LOCALIZATION OF FORGERIES IN MPEG-2 VIDEO THROUGH GOP SIZE AND DQ ANALYSIS

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SPAIN

REWIND

SEVENTH FRAMEWORK PROGRAMME

Outline

1. Motivation and Goal
2. Overall Structure of the Proposed System
3. Description of Two Main Steps
   - Localization of To-Be-Analyzed Frames
   - Double Quantization Analysis
4. Experimental Results

Video forensics today

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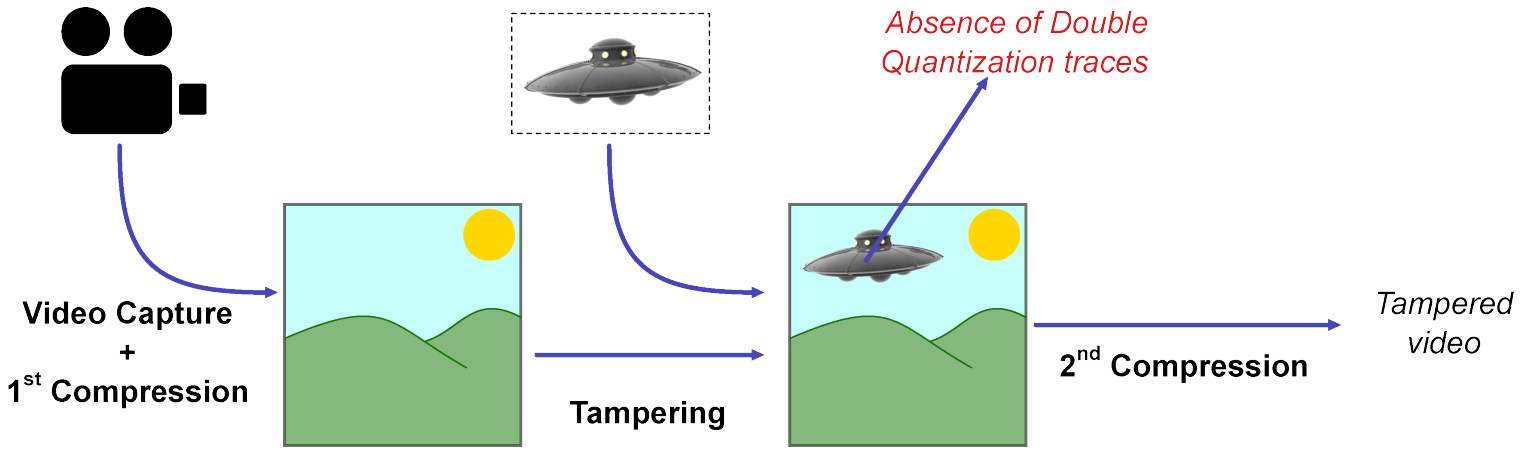
  - Not always the case (e.g. video may be re-encoded during device-to-computer transfer)
- Several works focusing on the removal/copying/replication of whole frames
- Existing approaches for **intra-frame forgery localization** make strong assumptions, e.g. assuming only intra-coded frames, aka M-JPEG

Outline

Proposed Scheme

- Leveraging on the double compression undergone by forged video



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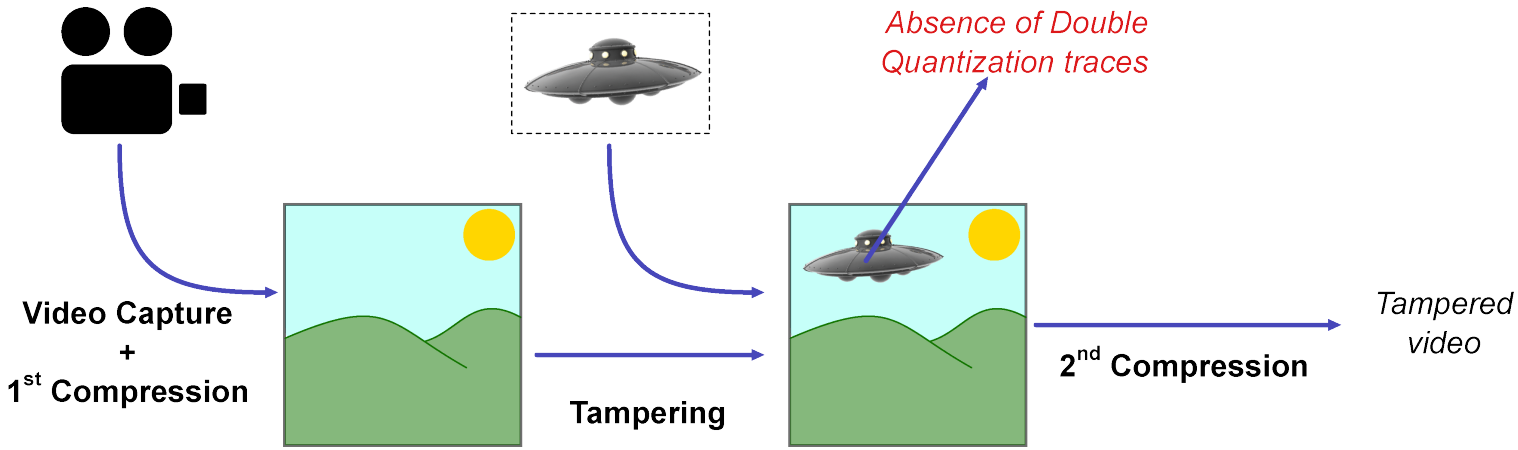
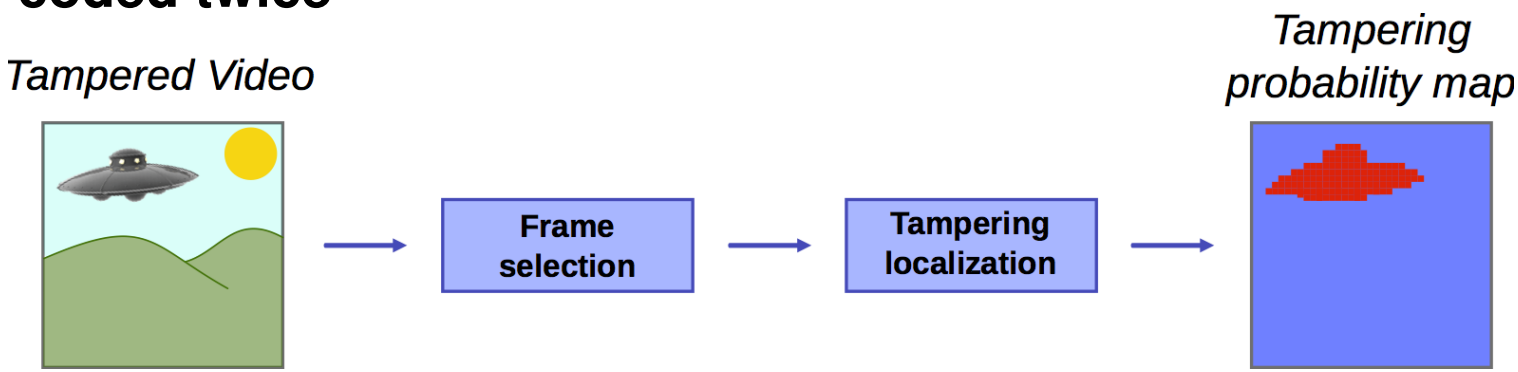


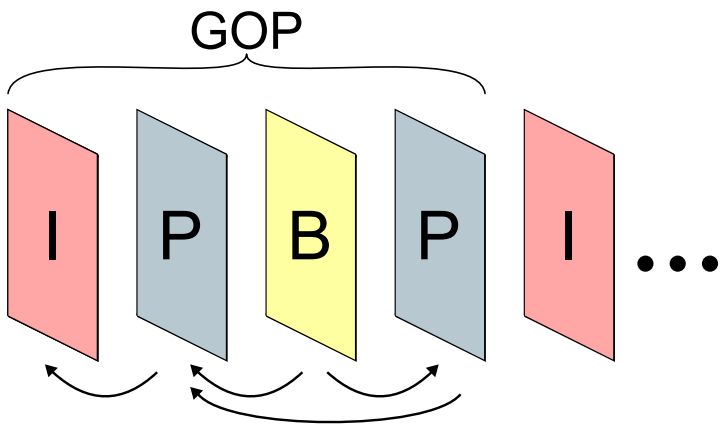
- Use DQ analysis to localize the forged region within frames that were **intra-coded twice**



