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# Fragile Sensor Fingerprint Camera Identification

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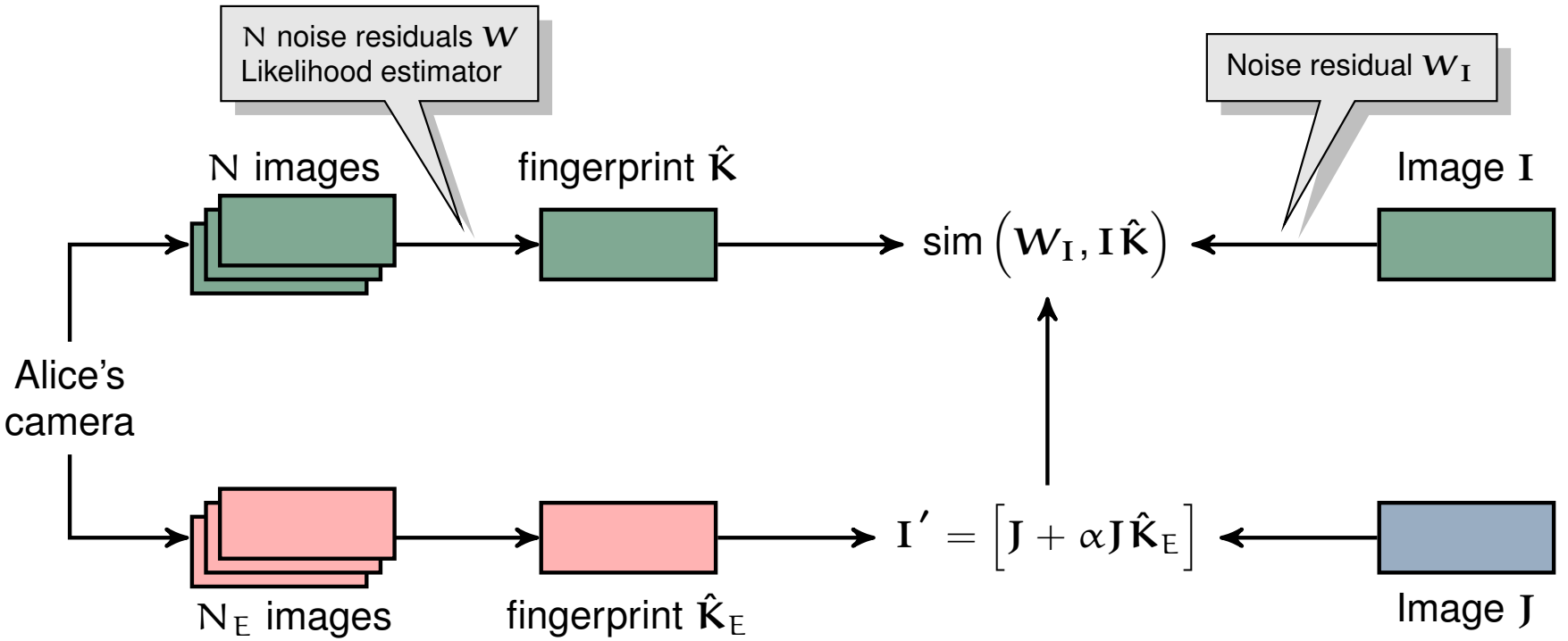
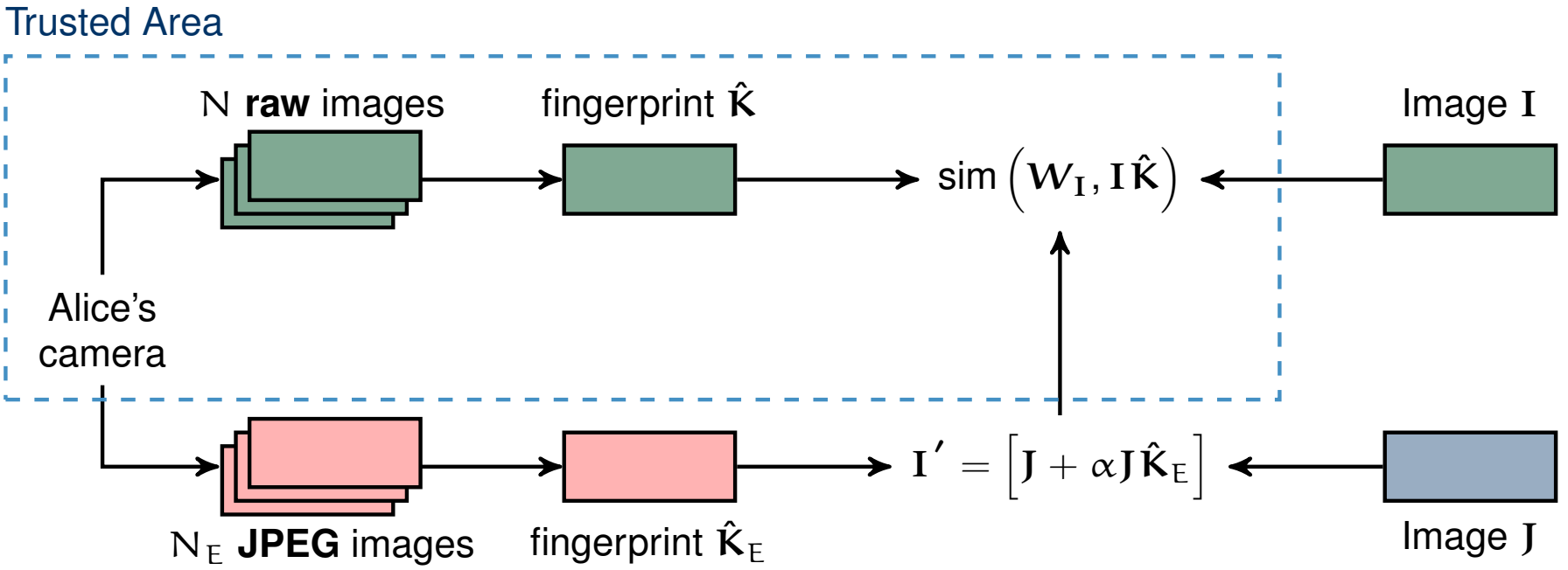
# Camera Identification with Adversaries




