H.264 / AVC (Advanced Video Coding)

CGG MFF UK Praha

pepca@cgg.mff.cuni.cz
http://cgg.mff.cuni.cz/~pepca/

Context

- **1988: px64kbps (ITU-T H.261)** – video over ISDN
- **1993: MPEG-1** – VHS quality video (audio layers!)
- **1995: MPEG-2 part 2 (H.262)** – DVD video (SD), DVB (SD, HD)
- **1996[1998]: H.263[+]** – low bitrate video, video-conferencing, YouTube, ..
- **1999: MPEG-4 part 2** – DivX, XviD, QuickTime
- **2003: MPEG-4 part 10 (H.264 / AVC)**

Enhancements (prediction)

- **variable block-size motion compensation**
  even small block sizes (down to 4×4)
- **quarter-sample-accurate** motion compensation
- motion vectors over **picture boundaries**
- **multiple reference picture** motion compensation
- arbitrary **referencing order** (limited by total memory capacity only) ≠ **display order**

Enhancements (prediction) II

- **any picture** can be used as **reference** (even B)
- **weighted prediction** (bi-directional prediction)
- improved „**skipped**” and „**direct**” motion inference
- **directional spatial prediction** for intra coding
- in-the-loop **deblocking filtering**

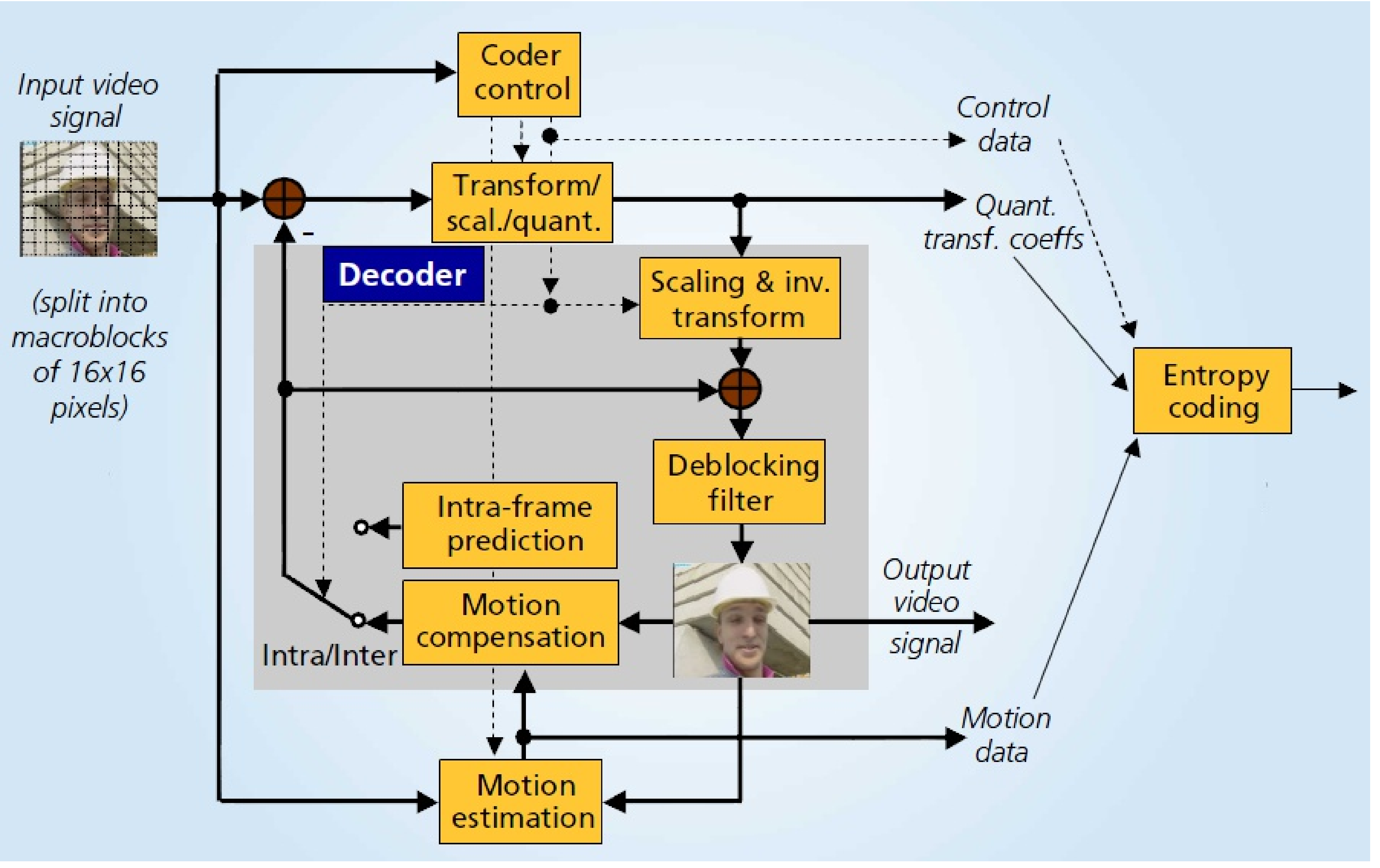
Enhancements (compression)