Outline

MPEG-2 Coding 1/2

- **Frame types**
  - I: coded independently (much like JPEG)
  - P: predicted from a previous reference frame (I o P)
  - B: predicted from a previous and/or following reference frame (I o P)



- **Macroblock Types** (16x16 pixels)
  - intra-coded macroblocks (I-MB)
  - inter-coded macroblocks (P-MB)
  - skipped macroblocks (S-MB)

MPEG-2 Coding 2/2

- **DCT Coefficients Quantization**
  - Differently from JPEG, a quantization matrix is provided by the standard
  - Quantization strength adapted through a multiplier integer k
  - Different matrices are defined for I- and P- frames (we only care about I-frame quantization)

$$Q_{i,j} = k \times \begin{pmatrix} 8 & 16 & 19 & 22 & 26 & 27 & 29 & 34 \\ 16 & 16 & 22 & 24 & 27 & 29 & 34 & 37 \\ 19 & 22 & 26 & 27 & 29 & 34 & 34 & 38 \\ 22 & 22 & 26 & 27 & 29 & 34 & 37 & 40 \\ 22 & 26 & 27 & 29 & 32 & 35 & 40 & 48 \\ 26 & 27 & 29 & 32 & 35 & 40 & 48 & 58 \\ 26 & 27 & 29 & 34 & 38 & 46 & 56 & 69 \\ 27 & 29 & 35 & 38 & 46 & 56 & 69 & 83 \end{pmatrix}$$

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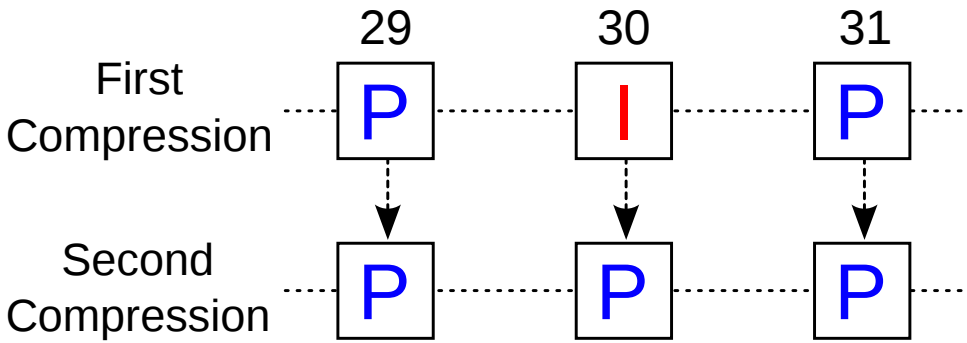
- **VBR coding**
  - We assume Variable BitRate coding (VBR) $\Rightarrow$ k is fixed by the user
  - Knowing k gives all the quantization step $Q_{i,j}$ used in a compression
  - This facilitates the task compared to JPEG

Variation of Prediction Footprint (VPF)[1]



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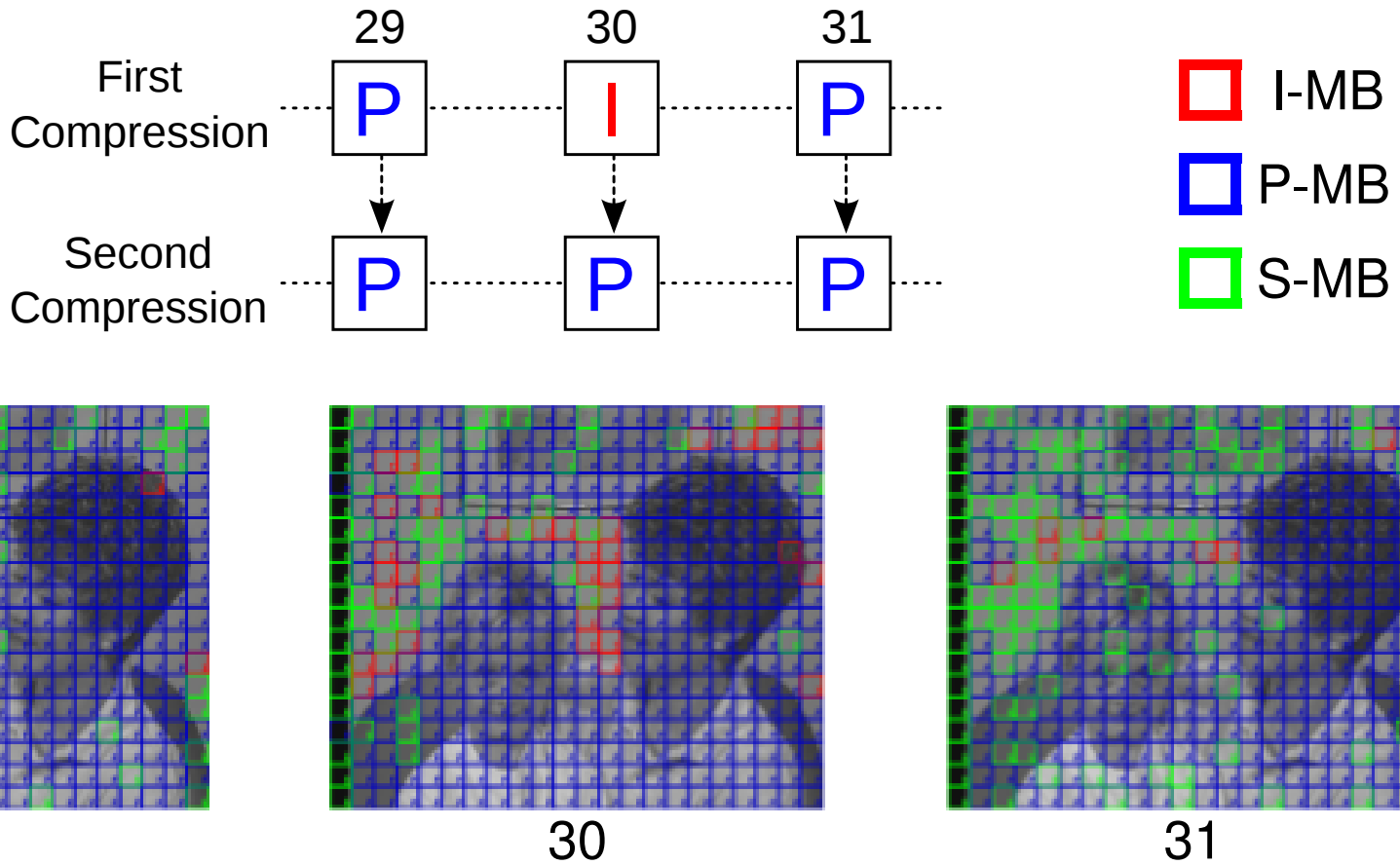