- Countermeasure: Triangle Test
  - Alice may test all images ever made public by her
  - Less reliable with increasing $N_E$

(Fridrich 2013; Goljan et al. 2011)

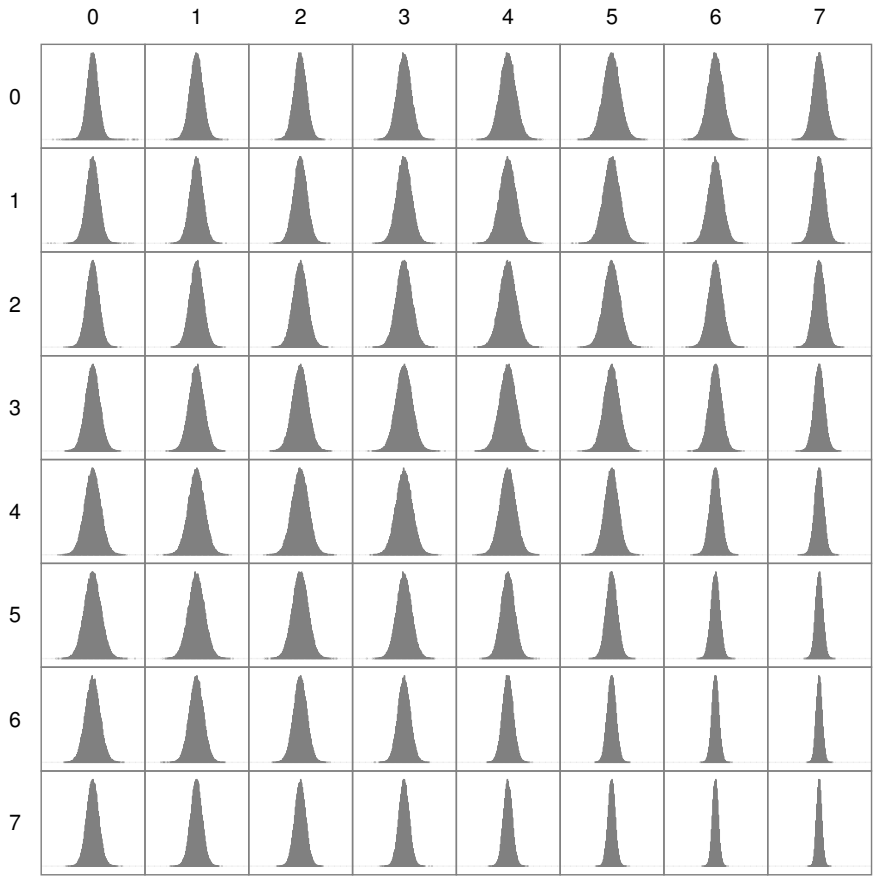
# Scenario with Asymmetries



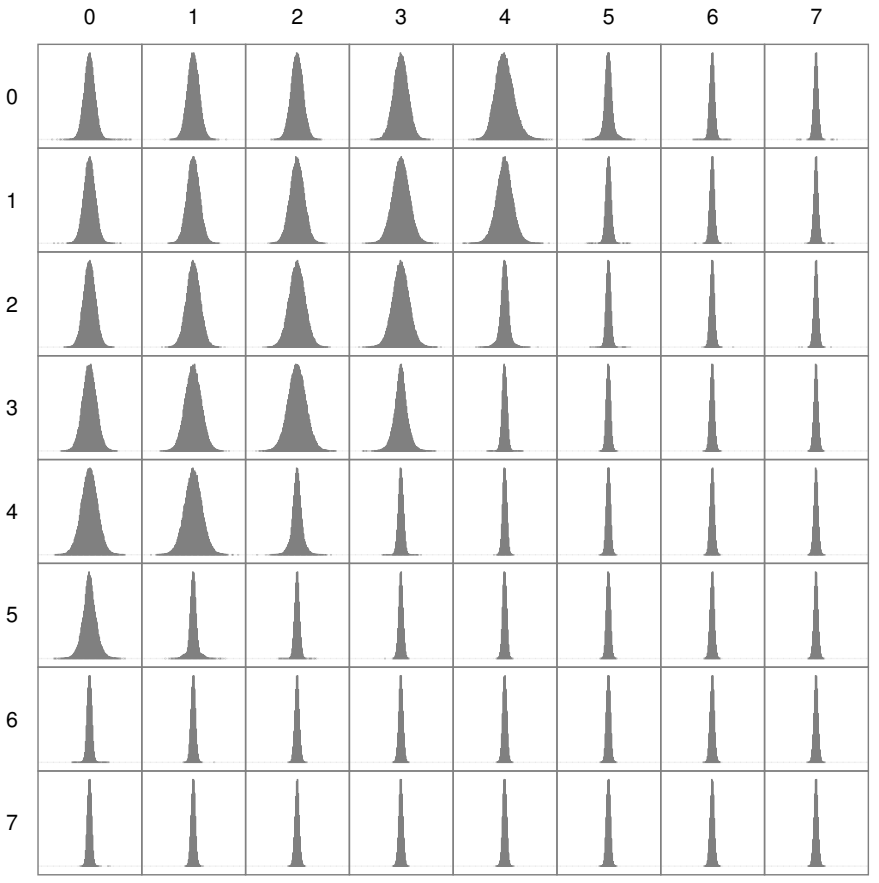

- Alice's camera supports raw images
- Alice has shared only JPEG images with the public
- Eve's goal is to make an image look like Alice's raw images