- **small block-size transform** (4×4), fast, 16-bit **integer**, **exact inverse**
- **hierarchical** block transform (8×8, 16×16)
- arithmetic entropy coding **CABAC**, context-adaptive entropy coding **CAVLC**

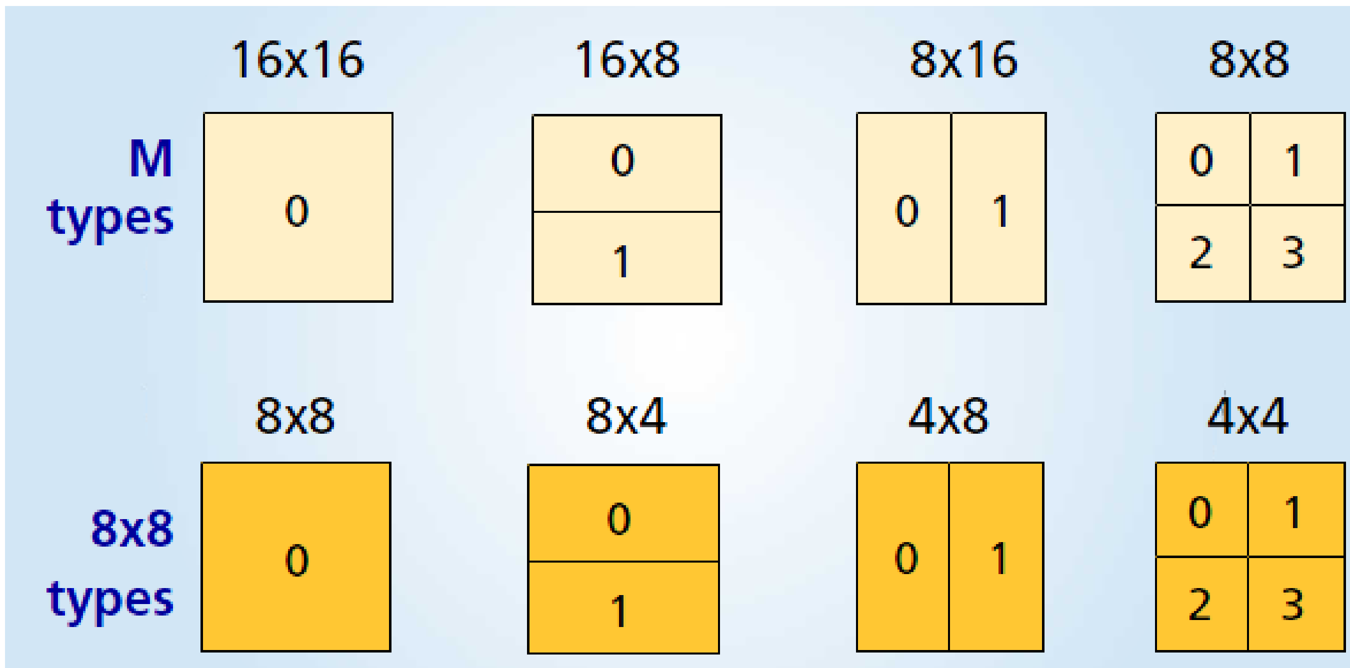
Enhancements (stream, robustness)