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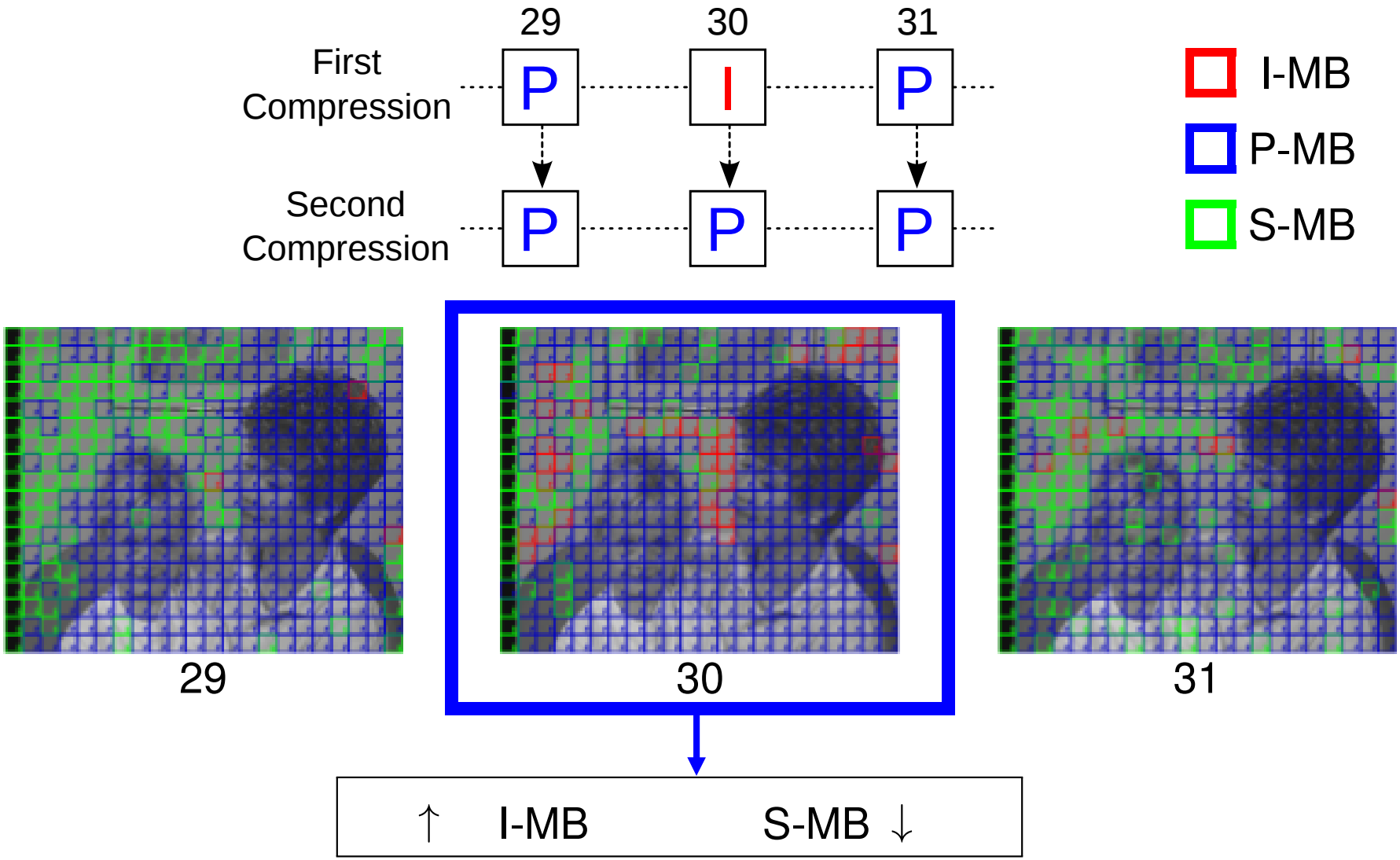

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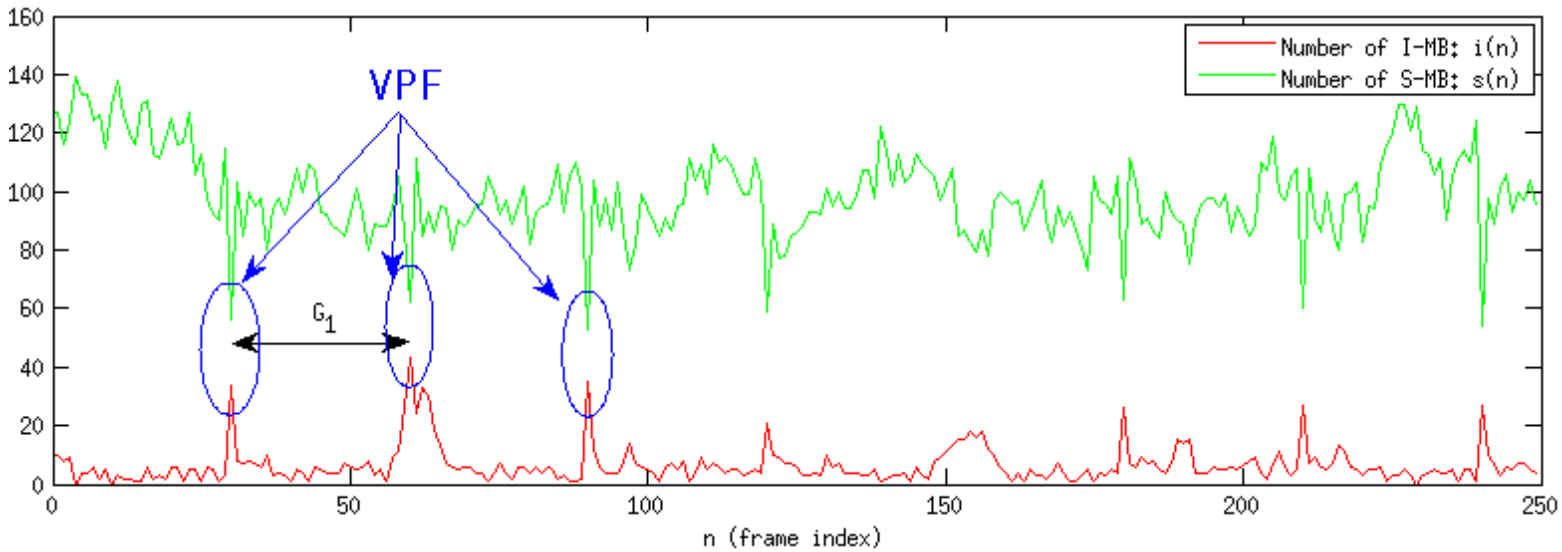
Variation of Prediction Footprint (VPF)[1]

- By estimating GOP_1, we can locate those frames that have been intra-coded twice



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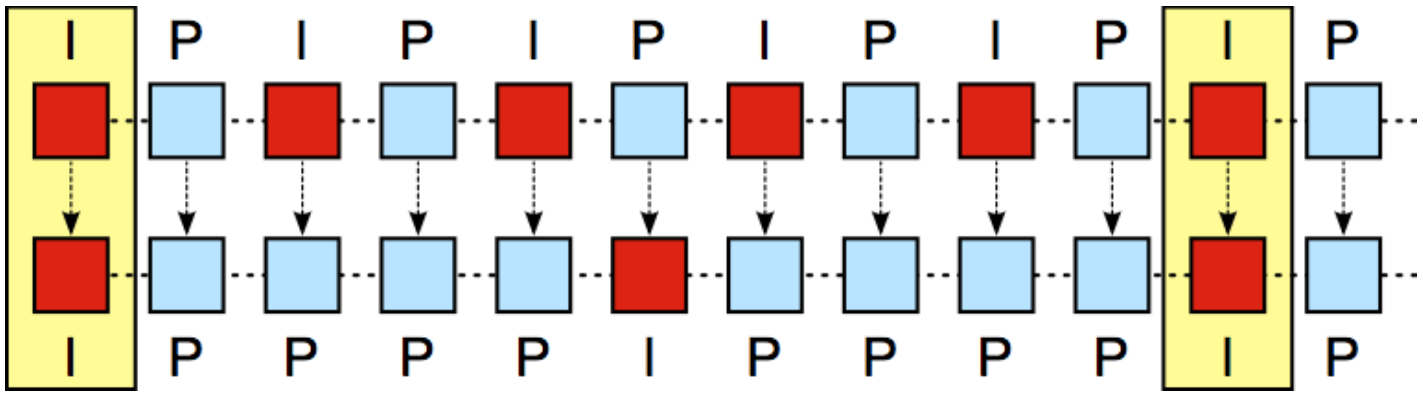