# Sensor Fingerprint DCT Distribution

$\hat{K}_A$ from uncompressed images



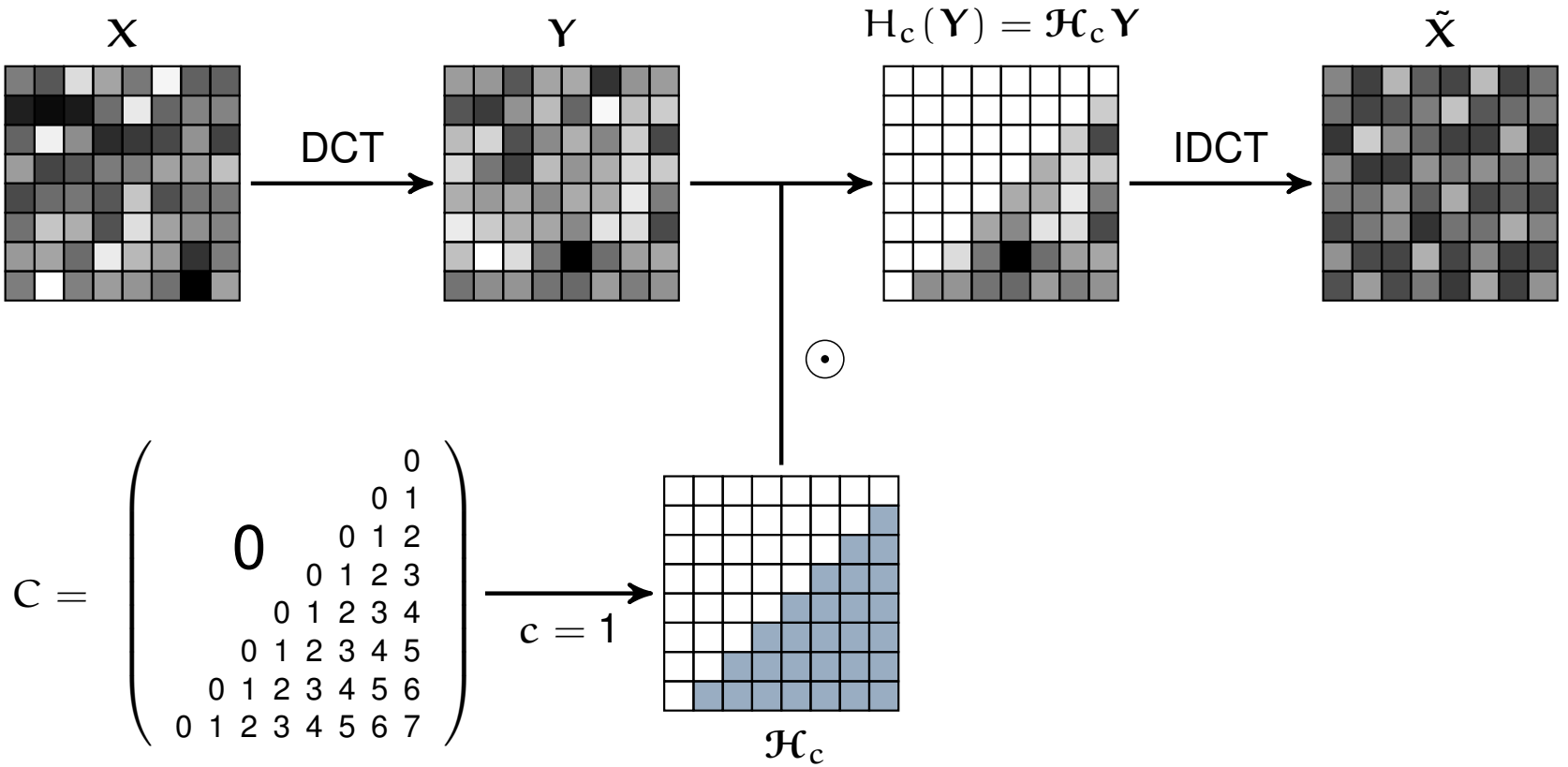

$\hat{K}_E$ from JPEG90 images



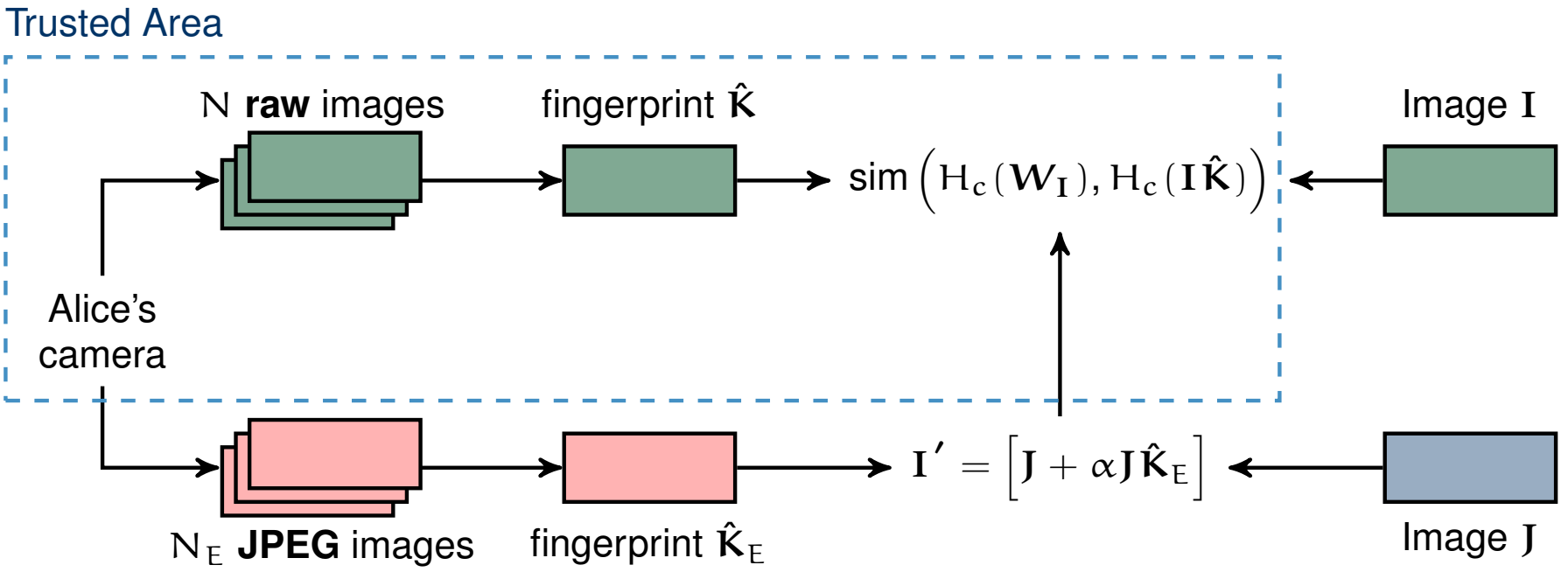

Each fingerprint was estimated from the same 25 flat field images taken by a Nikon D200

# Fragile Sensor Noise Fingerprint

- Fingerprint from high-frequency sub-bands only
