2020

Tomasz Grajek

Multimedia Communications

Lecture slides

Poznań University of Technology

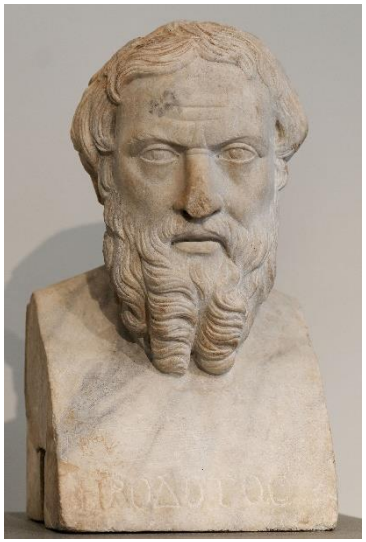
These slides are intended as suplementary material for the lecture
Multimedia Communications
given by dr Tomasz Grajek
for students of Electronics and Telecommunications
at Poznan University of Technology.

Steganography vs. cryptography

- Steganography
  is the practice of concealing a file, message, image, or video within another file, message, image, or video.
  Concealing:
  - the fact that a secret message is being sent, and
  - the contents of the message

- Cryptography
  is the practice of protecting the contents of a message alone.

Ancient steganography



- Herodotus (485 – 525 BC)
  is the first Greek historian. His great work, The Histories, is the story of the war between huge Persian empire and the much smaller Greek city-states.

Herodotus recounts the story of **Histaiaeus**, who wanted to encourage **Aristagoras of Miletus** to revolt against the Persian king.

In order to securely convey his plan, Histaiaeus shaved the head of his messenger, wrote the message on his scalp, and then waited for the hair to regrow.

The messenger, apparently carrying nothing contentious, could travel freely. Arriving at his destination, he shaved his head and pointed it at the recipient.

Conventional watermarking - example

- Patterns in currency notes which are visible only when the note is held to light.

Digital watermarking

- A digital watermark is a kind of marker covertly embedded in a noise-tolerant signal such as an audio, video or image data.
- Watermarking is the process of hiding digital information in a carrier signal.
- The hidden information should, but does not need to, contain a relation to the carrier signal.
- Digital watermarks may be used to verify the authenticity or integrity of the carrier signal or to show the identity of its owners. It is prominently used for tracing copyright infringements and for banknote authentication.

Digital watermark

- Visible

  The watermark remains visible
  (can be easily localized)
  in the signal in which it was embedded.

- Invisible

  The watermark is unnoticeable by the recipient,
  properties of human hearing or visual systems are utilized

Digital watermark

- Robust
  Modifications of watermarked content will not affect watermark

vs.

- Fragile
  The watermark is unnoticeable by the recipient,
  properties of human hearing or visual systems are utilized

- Public
  Users of content are authorized to detect watermark

vs.