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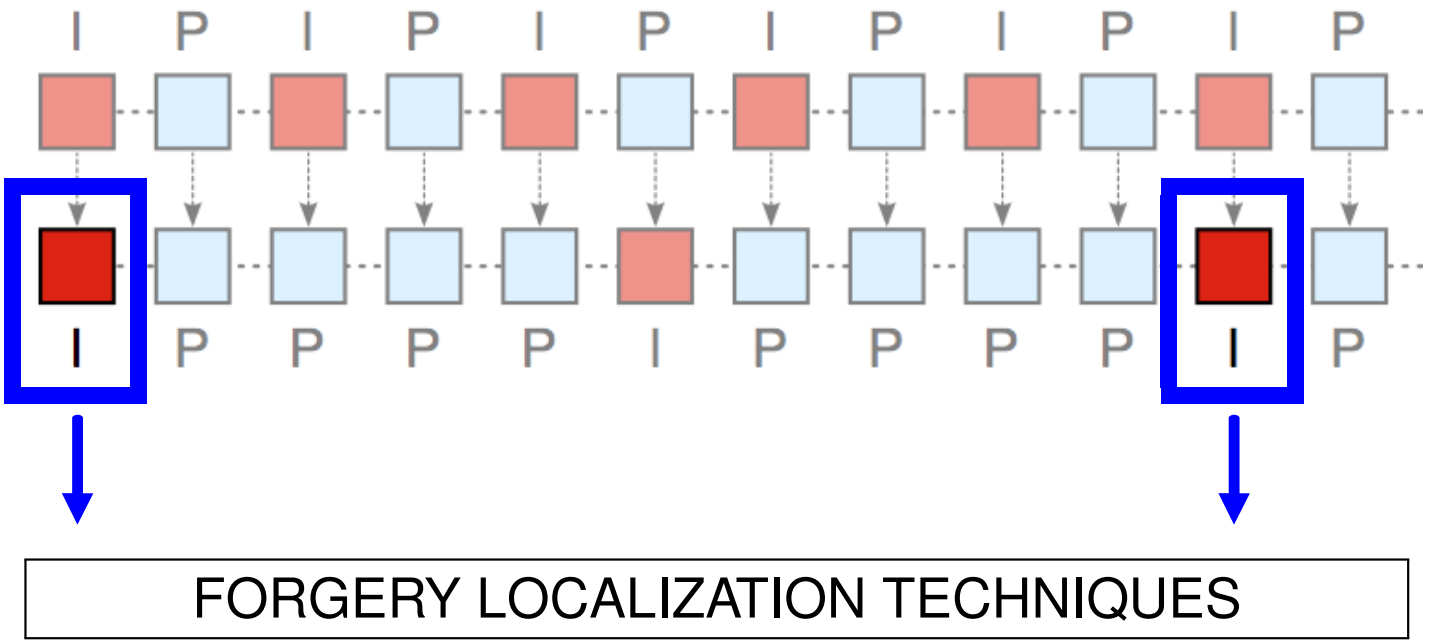

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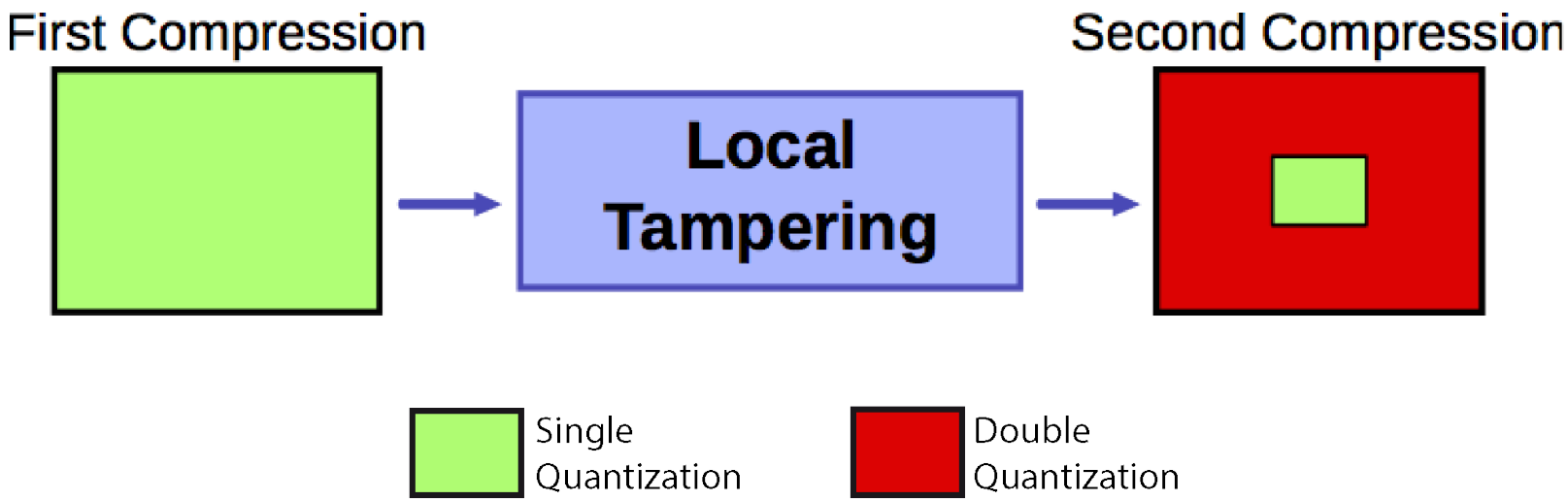
Outline

From Double Quantization to Forgery Localization[1]



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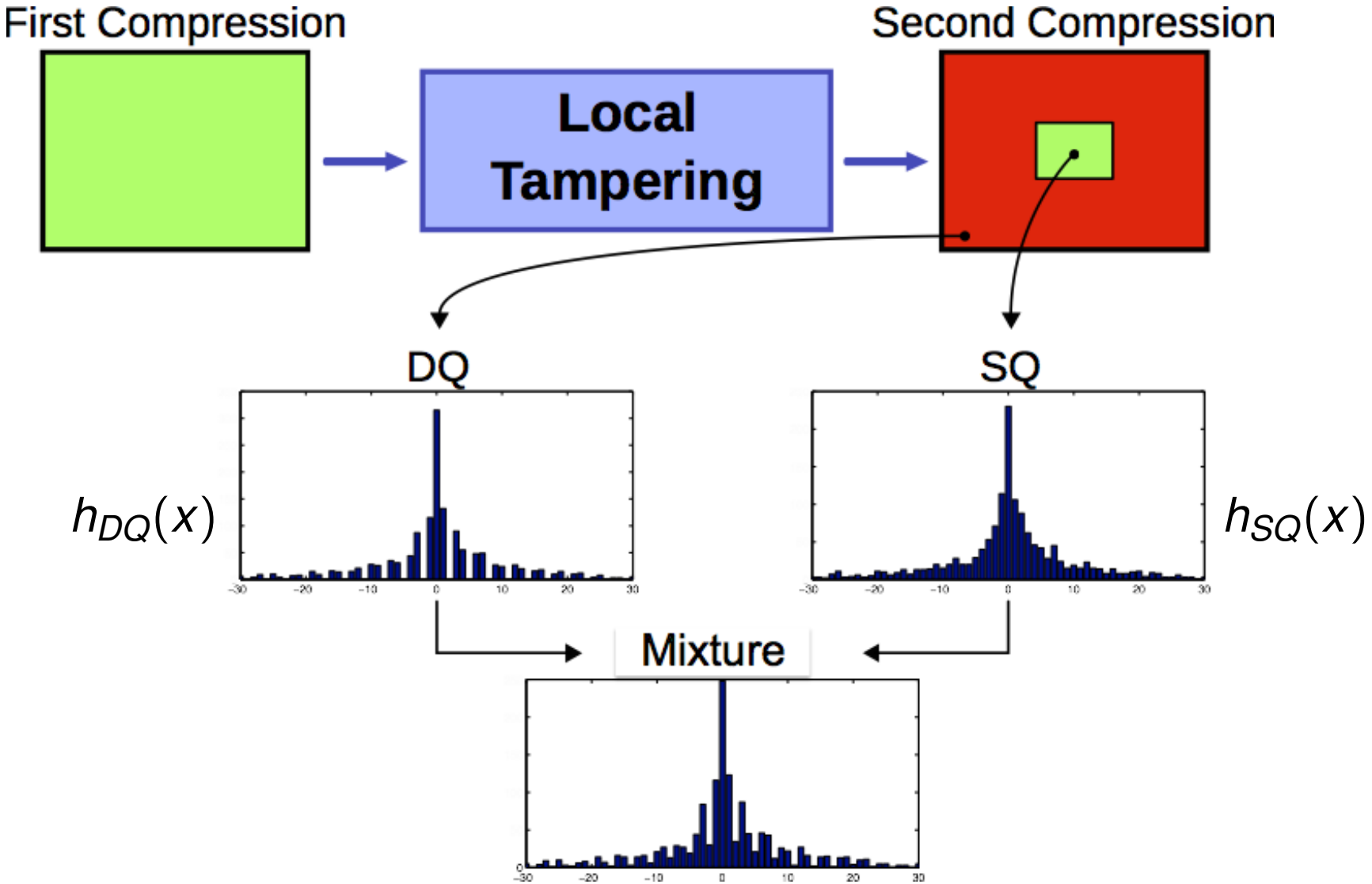
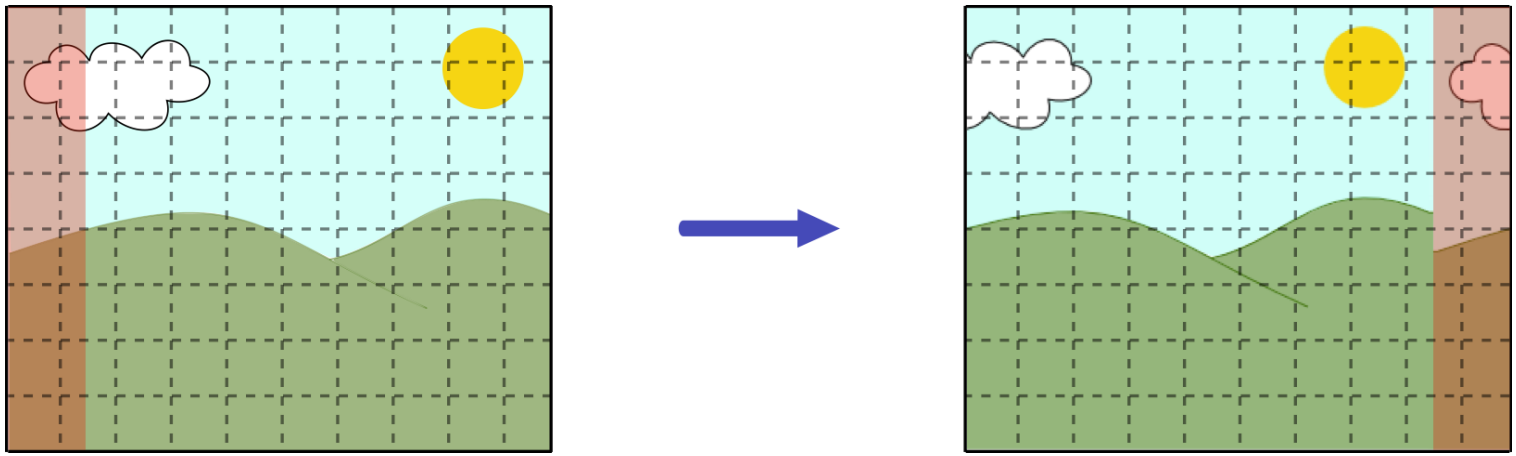