- Fingerprint part that is *fragile* to lossy JPEG compression
- Sub-band selective highpass filter $\mathrm{H_c}(\cdot)$:



# Revised Scenario




- Alice can always provide the full fingerprint
- Eve's estimate lacks accurate high-frequency information
- Presence of fragile fingerprint indicates authenticity of image
- Low-frequency fingerprint is orthogonal to fragile fingerprint

# Setup

- 6390 uncompressed images from two image databases:

| Image Database | Camera model | Camera 0 | Camera 1 |
|---|---|---|---|
| Dresden (Gloe and Böhme 2010) | Nikon D70 | 175 | 188 |
| | Nikon D70s | 175 | 174 |
| | Nikon D200 | 360 | 370 |
| RAISE (Dang-Nguyen et al. 2015) | Nikon D7000 | 4948 | — |

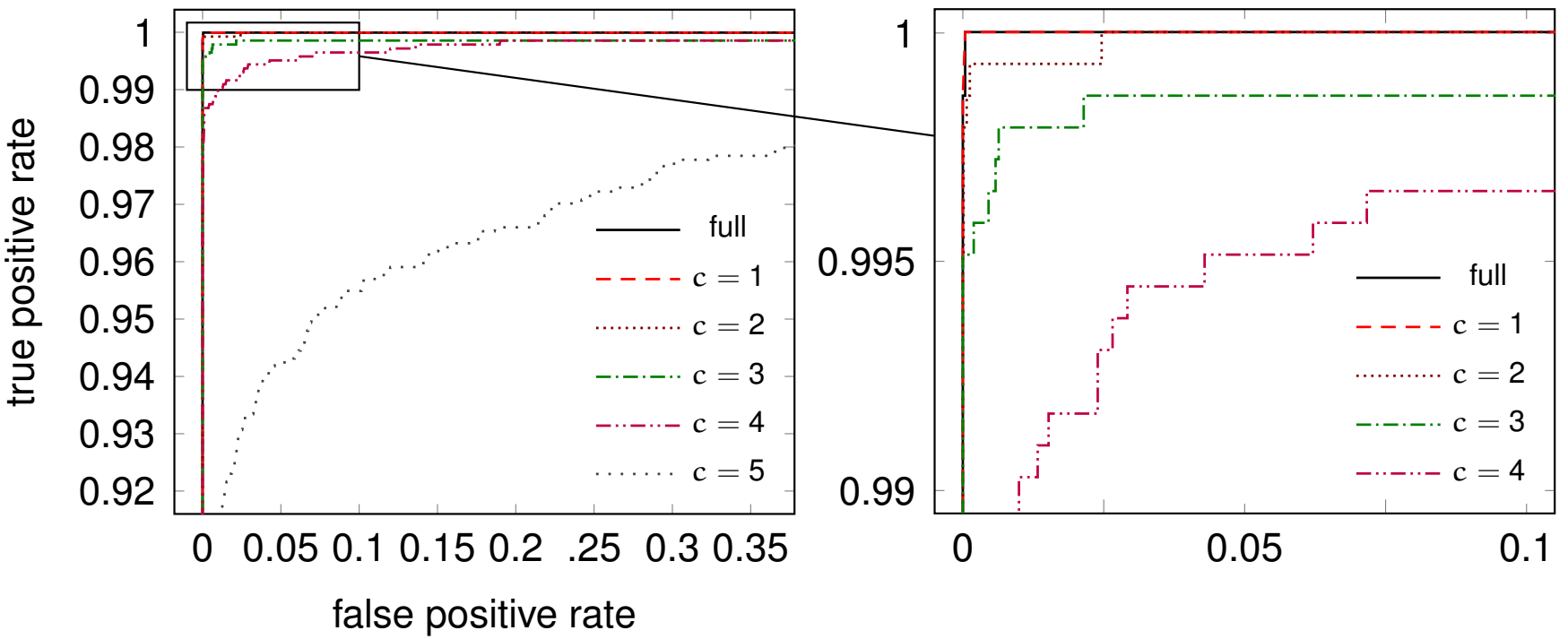
+ 25 flat field images from each Dresden Database camera