- **NAL** (Network Abstract Layer) – NAL units
- flexible **slice size**
- **flexible macroblock ordering** (FMO), slice groups
- **arbitrary slice ordering** (ASO) – for low latency
- **redundant pictures**
- **data partitioning** (important vs. regular data)
- **SP/SI** synchro/switching pictures („I“ not needed)

Basic coding structure

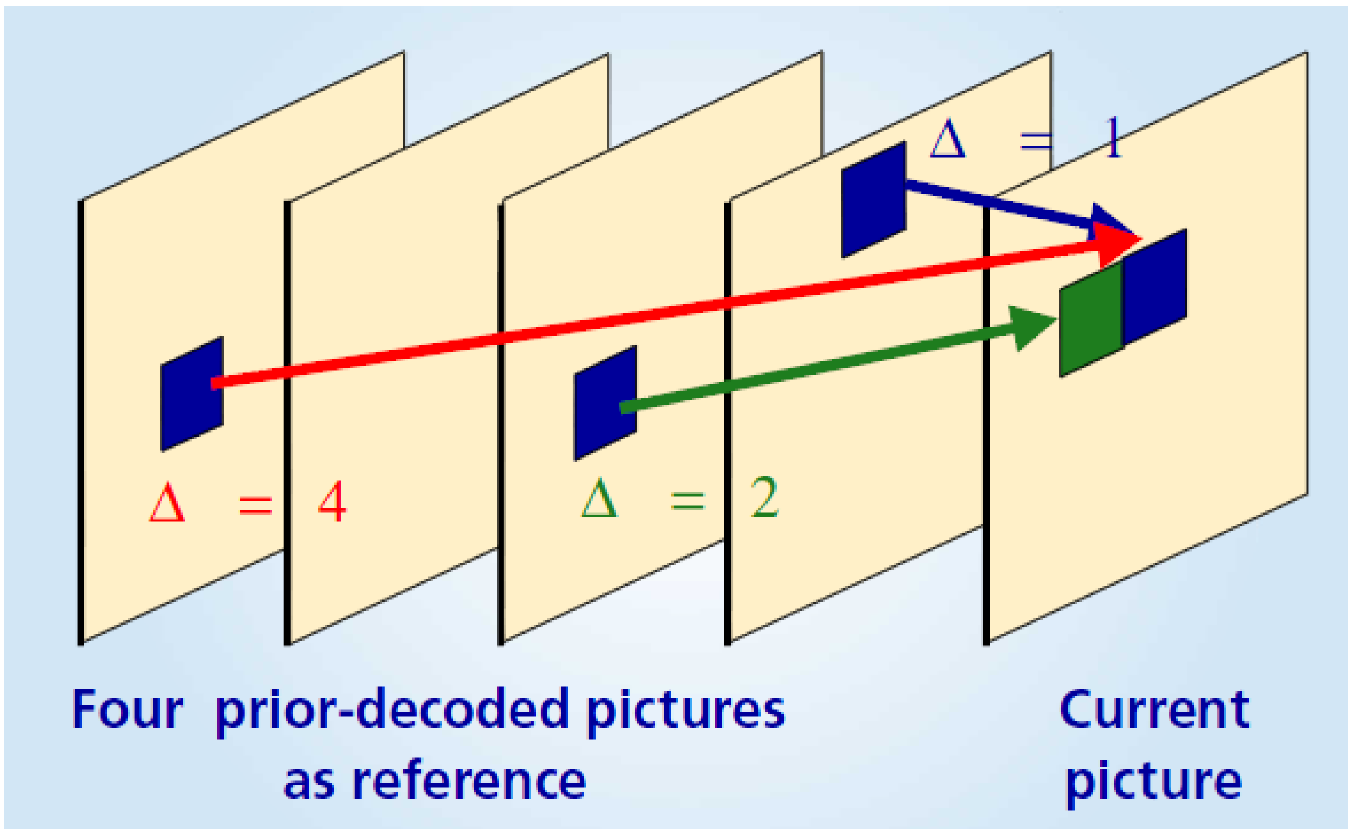


Motion compensation blocks