Estimation of h_{SQ} (calibration technique)



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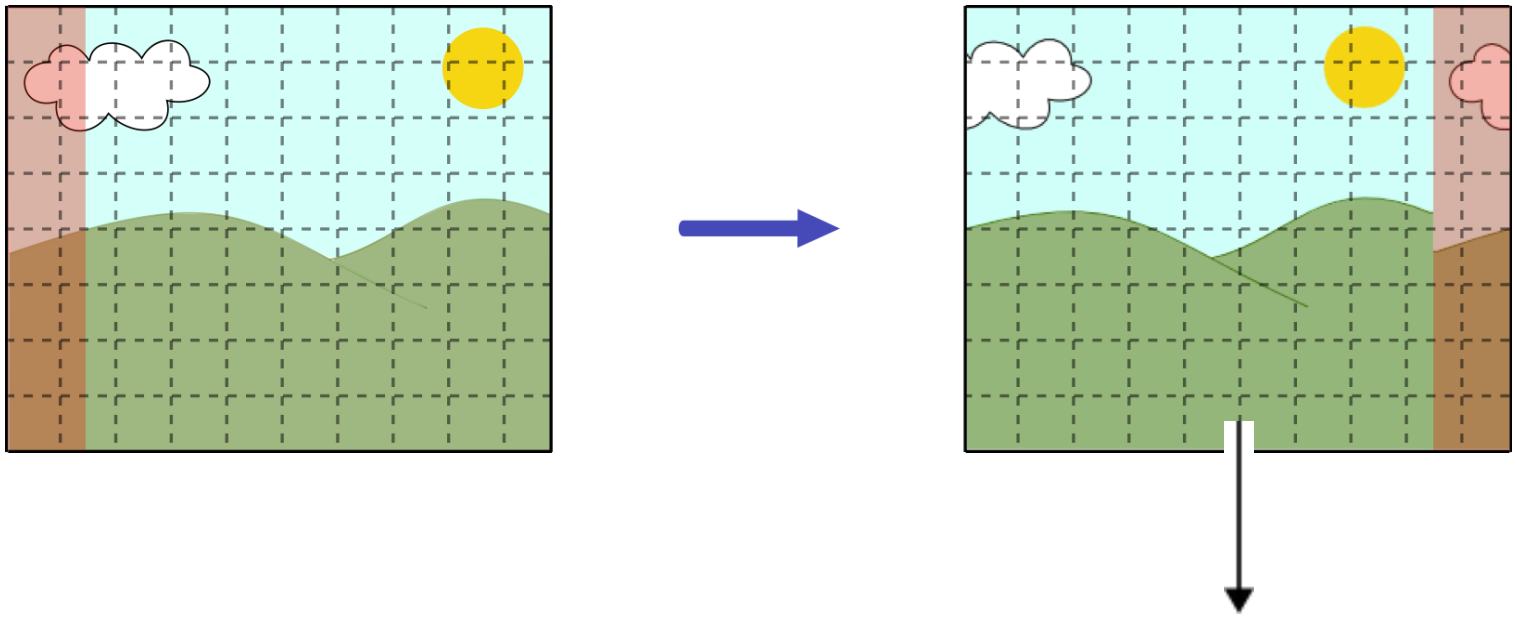
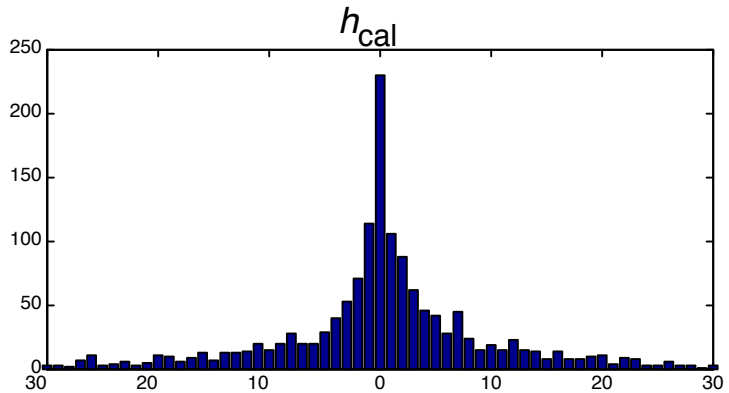
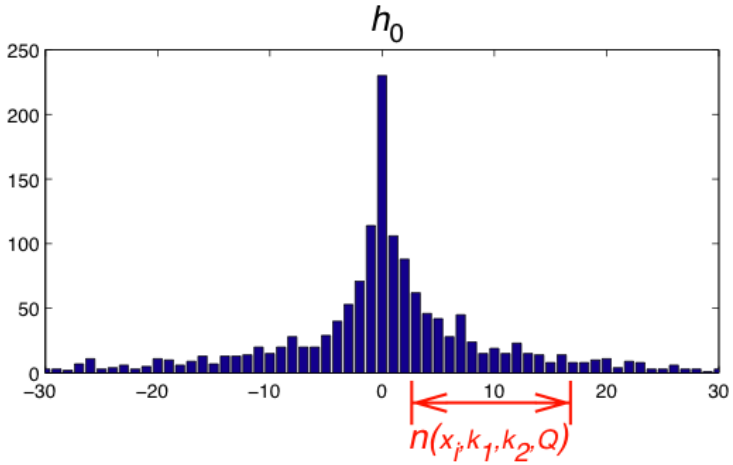


