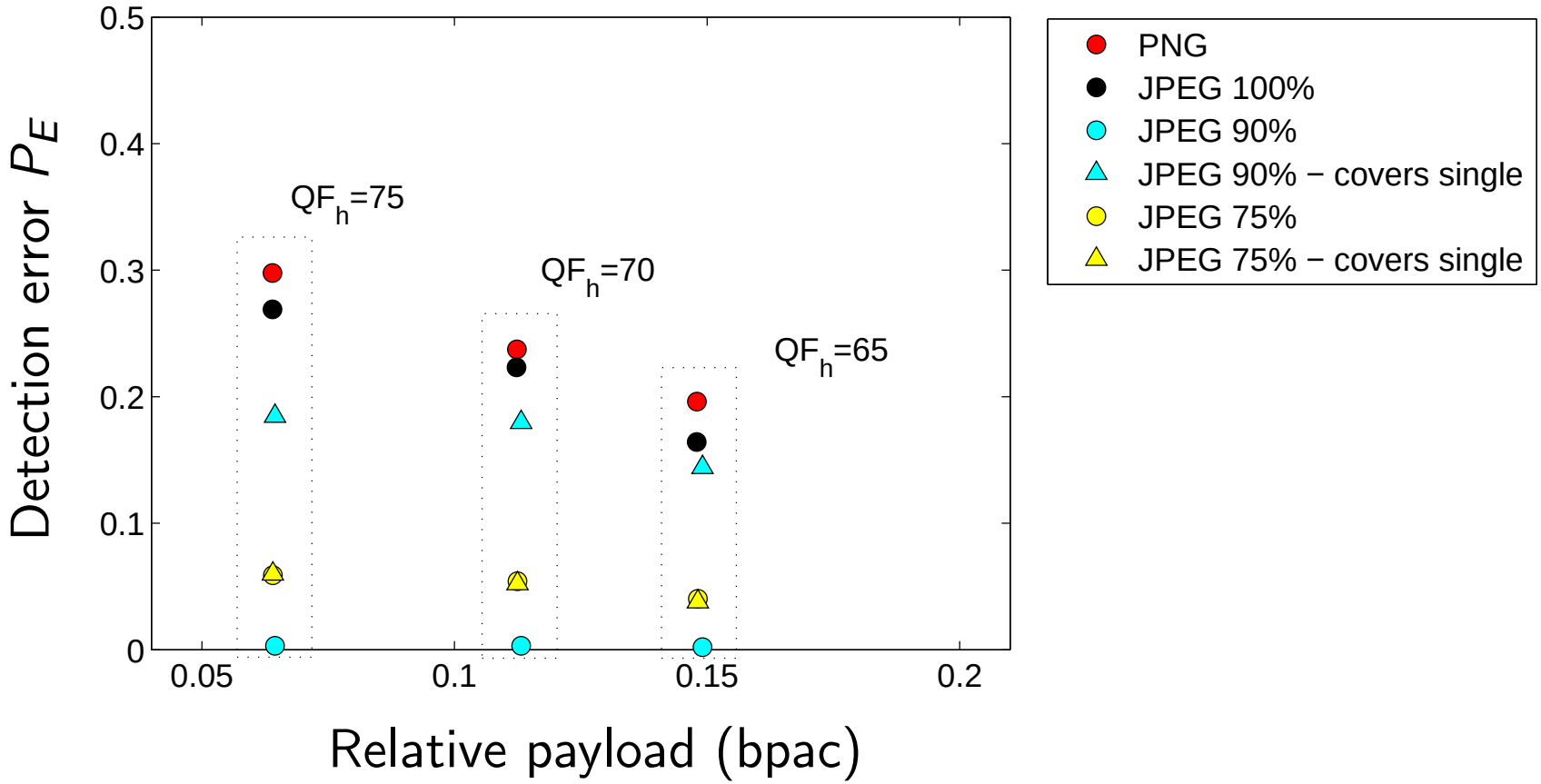