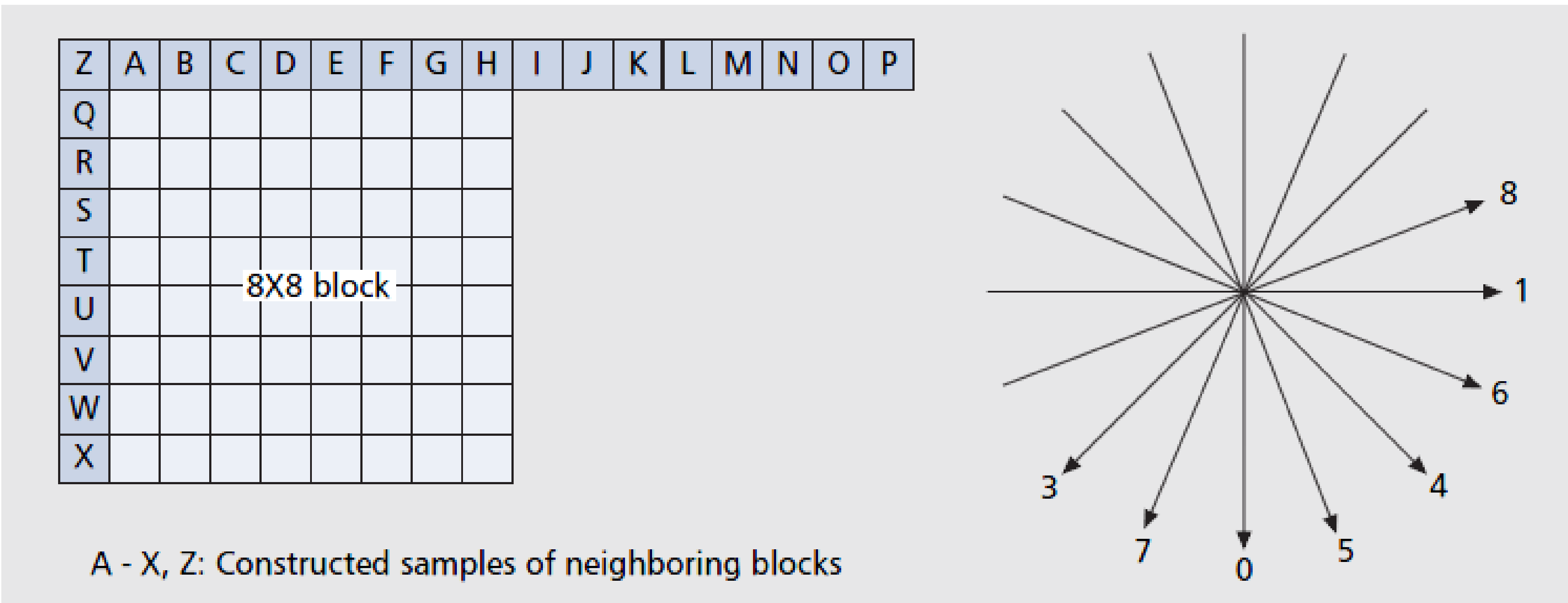


macroblocks & partitions

Multi-frame motion compensation



Intra prediction for luma (8×8)



mode 2: mean of A–H, Q–X

Prediction mode

- looking for mode with **the smallest residuals**
- the **most probable mode** … mode used in surrounding, already coded blocks
- **default** … the most probable mode (1-bit flag)
  otherwise … the current mode