- Fingerprint Estimation
  - Noise residuals obtained from Wavelet denoising filter (Mıhçak et al. 1999)
  - Likelihood Estimator
  - Post-processing: Zero-meaning & Wiener filtering
- Similarity criterion: Peak-to-Correlation Energy (PCE)

# Camera Identification

| | Predicted Camera | |
|---|---|---|
| Image source | From camera | Other camera |
| From camera | **True positive** | False negative |
| Other camera | **False positive** | True negative |

$$C = \begin{pmatrix} 0 & & & & & & & 0 \\ & 0 & & & & & & 0\ 1 \\ & & 0 & & & & & 0\ 1\ 2 \\ & & & 0 & & & & 0\ 1\ 2\ 3 \\ & & & & 0 & & & 0\ 1\ 2\ 3\ 4 \\ & & & & & 0 & & 0\ 1\ 2\ 3\ 4\ 5 \\ & & & & & & 0 & 0\ 1\ 2\ 3\ 4\ 5\ 6 \\ 0 & 1 & 2 & 3 & 4 & 5 & 6 & 7 \end{pmatrix}$$



# Fragile Fingerprint Estimation (1/2)

» Quality of fingerprint estimation:

$$\mathrm{corr}(H_c(\hat{\mathbf{K}}_A), H_c(\hat{\mathbf{K}}_E))$$

from uncompressed images

from JPEG images

» Dresden Image Database:

| $N_E$ | JPEG | c | | | | | |
|---|---|---|---|---|---|---|---|
| | | full | 1 | 2 | 3 | 4 | 5 |
| 150 | 100 | 0.3720 | 0.3484 | 0.3245 | 0.2850 | 0.2302 | 0.1607 |
| | 95 | 0.2522 | 0.0870 | 0.0561 | 0.0337 | 0.0160 | 0.0100 |
| | 90 | 0.1865 | 0.0294 | 0.0157 | 0.0058 | 0.0009 | 0.0029 |
| | 85 | 0.1449 | 0.0109 | 0.0029 | -0.0007 | -0.0022 | 0.0012 |
| | 80 | 0.1174 | 0.0027 | -0.0014 | -0.0031 | -0.0027 | -0.0000 |
| | 75 | 0.0977 | -0.0012 | -0.0029 | -0.0030 | -0.0026 | -0.0005 |
| | 70 | 0.0851 | -0.0029 | -0.0037 | -0.0036 | -0.0030 | -0.0011 |