- Private
  Users of content are NOT authorized to detect watermark

The need of watermarking: robust vs. fragile

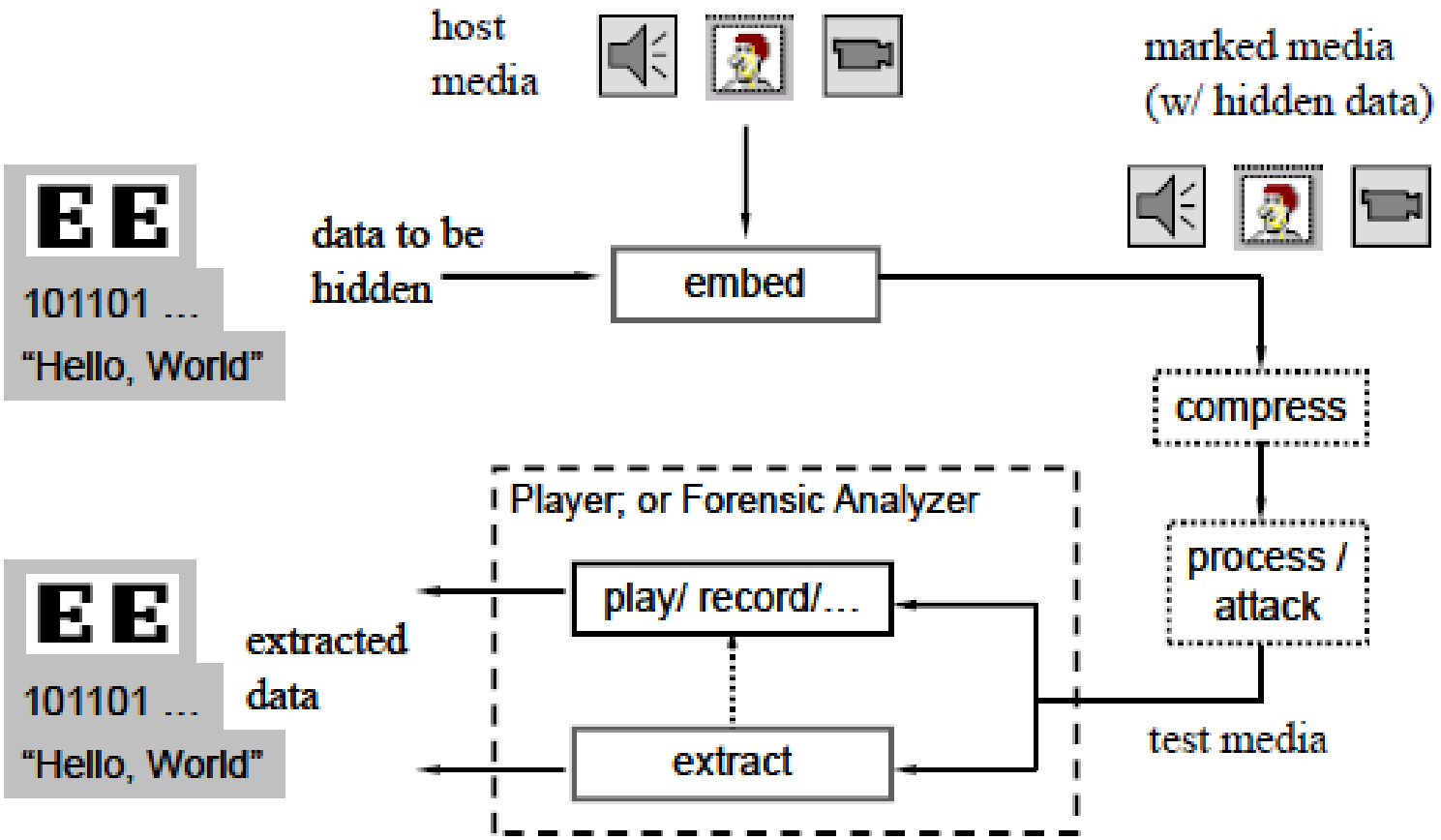
- Copyright protection:
  prove the ownership, DRM systems

- Fingerprinting:
  trace the source

- Copy protection:
  prevent illegal copying

- Data authentication:
  check authenticity of data
  - *Fragile or semi-fragile watermarking*

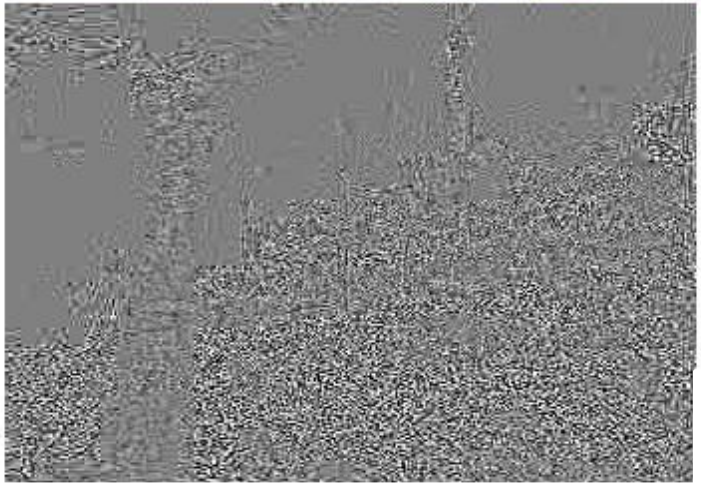
General framework of watermarking



Basic requirements for watermarking

- Imperceptibility (perceptual transparency)
- Payload
  - the amount of information that can be stored in a watermark
- Robustness (against different modifications - attacks)
- Security – Kerckhoff Principle
  - A system should be secure even if everything about the system, except the key, is public knowledge (the choice of the key is crucial)
- Blind and non-blind detection (Oblivious vs Non-oblivious)
  - Blind detection does not use the original, unmarked copy