- h_{cal} is an estimate of h_0 (histogram of unquantized coeffs)
- $h_{SQ}(x) \simeq \tilde{h}(x) = \Delta_{k_2}(h_{\text{cal}})$



Estimation of h_{DQ} [1]

- For a given k_1, k_2 and Q, we can count how many bins of h_0 fall in each bin of h_{DQ}



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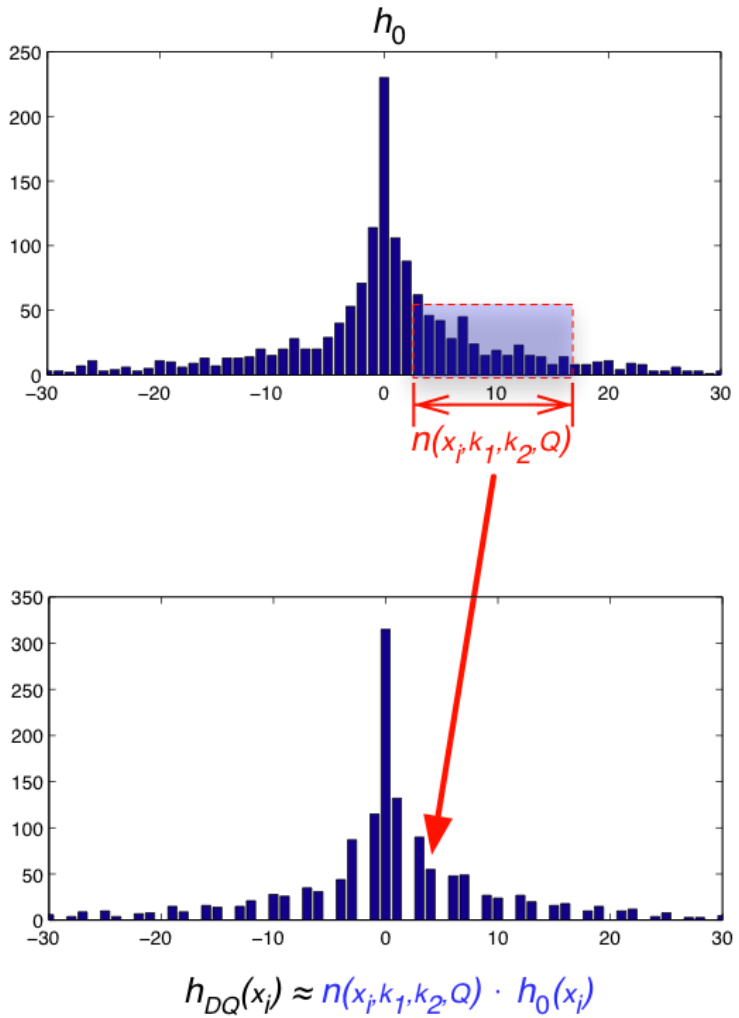
- For a given k_1, k_2 and Q, we can count how many bins of h_0 fall in each bin of h_{DQ}
- Assuming h_0 locally uniform

$$h_{DQ}(x) \simeq n(x; k_1, k_2, Q) \cdot \tilde{h}(x)$$



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MPEG-2 de-quantization formula differs from JPEG ones. The function $n(\cdot)$ was derived, resulting in:

$$n(x; k_1, k_2, Q) = \frac{k_1 \times Q}{16} \left(\left\lceil \frac{16}{Q \times k_1} \left\lceil \frac{k_2 \times Q}{16} \left(x + \frac{1}{2} \right) \right\rceil \right\rceil - \left\lceil \frac{16}{Q \times k_1} \left\lceil \frac{k_2 \times Q}{16} \left(x - \frac{1}{2} \right) \right\rceil \right\rceil \right)$$

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Estimating k_1

Model $$\tilde{h}_{mix}(x; k_1, \alpha) = \alpha \cdot \underbrace{n(x; k_1) \cdot \tilde{h}(x)}_{h_{DQ} \text{ estimate}} + (1 - \alpha) \cdot \underbrace{\tilde{h}(x)}_{h_{SQ} \text{ estimate}}$$

Estimating k_1

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Error

$$e(k_1, \alpha) = \sum_{x \neq 0} \left[h_{mix}(x) - \tilde{h}_{mix}(x; k_1, \alpha) \right]^2$$

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Error $$e(k_1, \alpha) = \sum_{x \neq 0} \left[h_{mix}(x) - \tilde{h}_{mix}(x; k_1, \alpha) \right]^2$$

Estimate k_1 and α by minimizing $e(k_1, \alpha)$

Probability map

Knowing k_1 allows us to write, for the i-th coefficient x_i:

$$p(x_i|T) = \tilde{h}(x_i) \qquad p(x_i|O) = n(x_i; k_1) \cdot \tilde{h}(x_i).$$

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By Bayes rule, and assuming equal priors:

$$p(T|x_i) = \frac{P(x_i|T) \cdot P(T)}{P(x_i|T) \cdot P(T) + P(x_i|O) \cdot P(O)} = \frac{1}{1 + n(x_i, k_1)}$$

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HYPOTHESIS

statistical independence between coeffs within a block

$$\Downarrow$$

$$P_B = \frac{1}{\prod_{i|x^{(i)} \neq 0} n(x_i; k_1) + 1}$$

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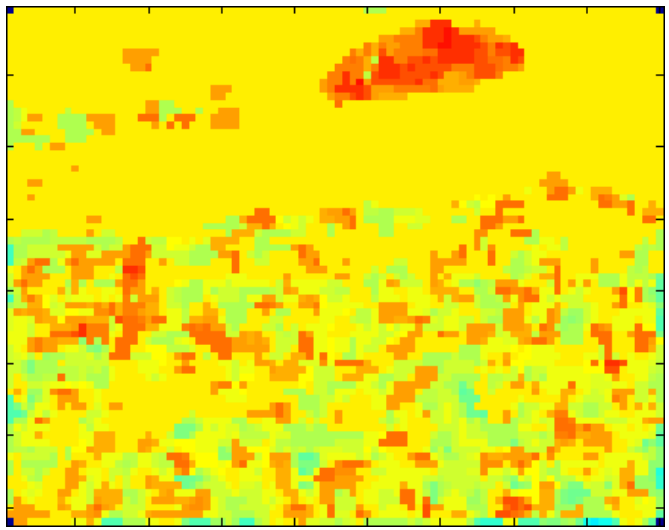
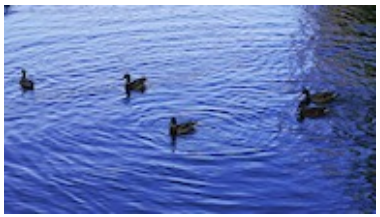


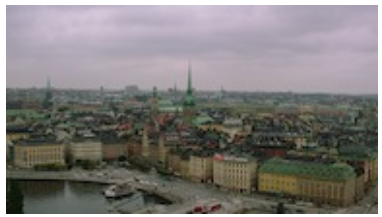
Outline

Dataset

Dataset built from 7 “raw” videos available in the Internet (resolution: 720x576 pixels)