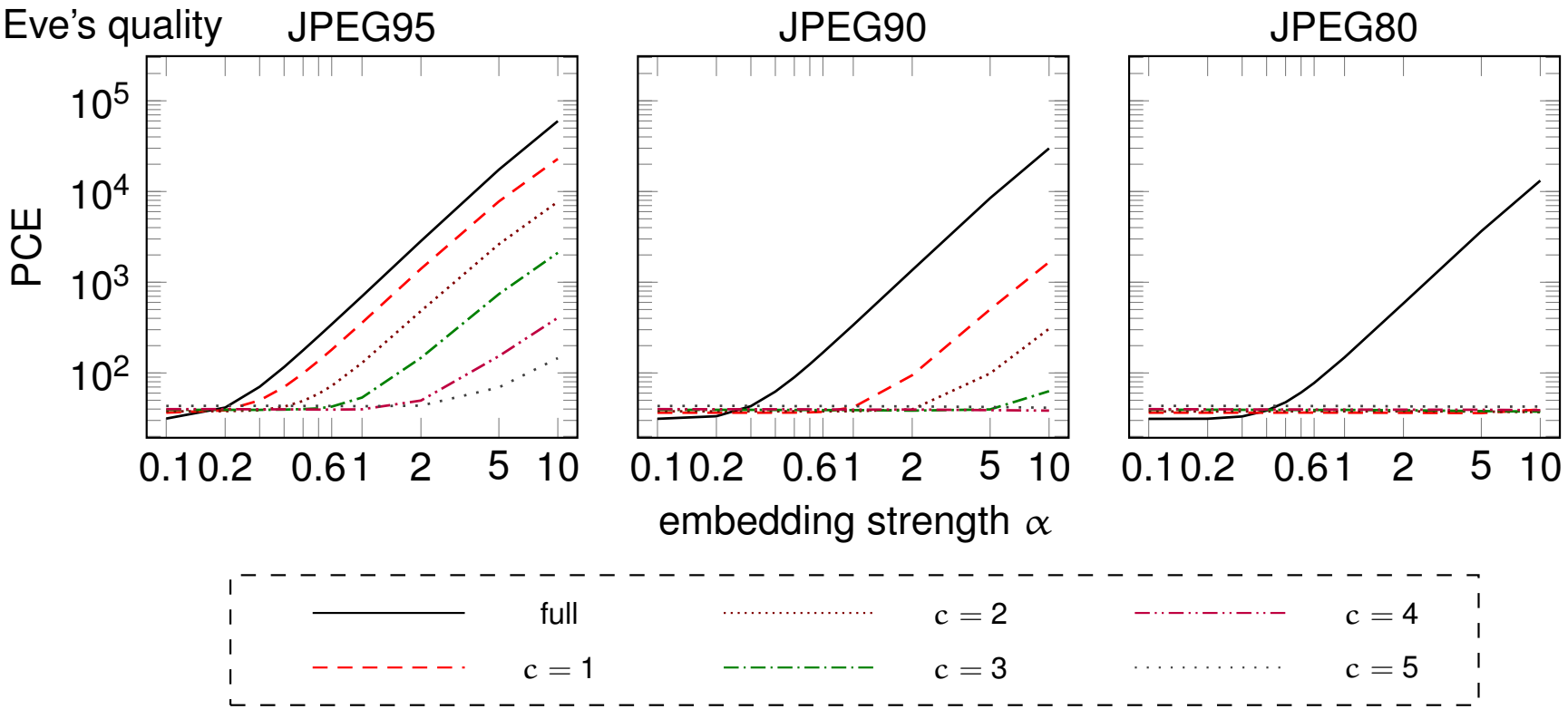
# Fragile Fingerprint Estimation (2/2)

» RAISE Image Database:

| $N_E$ | JPEG | c | | | | | |
|---|---|---|---|---|---|---|---|
| | | full | 1 | 2 | 3 | 4 | 5 |
| 2000 | 100 | 0.6128 | 0.6002 | 0.5565 | 0.4838 | 0.3828 | 0.2627 |
| | 95 | 0.5291 | 0.3752 | 0.2645 | 0.1600 | 0.0800 | 0.0524 |
| | 90 | 0.4381 | 0.1513 | 0.0762 | 0.0357 | 0.0169 | 0.0177 |
| | 85 | 0.3758 | 0.0506 | 0.0154 | 0.0055 | 0.0023 | 0.0046 |
| | 80 | 0.3347 | 0.0172 | 0.0009 | -0.0014 | -0.0008 | 0.0028 |
| | 75 | 0.3035 | 0.0055 | -0.0041 | -0.0034 | -0.0007 | 0.0016 |
| | 70 | 0.2837 | 0.0015 | -0.0053 | -0.0042 | -0.0015 | 0.0007 |
| 4648 | 100 | 0.6414 | 0.6322 | 0.5924 | 0.5250 | 0.4302 | 0.3123 |
| | 95 | 0.5704 | 0.4536 | 0.3464 | 0.2235 | 0.1173 | 0.0773 |
| | 90 | 0.4798 | 0.2047 | 0.1087 | 0.0520 | 0.0243 | 0.0253 |
| | 85 | 0.4167 | 0.0705 | 0.0231 | 0.0084 | 0.0028 | 0.0078 |
| | 80 | 0.3756 | 0.0249 | 0.0024 | -0.0019 | -0.0013 | 0.0037 |
| | 75 | 0.3445 | 0.0085 | -0.0049 | -0.0042 | -0.0000 | 0.0027 |
| | 70 | 0.3254 | 0.0036 | -0.0063 | -0.0059 | -0.0008 | 0.0017 |