VLC coding

- **residual block data** (quantized transform data) … CAVLC (Context-Adaptive Variable Length Code)
- **other data** (header data, motion vectors) … Exp-Golomb codes
  – directly or via table-lookup

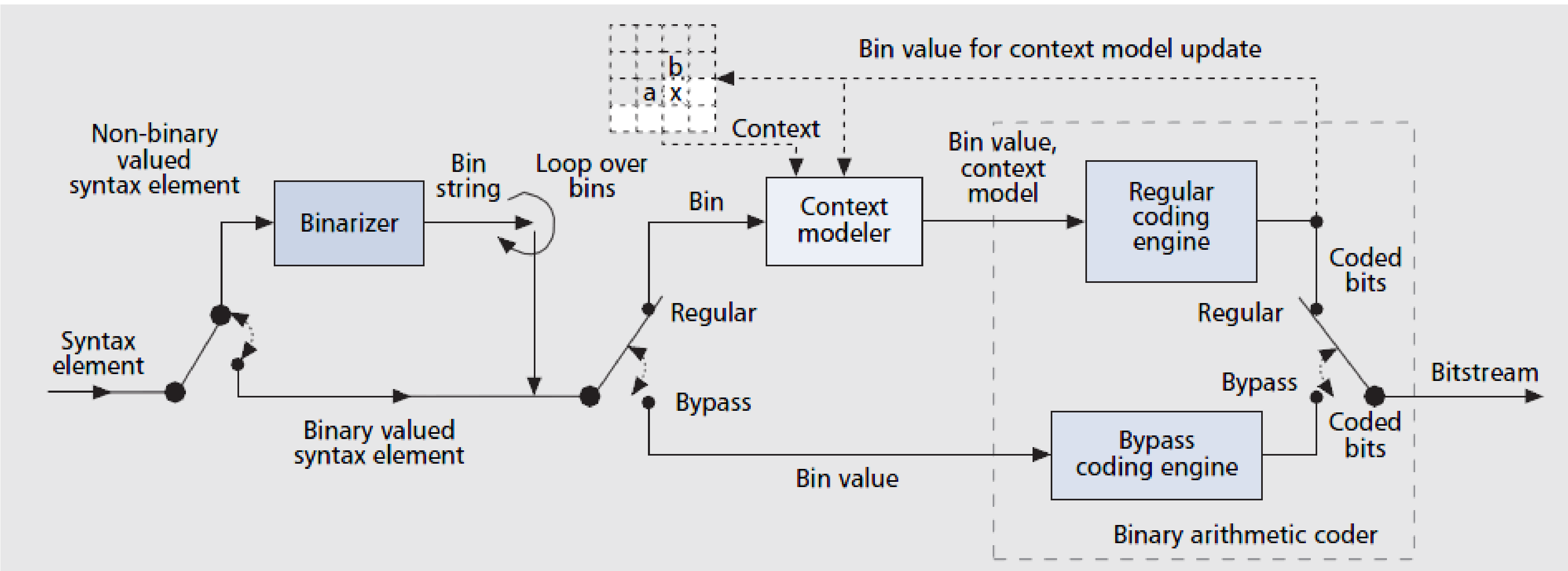
Exp-Golomb code

Code number	Codeword
0	1
1	01 0
2	01 1
3	001 00
4	001 01
5	001 10
6	001 11
7	0001 000
...	...

CAVLC Coding

- residual, zig-zag ordered quantized transform data
- sparse, long zero runs..
  - number of non-zero coeffs („N“)
  - number of trailing ±1s („T1s“)
  - TotalZeroes (between start and the last non-zero)
  - RunBefore (# of zeroes before the non-zero)
- magnitude is higher near the DC coeff, magnitude coding depends on recently coded magnitudes