ducks_take_off.y4m

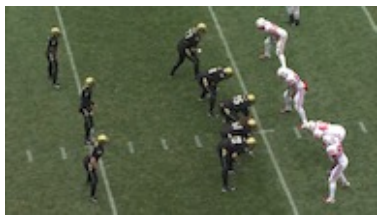

in_to_tree.y4m


old_town_cross.y4m

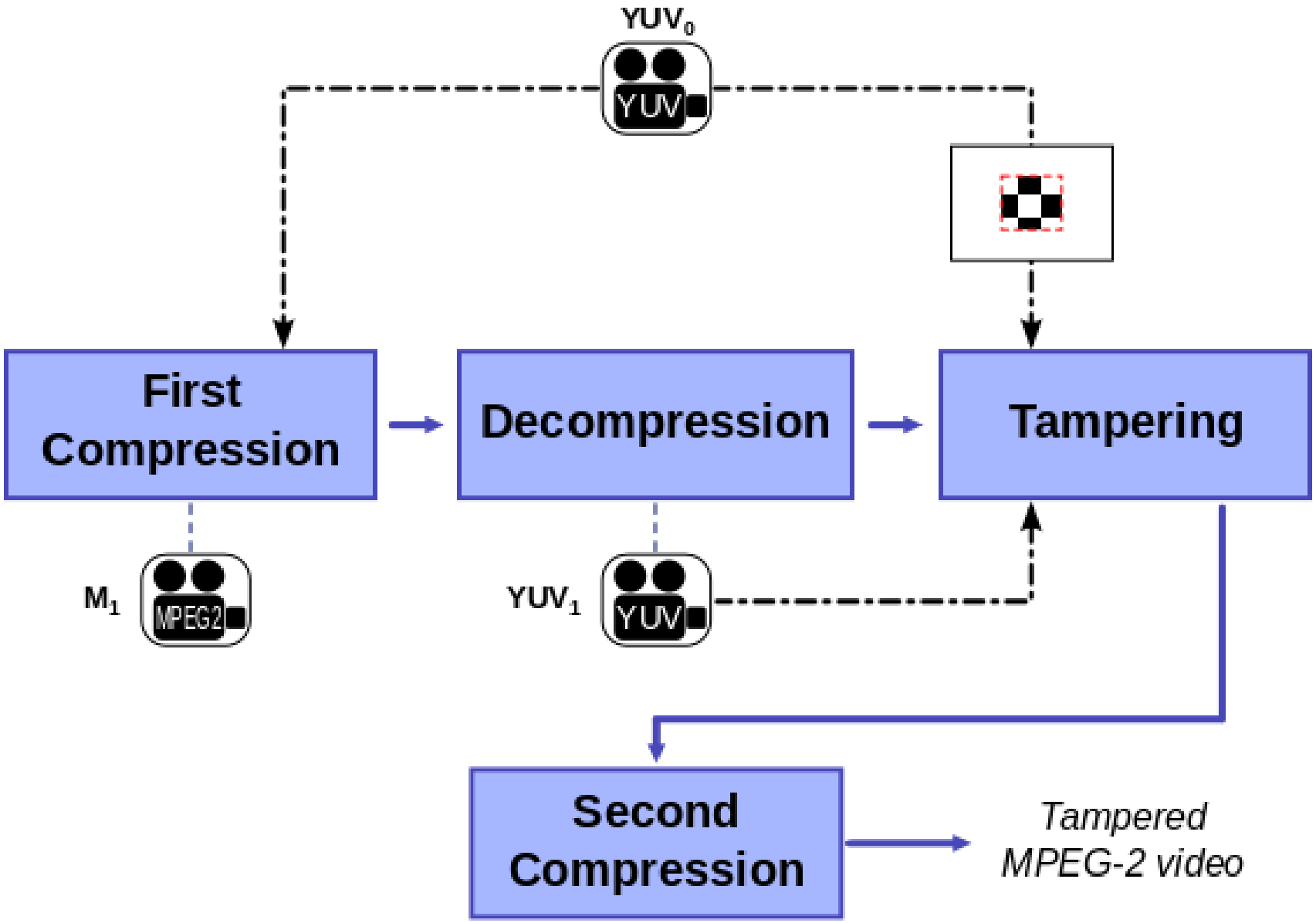

park_joy.y4m


shields.y4m


sunflower.y4m


touchdown_pass.y4m

Dataset – Tampering Procedure



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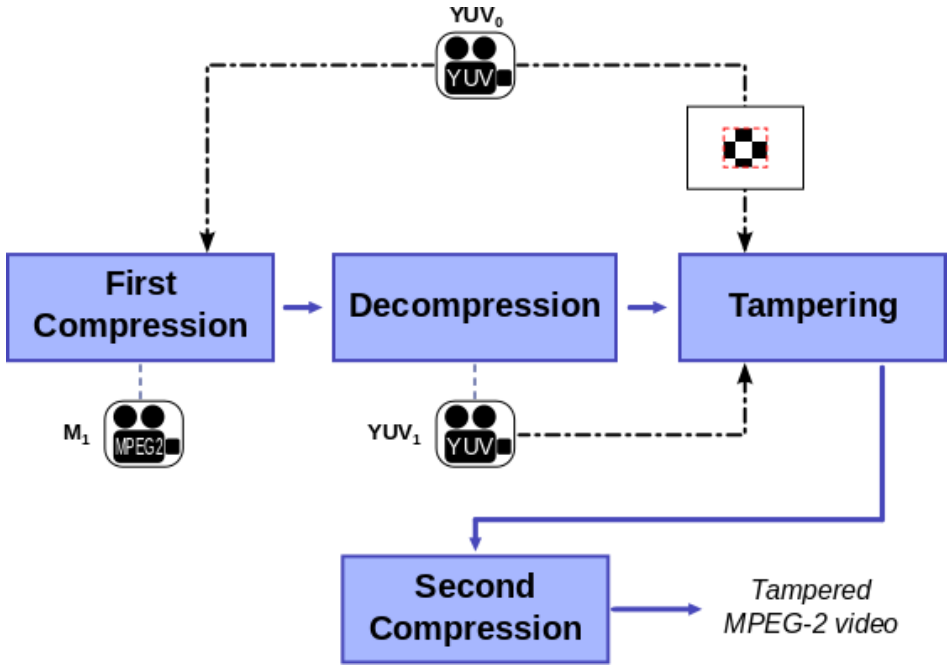

Chosen parameters for creating the dataset (112 video)

- $GOP_1 = 12,\ GOP_2 = 15$
- $k_1 \in \{12, 16, 20, 24\}$
- $k_2 \in \{4, 6, 8, 10\}$

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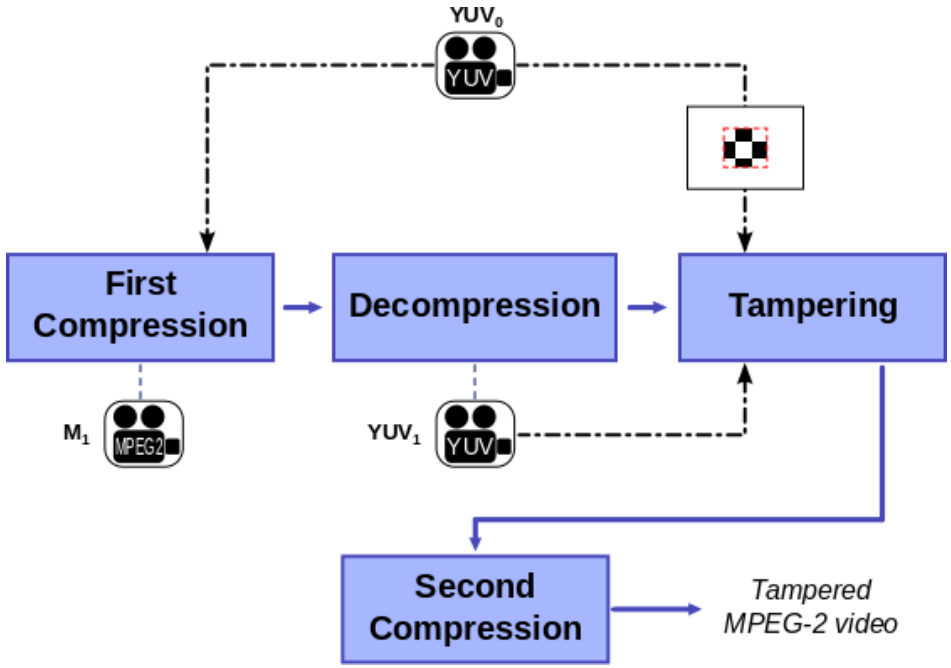