# Fingerprint-Copy Attack

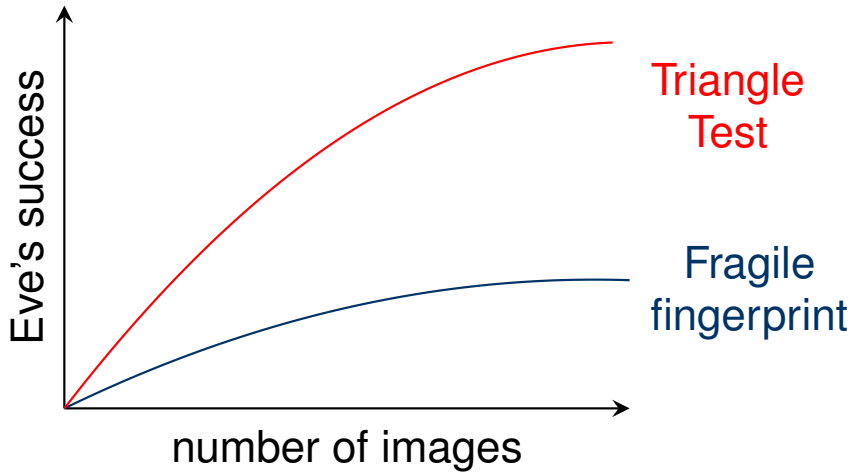
» Dresden Image Database ($N_E = 150$):

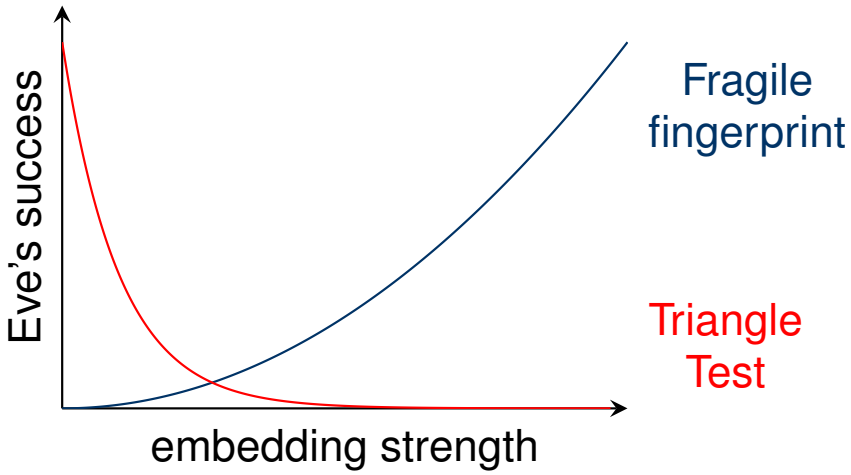


# Conclusion

- Context: Fingerprint-copy attack
  - Eve frames her victim Alice with a high-quality forgery
  - Eve plants a fake fingerprint from JPEG images on raw image

- Alice's countermeasures:
  - Fragile sensor fingerprint
  - Triangle Test (Goljan et al. 2011)



# Future Work

- Linkage to adversary-aware signal processing

  (Barni and Pérez-González 2013)

  - Alice and Eve have access to training data of different quality
  - Similarity to hypothesis testing problem in adversarial environment

- Side channel strategies for DCT coefficient selection

- Theoretical analysis of high-frequency information in JPEG images
  - When is Eve able to recover the fingerprint?
  - Effect of quantization on the fingerprint?

# References I


Barni, Mauro and Fernando Pérez-González (2013). “Coping With the Enemy: Advances in Adversary-Aware Signal Processing”. In: *IEEE International Conference on Acoustics, Speech, and Signal Processing*, pp. 8682–8686. DOI: 10.1109/ICASSP.2013.6639361.

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Goljan, Miroslav, Jessica Fridrich, and Mo Chen (2011). “Defending against Fingerprint-Copy Attack in Sensor-Based Camera Identification”. In: *IEEE Transactions on Information Forensics and Security* 6.1, pp. 227–236. DOI: 10.1109/TIFS.2010.2099220.

Mıhçak, M. Kıvanç, Igor Kozintsev, and Kannan Ramchandran (1999). “Spatially Adaptive Statistical Modeling of Wavelet Image Coefficients and its Application to Denoising”. In: *IEEE International Conference on Acoustics, Speech, and Signal Processing*. Vol. 6, pp. 3253–3256. DOI: 10.1109/ICASSP.1999.757535.