H.261 VIDEO CODING

Laboratory session

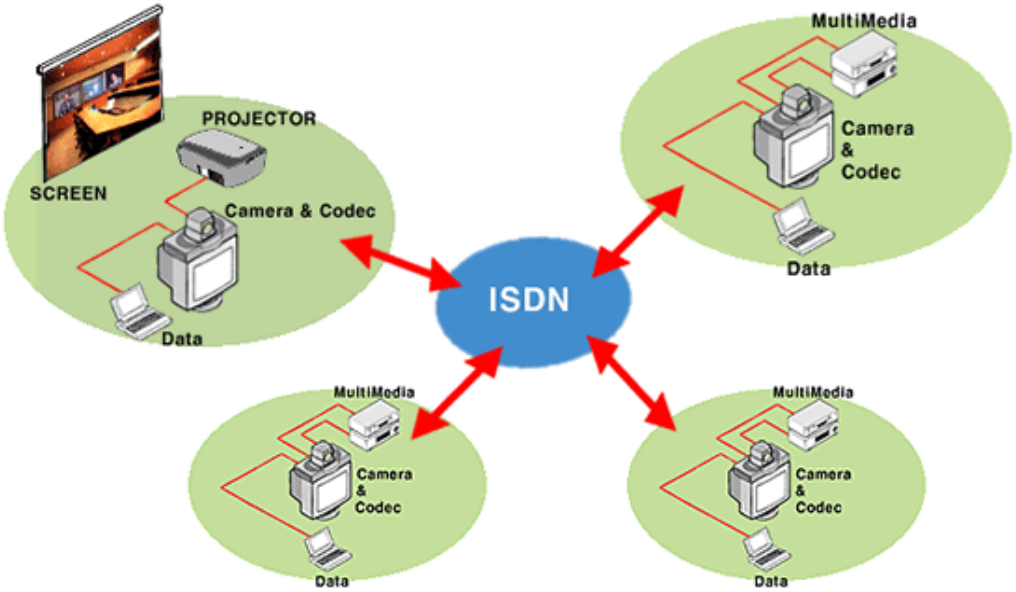
Fernando Pereira

Instituto Superior Técnico

Coding Changing Faces …

Recommendation H.261: Objectives

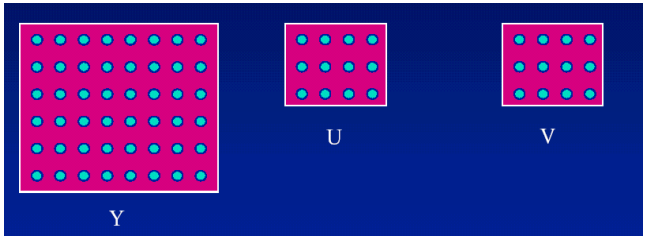
~1985



Efficient coding of videotelephony and videoconference visual data with a minimum acceptable quality using a bitrate from 40 kbit/s to 2 Mbit/s, targeting synchronous channels (ISDN) at p×64 kbit/s, with p=1,...,30.

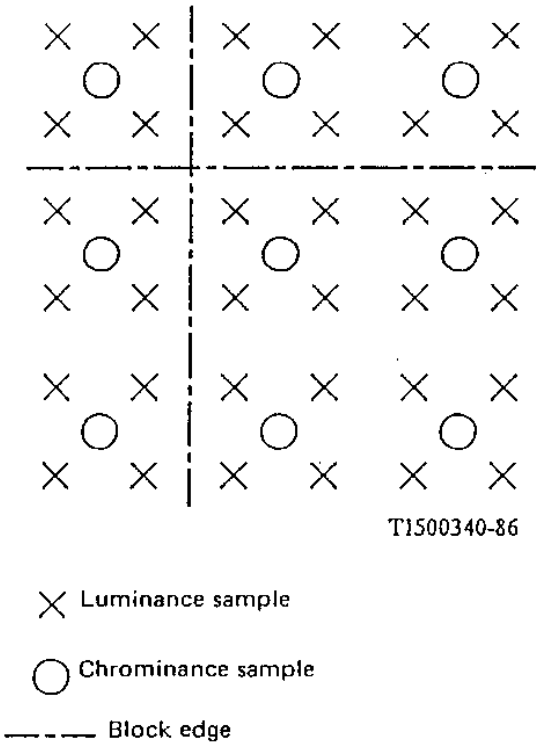
This is the first international video coding standard with relevant market adoption, thus introducing the notion of backward compatibility in video coding standards.