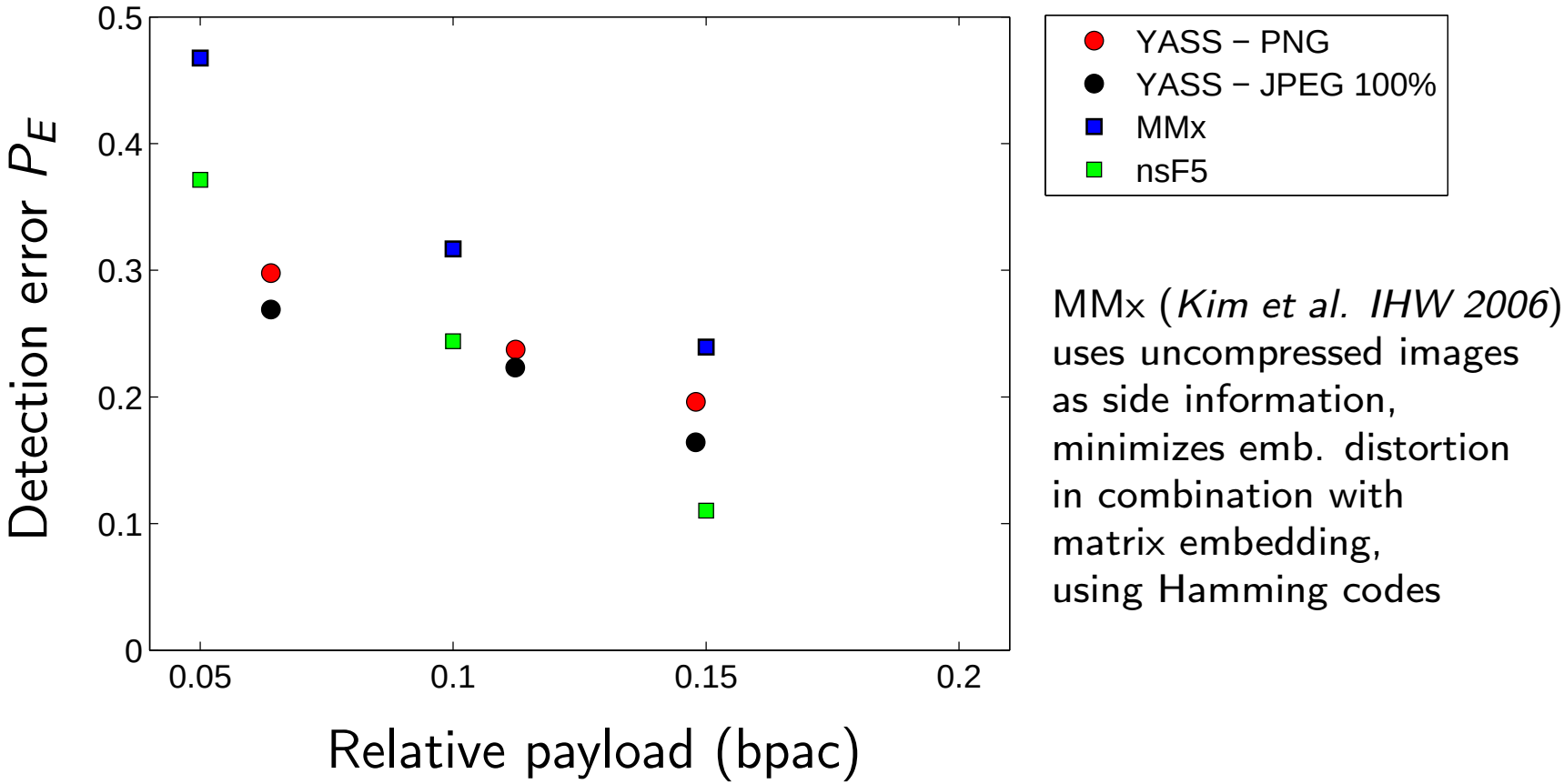