CABAC entropic coder



Up to approx. 15% better efficiency compared to CAVLC

Deblocking filter

1) Without Filter 2) with H264/AVC Deblocking

4×4 Transform

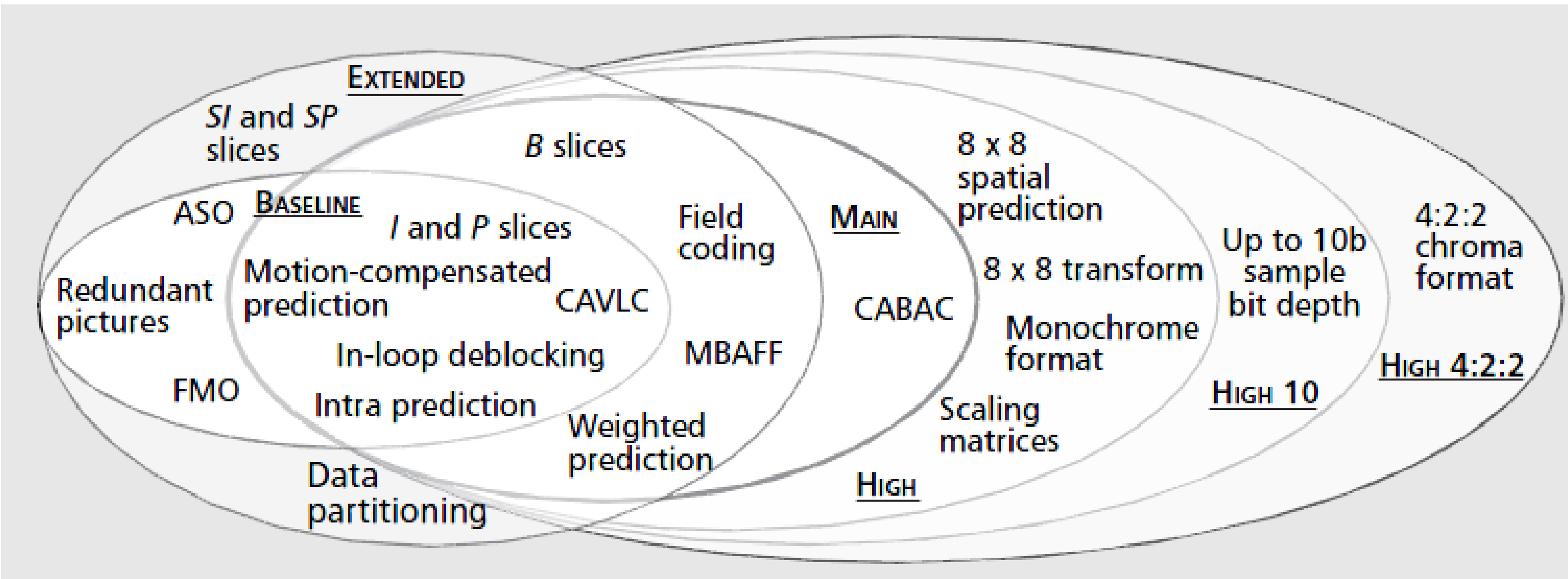
$$Y = H \cdot X \cdot H^T$$

$$H = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 2 & 1 & -1 & -2 \\ 1 & -1 & -1 & 1 \\ 1 & -2 & 2 & -1 \end{bmatrix}$$

Quantization

- **logaritmic** sequence
- **geometric** progression
  - coef = $2^{1/6}$
- can be **integrated** together with block transform
  - integer matrix (only 16-bit int arithmetic needed)

H.264 profiles



Baseline: minimum complexity, maximum robustness
Main: maximum efficiency, less robust
Extended: trade-off, more robust in video-streaming

References

- **D. Marpe, T. Wiegand, G. J. Sullivan**: ***The H.264/MPEG4 Advanced Video Coding Standard and its Applications***, IEEE Communications Magazine, Aug 2006

- **R. Schäfer, T. Wiegand, Hh Schwarz**: ***The Emerging H.264/AVC Standard***, EBU technical review, Jan 2003

- **T. Wiegand, G. J. Sullivan, G. Bjøntegaard, A. Luthra**: ***Overview of the H.264/AVC Video Coding Standard***, IEEE Transactions on Circuits and Systems for Video Technology, Jul 2003