H.261: Image Format



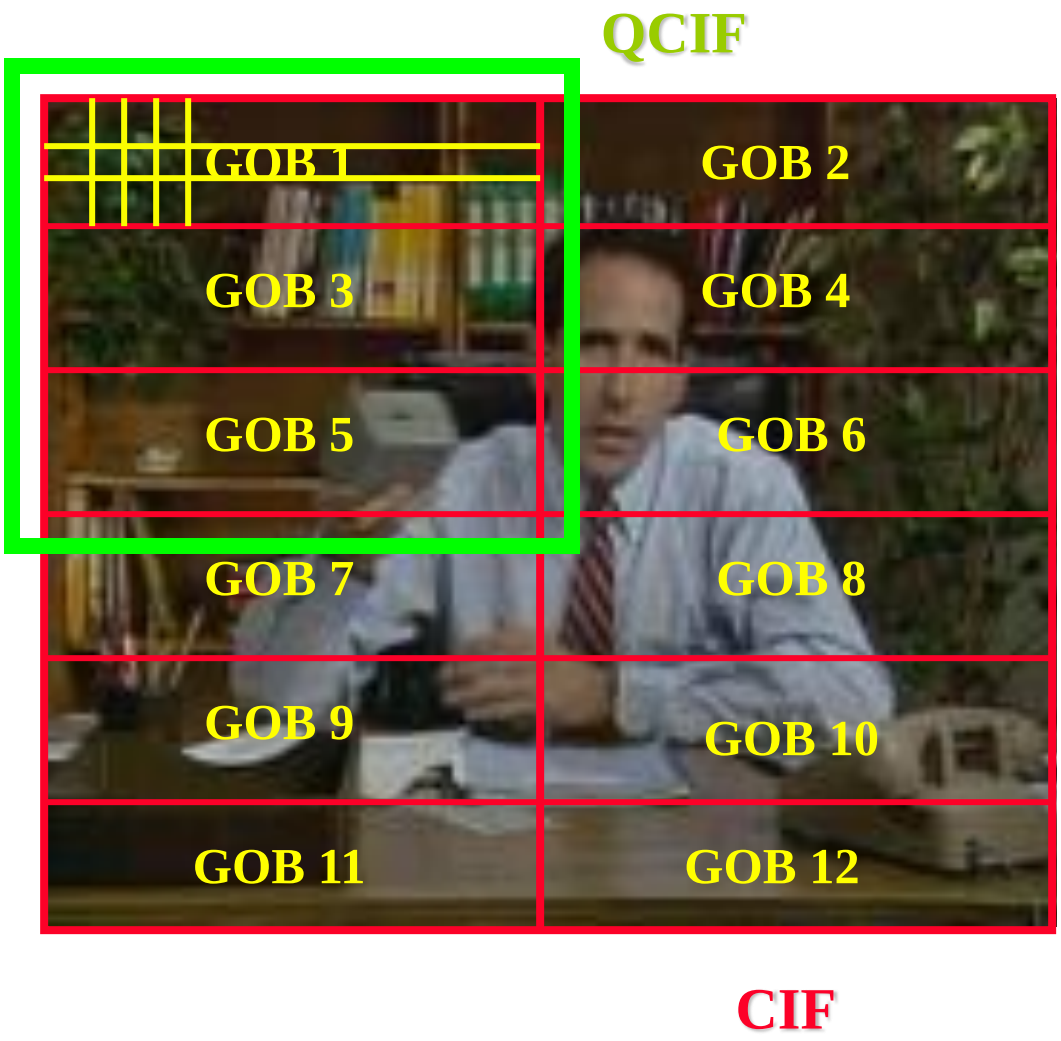
Two spatial resolutions are possible:

- **CIF (*Common Intermediate Format*) - 288 × 352 samples for luminance (Y) and 144 × 176 samples for each chrominance (U,V) this means a 4:2:0 subsampling format, with 'quincux' positioning, progressive, 30 frame/s with a 4/3 aspect ratio.**
- **QCIF (*Quarter CIF*) – Similar to CIF with half spatial resolution in both directions this means 144 × 176 samples for luminance and 72 × 88 samples for each chrominance.**



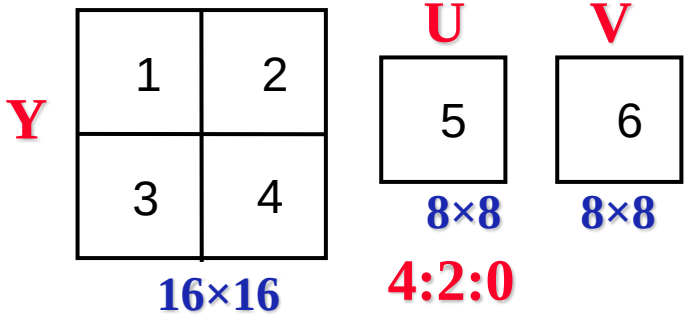
All H.261 codecs must work with QCIF and some may be able to work also with CIF (spatial resolution is set after initial negotiation).

Images, Groups Of Blocks (GOBs), Macroblocks and Blocks



The video sequence is spatially organized according to a hierarchical structure with 4 levels:

- Images/Frames
- Group of Blocks (GOB)
- Macroblocks (MB) – 16×16 pixels
- Blocks - 8×8 samples



H.261: Coding Tools

- **Temporal Redundancy**

  Predictive coding: temporal prediction residues

  without and with motion compensation

- **Spatial Redundancy**

  Transform coding (Discrete Cosine Transform, DCT)

- **Statistical Redundancy**

  Huffman entropy coding

- **Irrelevancy**

  Quantization of DCT coefficients

Coding and Decoding ...