Invisible and robust watermark



10011010 …

© Copyright …

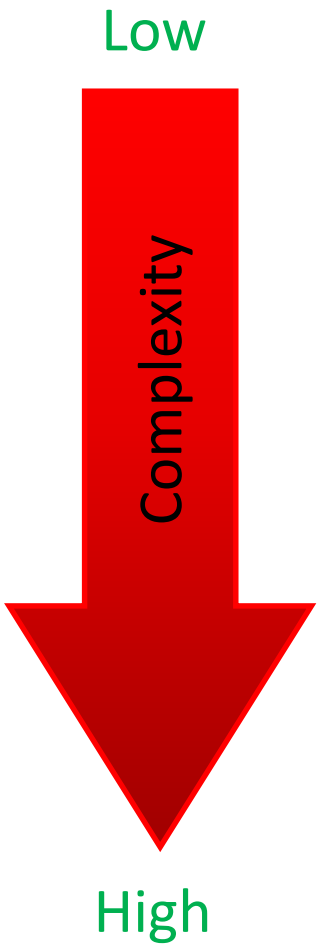
Watermarking – replacing LSBs

- Replace LSB with Pentagon's MSB

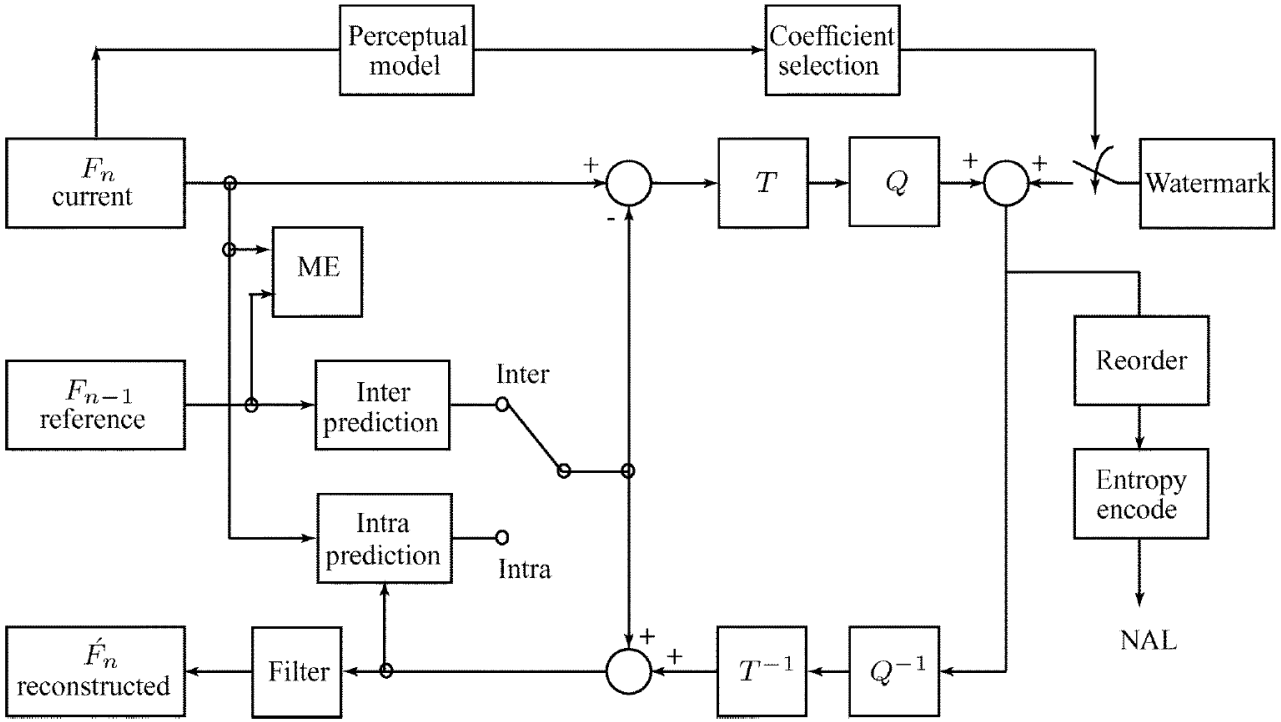


Embedding methods

- In spatial domain (samples, pixels)
- In frequency domain (transform coefficients)
- In compressed domain (compressed stream)