Comparison with Other Methods



MMx (*Kim et al. IHW 2006*) uses uncompressed images as side information, minimizes emb. distortion in combination with matrix embedding, using Hamming codes

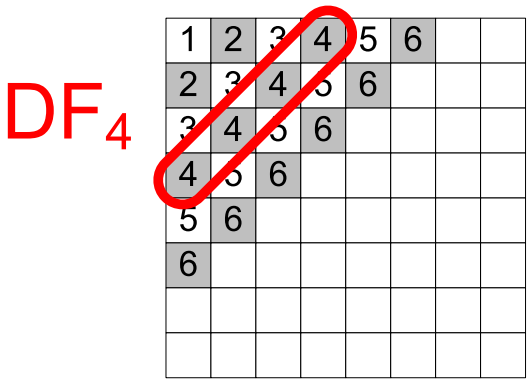
Additional Features

27 WAM features (*Goljan et al., SPIE 2006*)

- Higher order absolute moments of the noise residual calculated in wavelet domain

15 Diagonal features (DF)

- Normalized histogram of DCT coefficients from 15 diagonal bands



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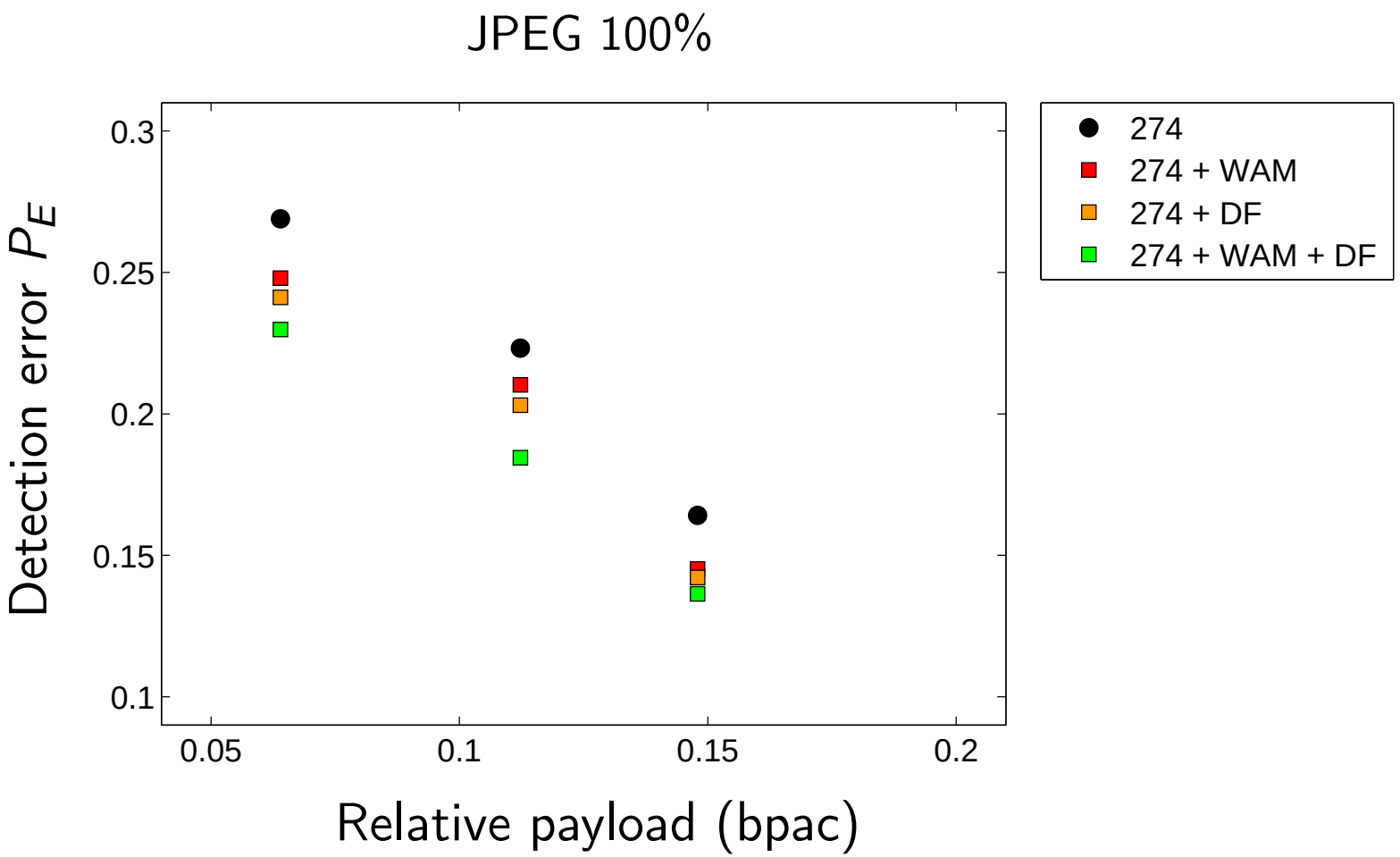

Summary

- F5 embedding operation minimizes combined distortion due to quantization and embedding
- Adaptive embedding into textured regions is relatively non-influential
- Syndrome coding is the most important design element
- Steganalysis of YASS reported