Original at encoder

Decoded at encoder & decoder

To be lossy coded at encoder

new picture

previous picture

difference

-

=

Encoder

Decoder

Decoded at decoder

Decoded at decoder

difference

previous picture

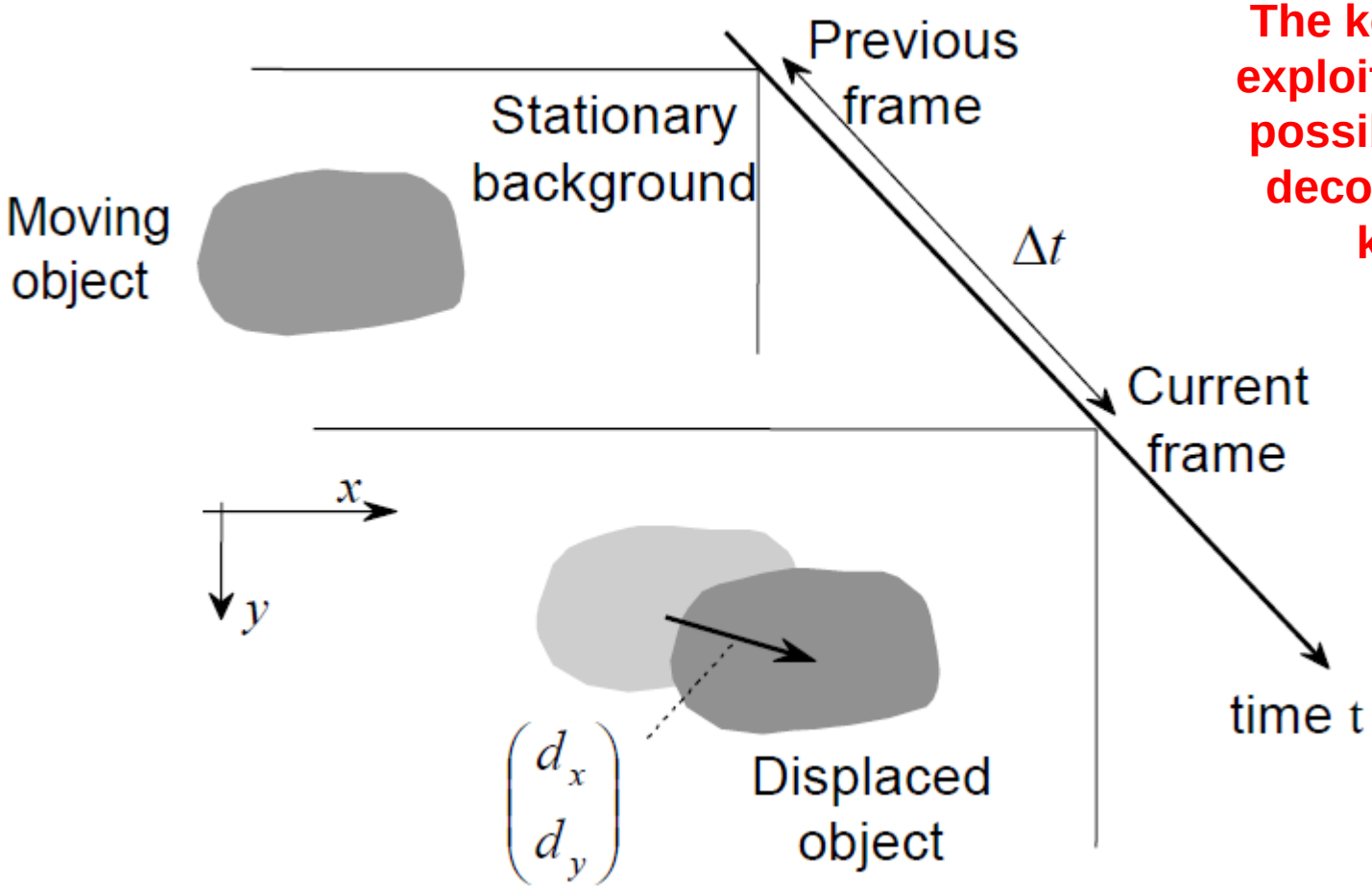
new picture

+

=

Decoded at decoder

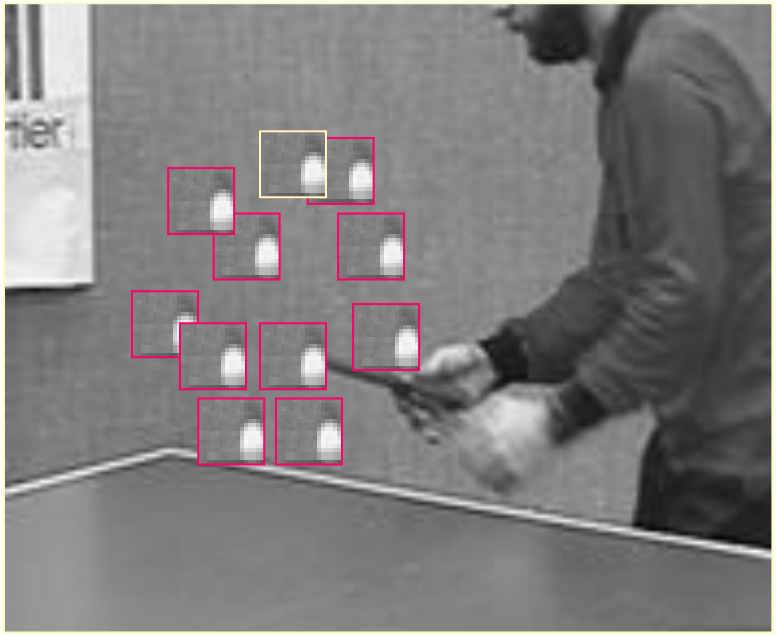
Motion in Action … Not New, Just Displaced !