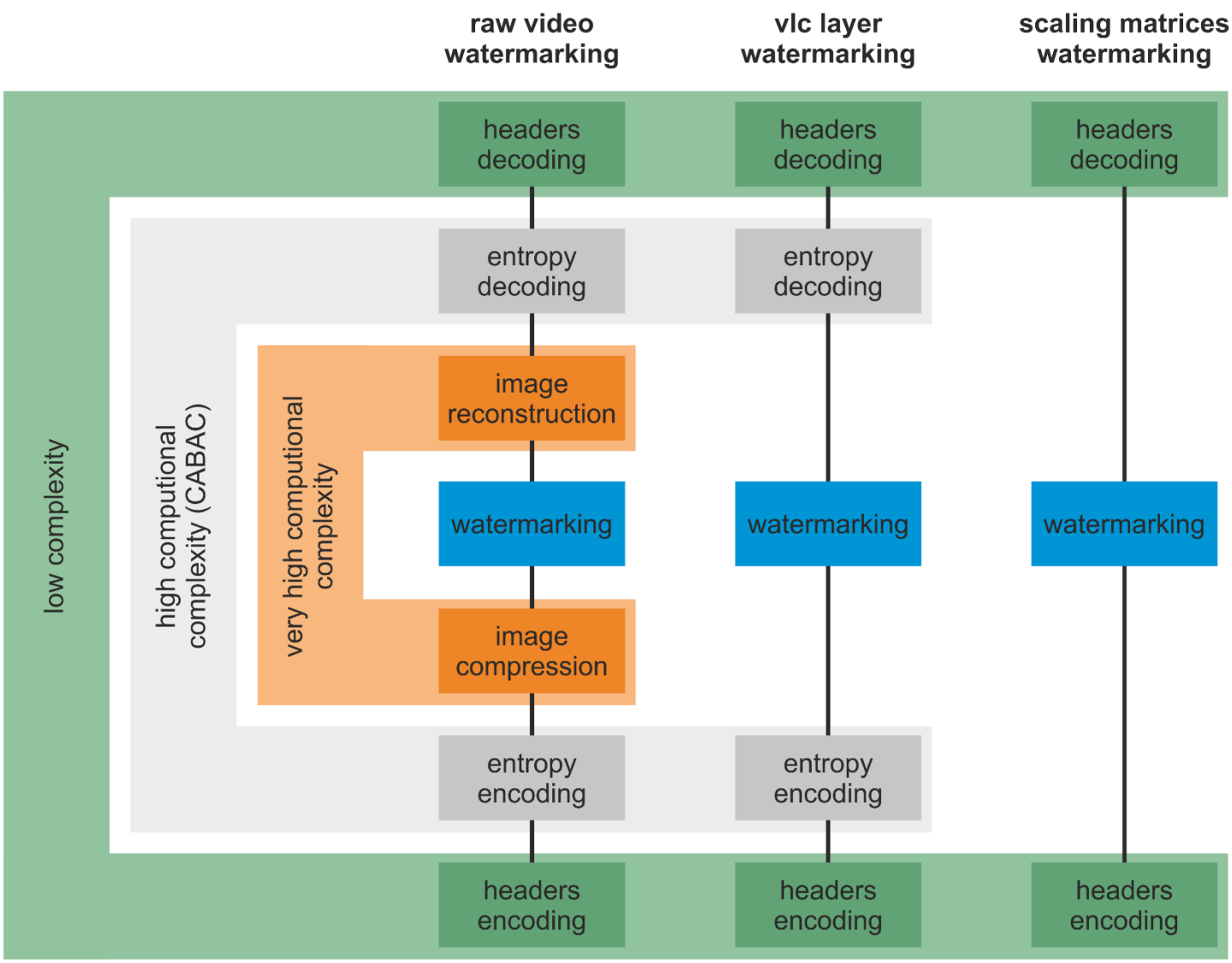


Watermarking system for AVC - example



M. Noorkami, R. M. Mersereau, „A Framework for Robust Watermarking of H.264-Encoded Video With Controllable Detection Performance", IEEE Transactions on Information Forensics and Security, vol. 2, vo. 1, March 2007.