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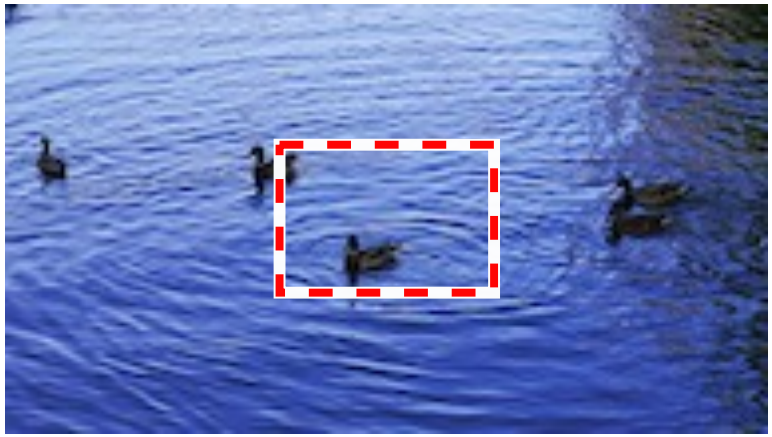
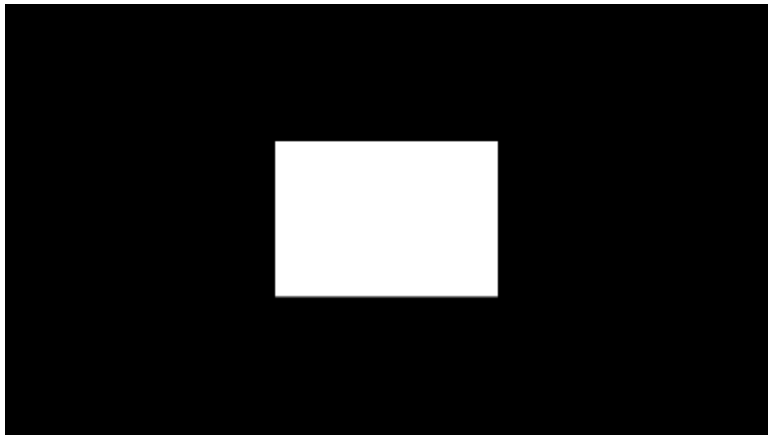
$\Big\} \longrightarrow$ constant throughout the frame (VBR coding)

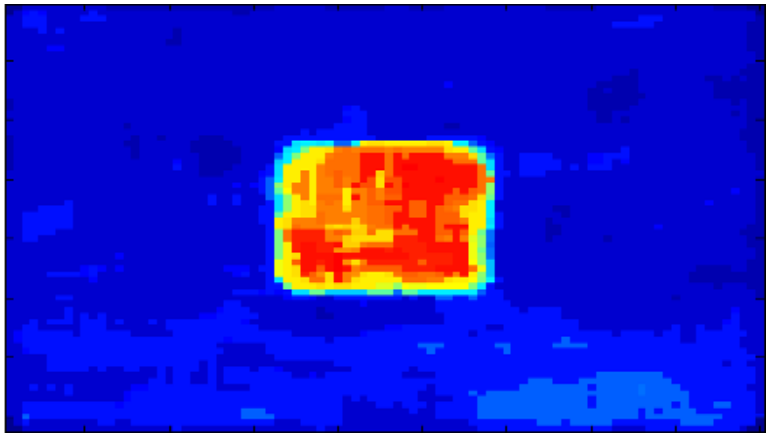
Localization example

Tampered frame



Ground truth

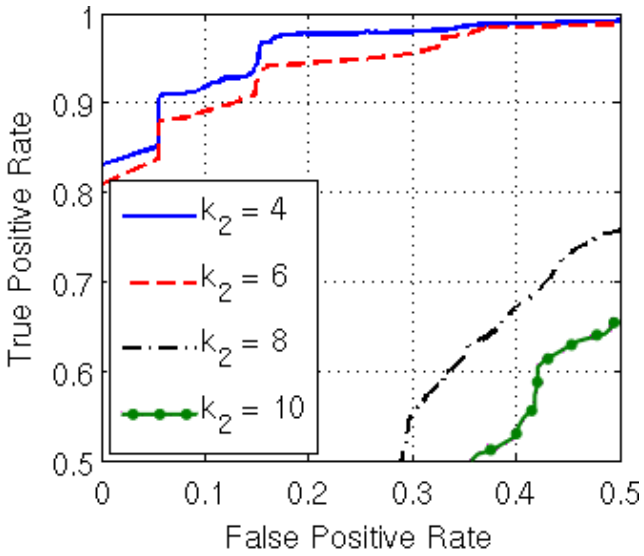


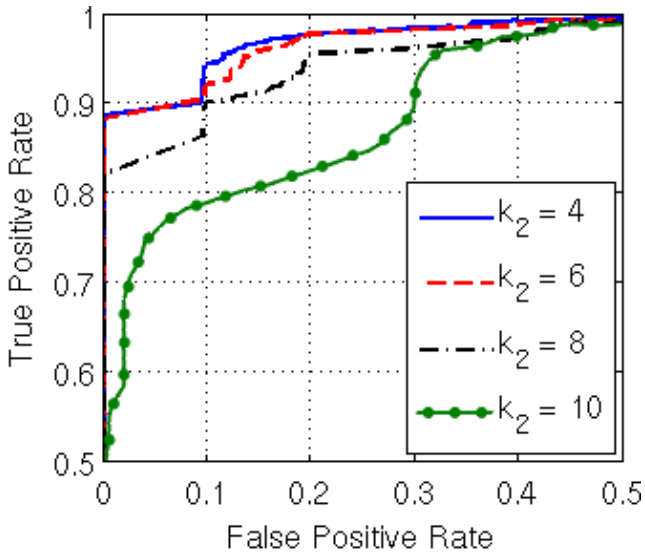


Probability map

ROC curves

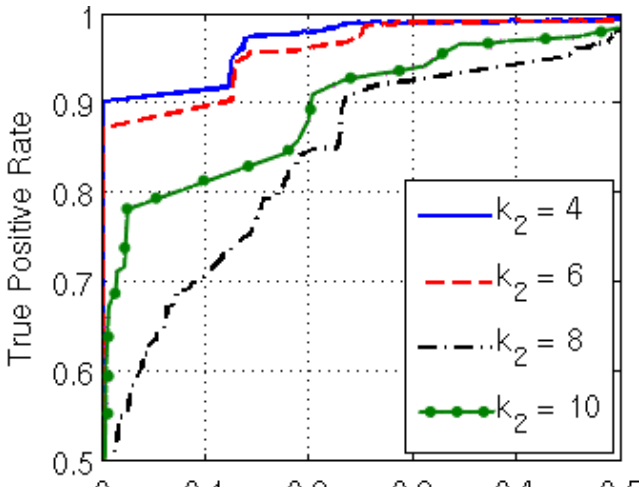
$k_1 = 12$

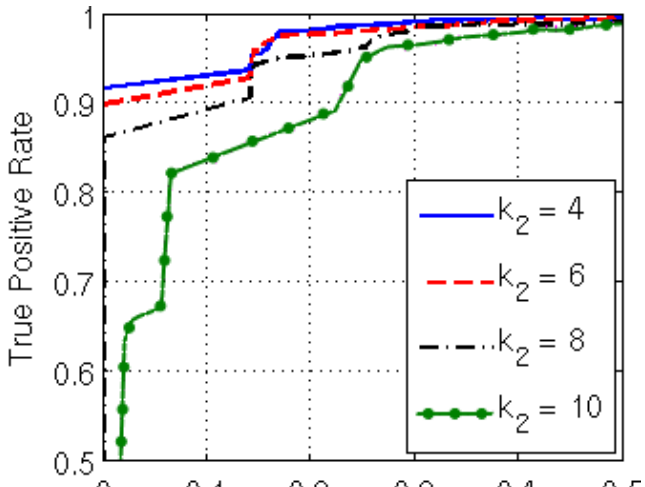




$k_1 = 16$

$k_1 = 20$





$k_1 = 24$

ROC curves

AUC obtained with the proposed method:

k_1 \ k_2	4	6	8	10
12	0.98	0.97	0.68	0.63
16	0.98	0.98	0.96	0.93
20	0.98	0.98	0.91	0.94
24	0.98	0.98	0.97	0.94

Future works

Relax constraints:

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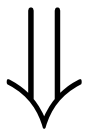

VPF

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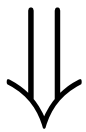
- $k_2 > k_1$
- Cropping detection



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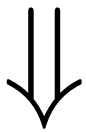

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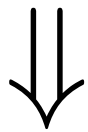

Localization Algorithm

Thanks for your attention

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This work was partially supported by the REWIND project.
More info at www.rewindproject.eu