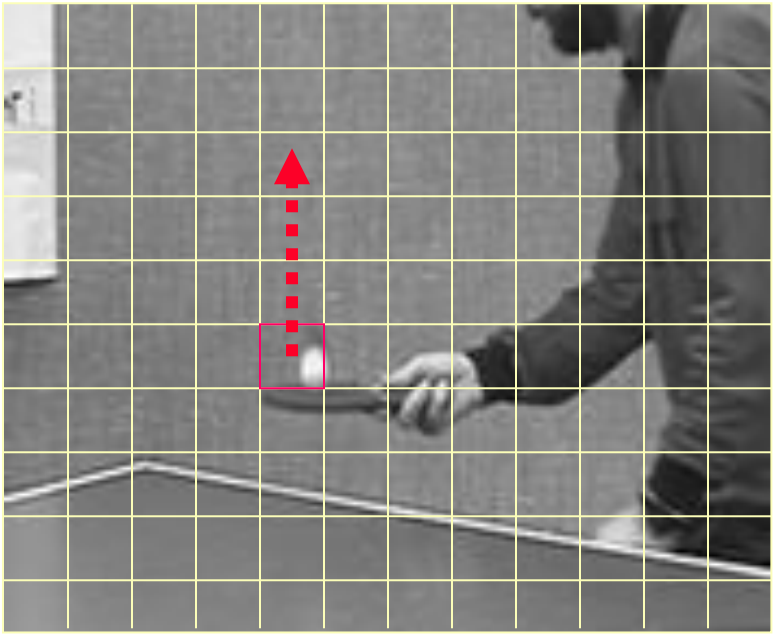
The key idea is to exploit as much as possible what the decoder already knows !

Motion Estimation by Macroblock Matching

Decoded Frame *i-1*
(available at encoder and decoder)



Original Frame *i*
(ONLY available at encoder)



t

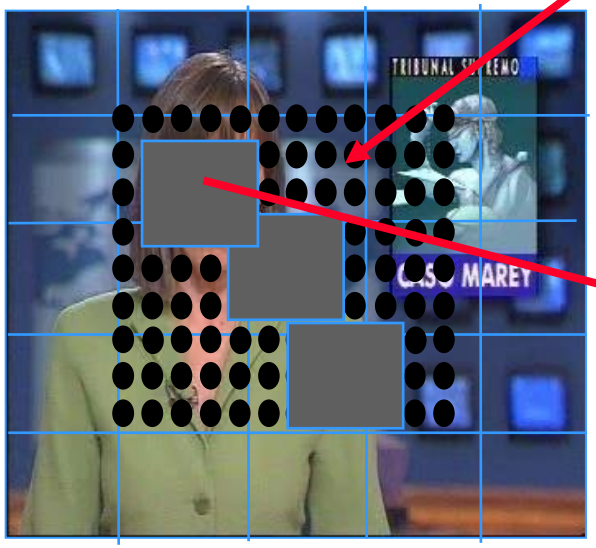
The best MB prediction from the previous decoded frame is the one minimizing an error metric, e.g. MSE or MAE, between the original MB in frame *i* and the candidate (displaced) MBs in frame *i-1*.

$$MSE = \frac{1}{n}\sum \underbrace{\left(y - \hat{y}\right)^2}_{\text{The square of the difference between actual and predicted}}$$

Motion Search: Where Worthwhile while Reducing Complexity ?

Searching area

In H.261, this motion vector search area has a size of ± 15 pixels in both directions.