Watermarking of compressed streams

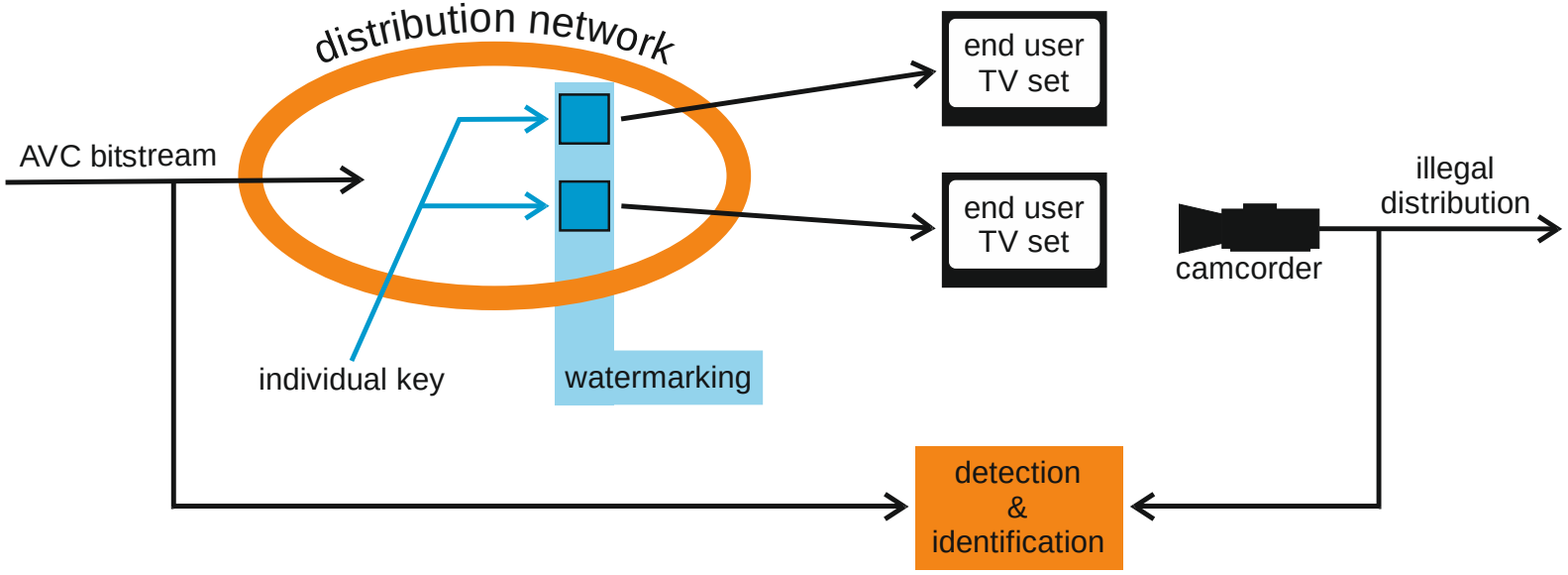


Watermarking of compressed streams

	raw video watermarking	vlc layer watermarking	scaling matrices watermarking
+	• access to each picture element • no watermark type restrictions • drift compensation	• no image reconstruction and recompression	• no image reconstruction and recompression • no slice data de- and encoding
—	• full de- and encoding • high computational power embedder required (uncompressed sequence processing)	• entropy de- and encoding (high complexity of CABAC) • access to some elements (coeffs, mv, etc.) • reduced drift control	• no local modifications • no drift compensation

System overview

- Constrains:
  - access to encoded bitstream only
  - separate watermarking of every video bitstream with individual key
  - low complexity real-time embedder
  - robustness against common attacks including camcording



Proposed method

- Changing the quantization (scaling) matrices

Quantization (encoder side)

$$Y_Q(i,j) = round\left(\frac{Y(i,j)}{Q_S} \cdot \frac{16}{Q_T(i,j)}\right)$$

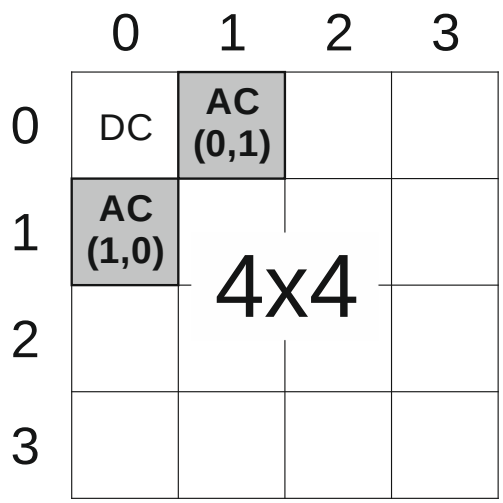
Quantization (scaling) matrix

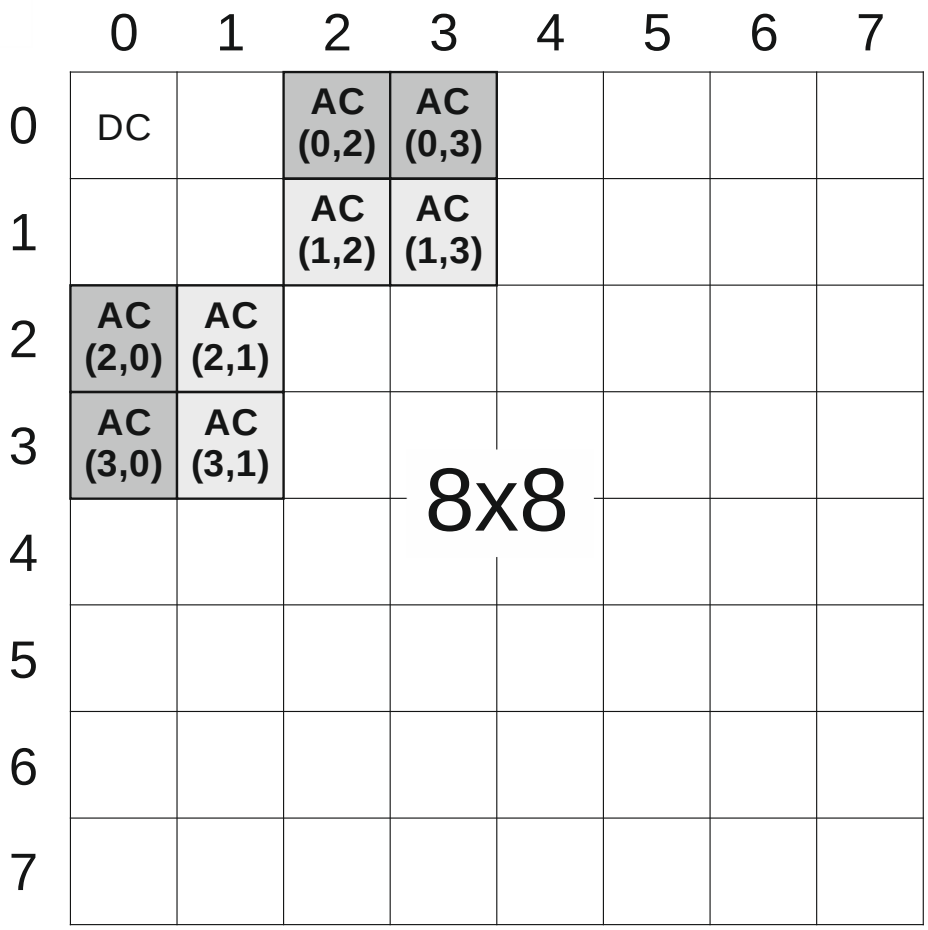
Scaling (decoder side)

$$X(i,j) = round\left(Y_Q(i,j) \cdot Q_S \cdot \frac{Q_T(i,j)}{16}\right)$$

Proposed method

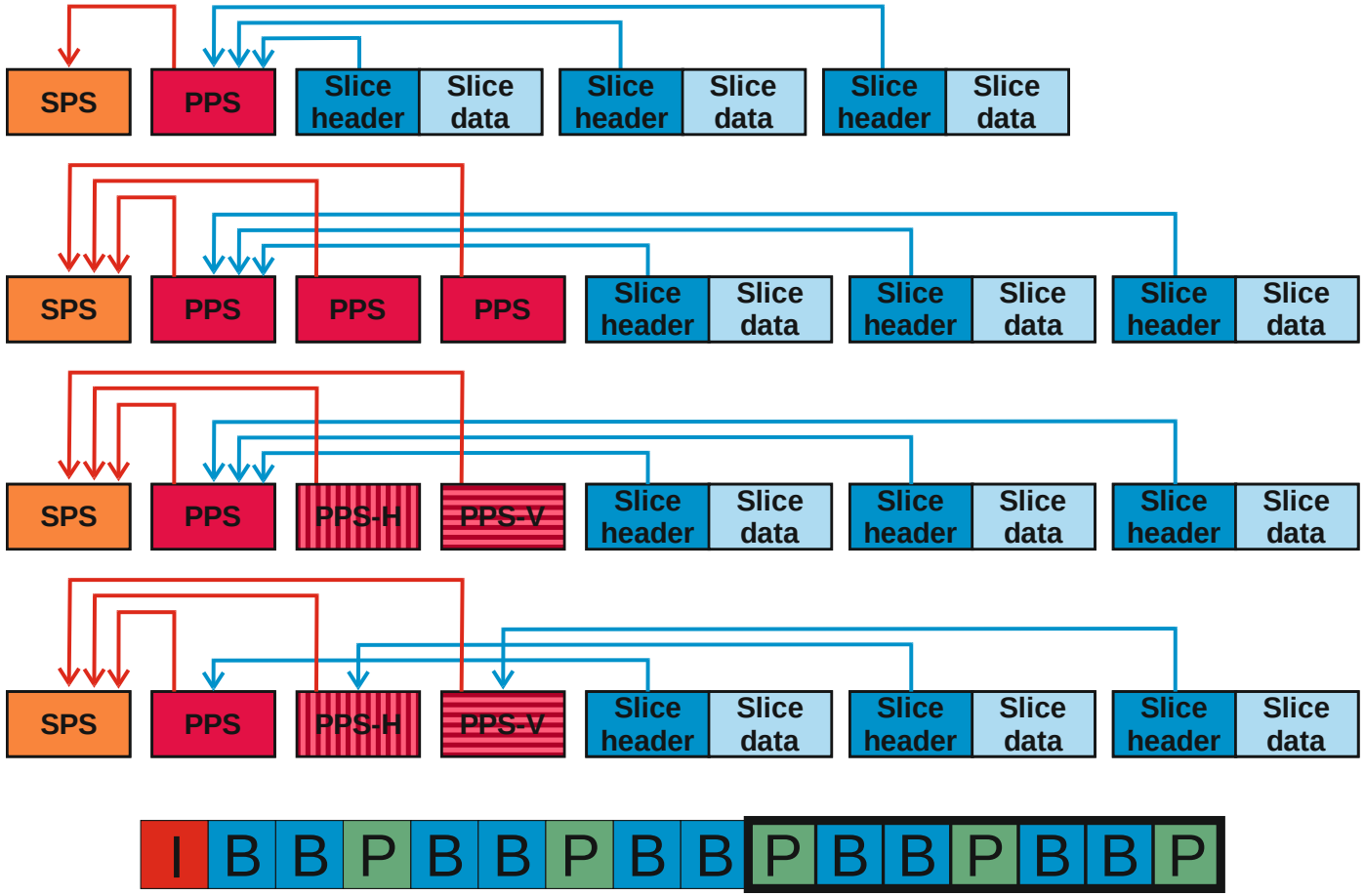
- Modified transform coefficients for 4x4 and 8x8 block size:





Proposed method

- Bitstream modifications made during watermarking process (PPS-H and PPS-V contain modified quantization matrices)



Profile issue

- In AVC (MPEG-4 part 10, H.264), the quantization (scaling) matrix transmission possible in the High profiles
- In HDTV broadcasts - the High profile mostly used
- Main profile - subset of the High profile tools
- Simple Main to High profile conversion:
  - *profile_idc* in Sequence Parameter Set (SPS)
  - additional flags required in the High profile
- Standard HDTV decoder compatible with the High profile of MPEG-4 AVC/H.264

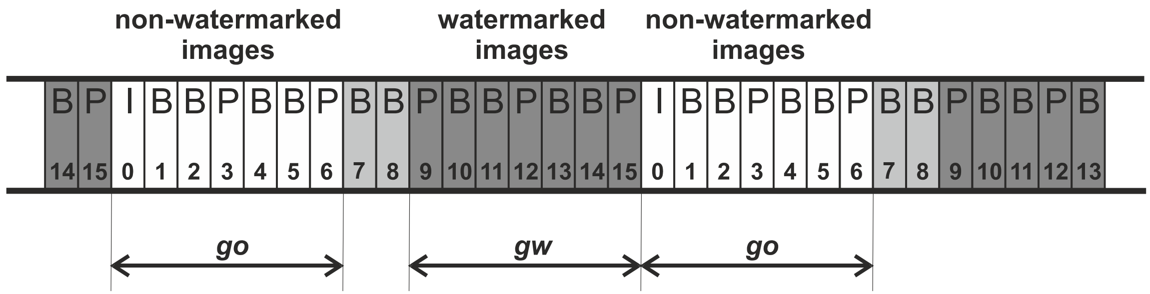
Watermark detection

- The original and the investigated video sequence needed
- Both sequences must be temporally aligned, but spatial alignment is not critical
- The detector's input sequences (the original and the investigated) analyzed in spectral domain (the 8x8 transform as defined in MPEG-4 AVC/H.264)
- The averaged energy of each coefficient over 8x8 blocks in a frame estimated as follows:

$$\overline{E_{i,j}} = \frac{1}{N}\sum_{k}(a_{i,j}^{k})^{2}$$

Watermark detection

- Assumption: the analyzed video sequence contains consecutive groups of watermarked (*gw*) and non-watermarked (*go*) images.



- Comparison of transform coefficient energy distribution of investigated sequence with energy distribution of original sequence:

$$S_{i,j} = \frac{G^{w}_{i,j}(cam)}{G^{O}_{i,j}(cam)} - \frac{G^{w}_{i,j}(org)}{G^{O}_{i,j}(org)}$$

$$G^{W}_{i,j} = \sum_{l \in gw} \overline{E_{i,j}}^{\,l}, \qquad G^{O}_{i,j} = \frac{1}{2}\left(\sum_{l \in go1} \overline{E_{i,j}}^{\,l} + \sum_{l \in go2} \overline{E_{i,j}}^{\,l} \right)$$

- Detector response:

$$\begin{aligned} r \;=\; & a \cdot \operatorname{sgn}(S_{0,2} - S_{2,0}) + b \cdot \operatorname{sgn}(S_{0,3} - S_{3,0}) \;+ \\ +\; & c \cdot \operatorname{sgn}(S_{1,2} - S_{2,1}) + d \cdot \operatorname{sgn}(S_{1,3} - S_{3,1}) \end{aligned}$$

Methodology

- Four different scenarios were tested to check robustness against most popular attacks:
  - Scenario 1: (attack simulation): Low-pass filtering, 10% image cropping and 10% image resizing
  - Scenario 2: Camcording using HD camera
  - Scenario 3: Camcording using HD camera and downscaling to SD resolution
  - Scenario 4: Camcording using HD camera and frame rate reduction (from 25 to 12.5 fps)

- Two different random bit streams (A and B) were used as the watermark payload.