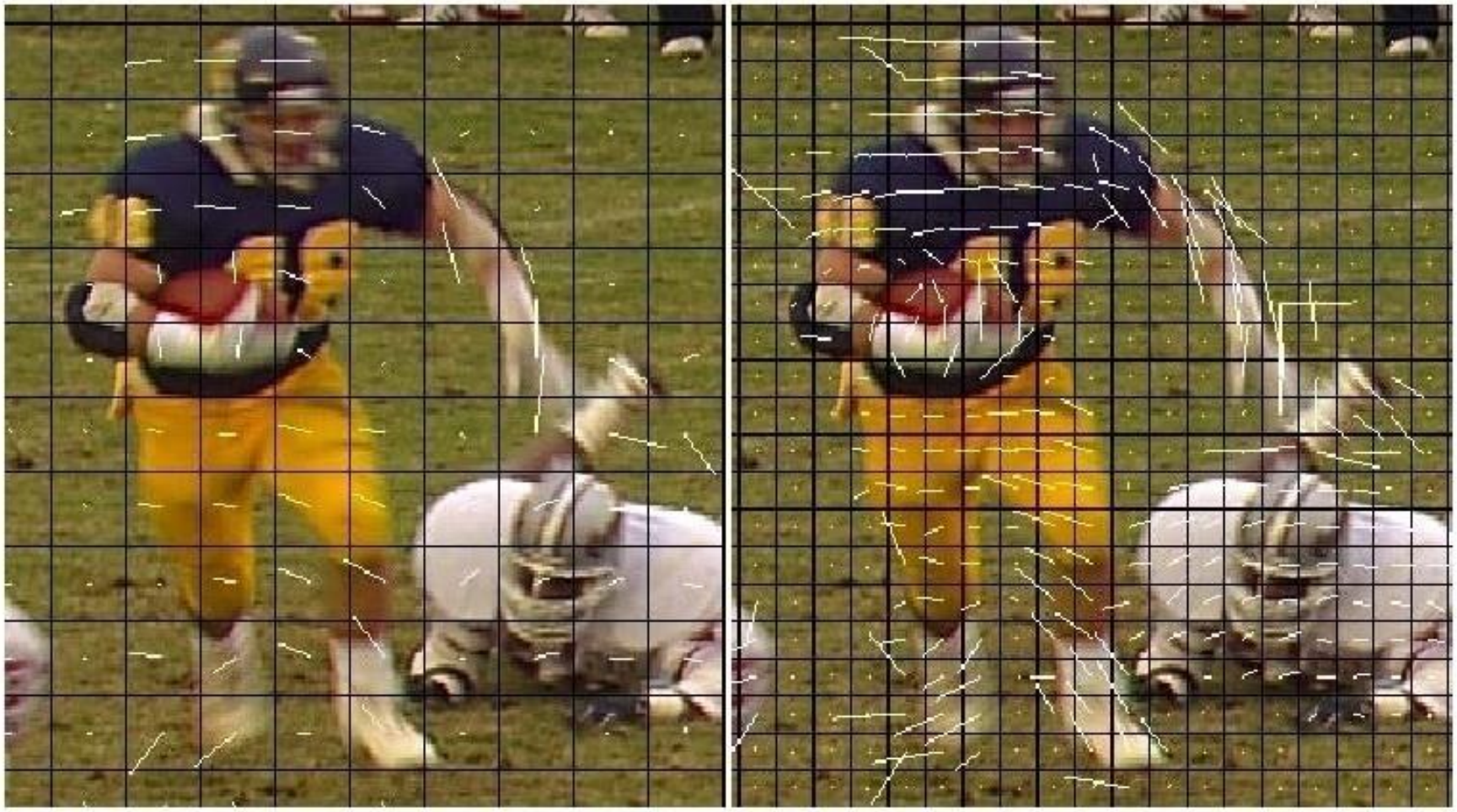
Previous decoded image available at the decoder AND encoder