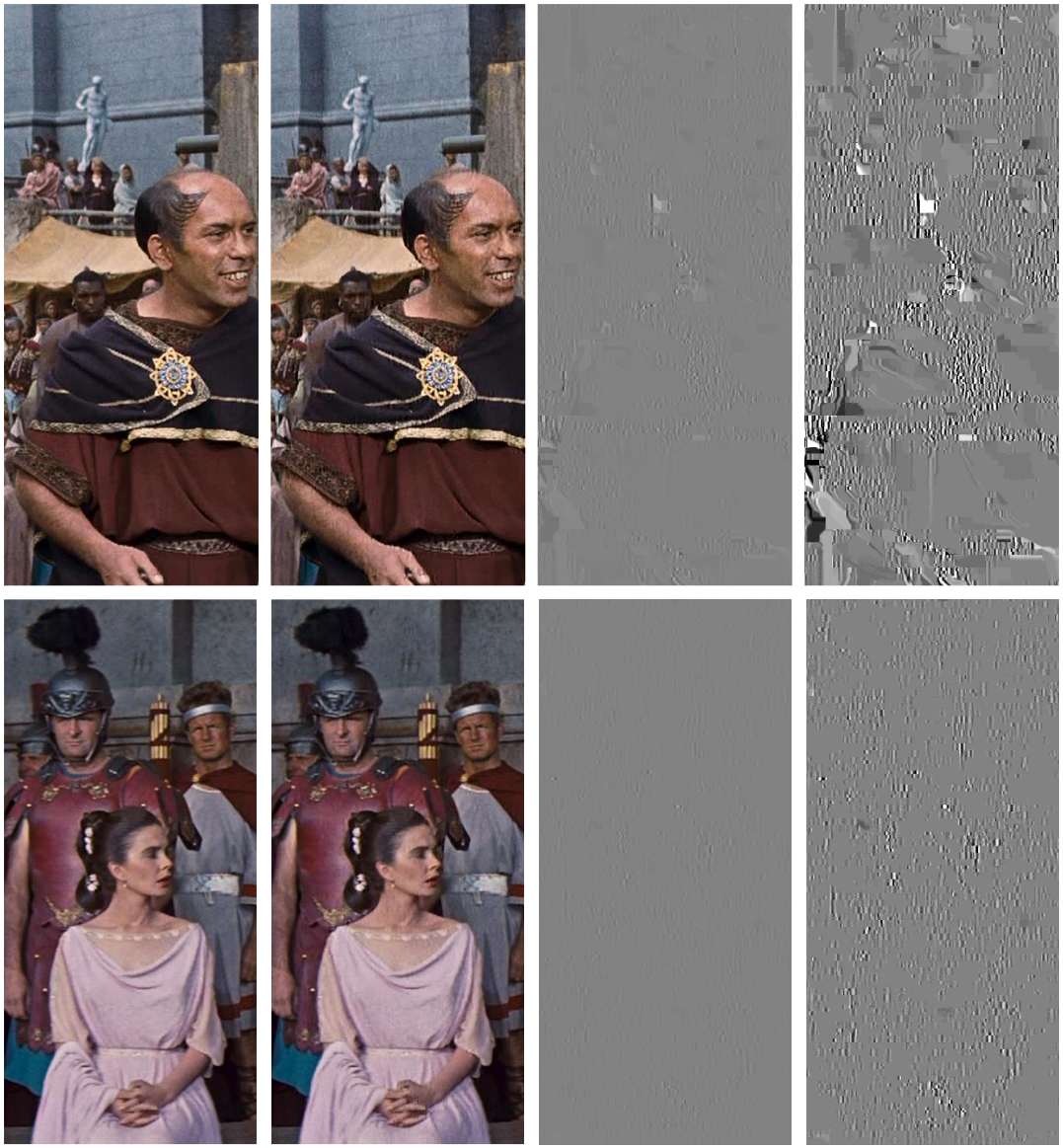
- Five HDTV (1920x1080, 25 fps) video sequences - 10 min. length.

- x264 encoder, configured to produce the MPEG-4 AVC/H.264 High-profile-compliant bitstreams.

Results

Sequence type	Payload bitstream	Properly detected bits [%] in scenario:			
		1.	*2.*	*3.*	*4.*
Soap opera 1	A	97.7	88.5	83.3	88.4
	B	97.4	87.6	82.0	87.8
Soap opera 2	A	98.4	88.5	88.5	88.5
	B	98.7	92.4	87.3	91.1
Historical novel	A	99.8	97.4	96.3	96.7
	B	99.9	99.6	98.7	99.2
Computer animated film	A	96.6	87.2	82.7	84.7
	B	97.0	87.7	82.8	86.0
War film	A	94.9	76.2	72.4	73.8
	B	95.4	75.0	73.9	74.6
Average	A	97.5	87.6	84.6	86.4
	B	97.7	88.5	84.9	87.7

Results



Summary

Advantages of the proposed method:

- Low computationally complex embedder
- Negligibly small bitstream increase
- Robustness against:
  - blurring
  - camcording
  - downscaling to SD
  - dawnsampling to lower frame rate
- Suitable for implementation on low processing power devices or systems