Original image to encode ONLY available at encoder

Motion Vectors at Different Spatial Resolutions

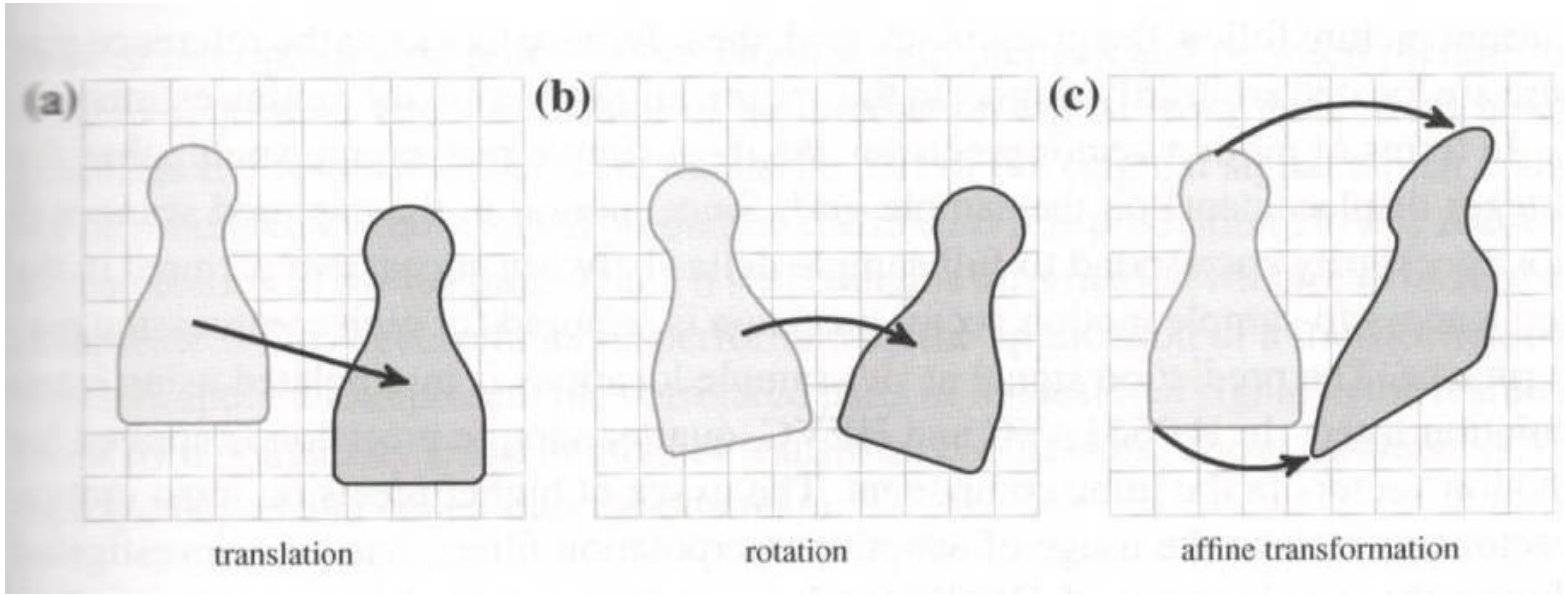
Low resolution

Higher resolution



MBs have always the same number of pixels, i.e. 16×16.

Motion is More than Translations !



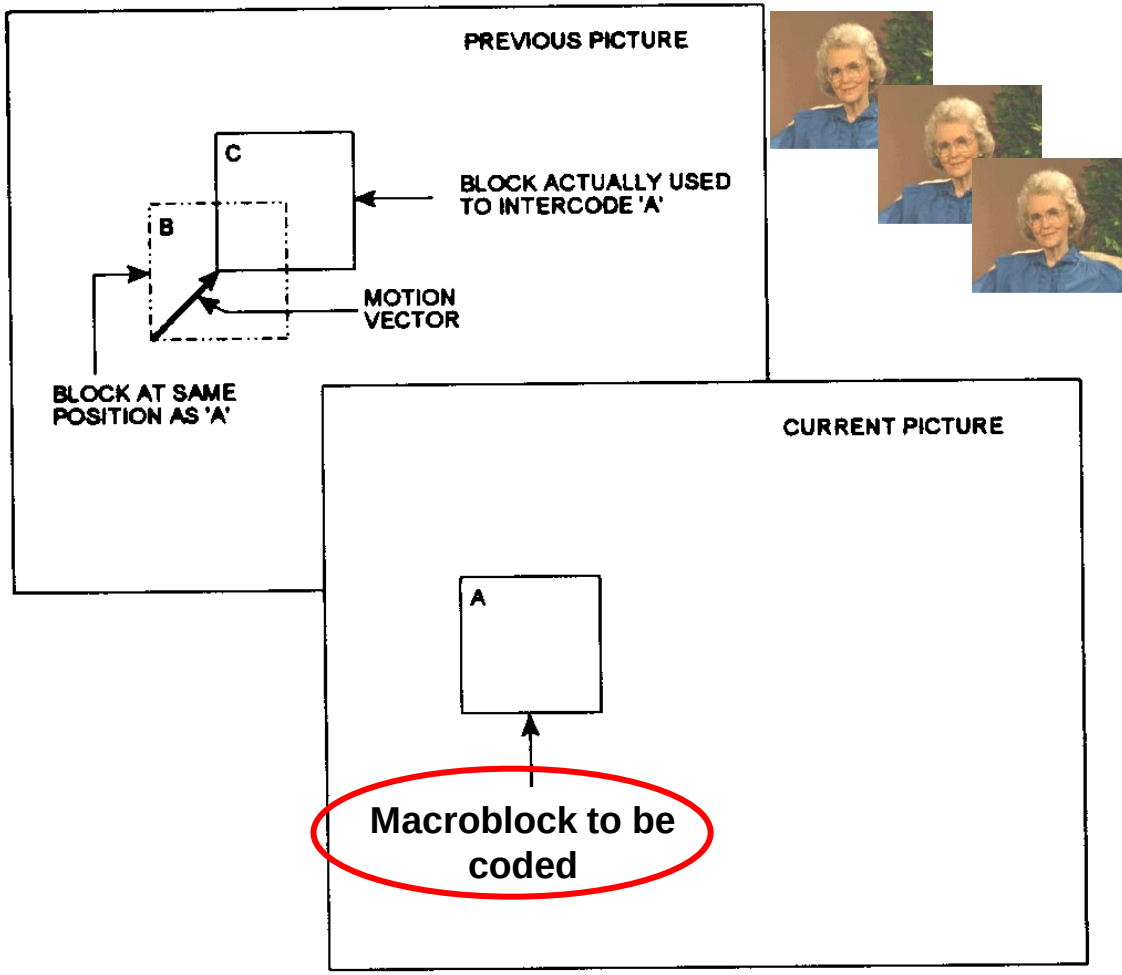
Clearly, a (translational) motion vector cannot represent well many types of motion … But it is still very much worthwhile !

Predicting in Time … With or Without Motion

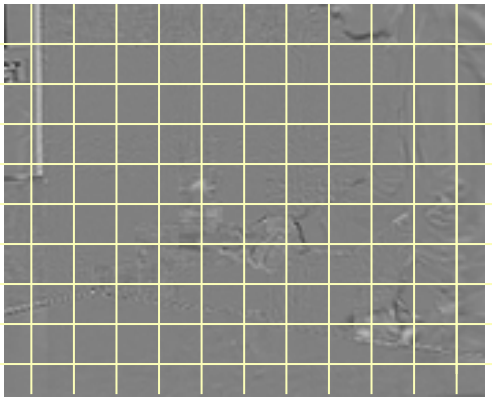
Two main temporal prediction coding modes (Inter modes) are available for each MB:

- Inter with No motion vector: Prediction from the same position in the previous frame
- Inter With a motion vector: Prediction from a displaced position in the previous frame

The encoder has to choose the *best coding deal* using some (non-normative) criteria !

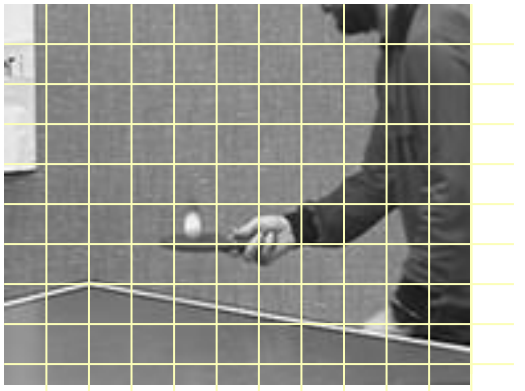


Inter Versus Intra Coding



In H.261, the MBs are coded either in Inter or Intra coding mode:

- **INTER CODING MODE – To be used when there is substantial temporal redundancy; may imply the usage or not of motion compensation, i.e. *Inter+MC* and *Inter(+noMC)*.**



- **INTRA CODING MODE – To be used when there is NO substantial temporal redundancy; no temporal predictive coding is used in this case ('absolute' coding like in JPEG is used to exploit the spatial redundancy).**

After Temporal Redundancy, Spatial Redundancy

Original

Actual original image

+

+

-

Residual to be coded with quantization

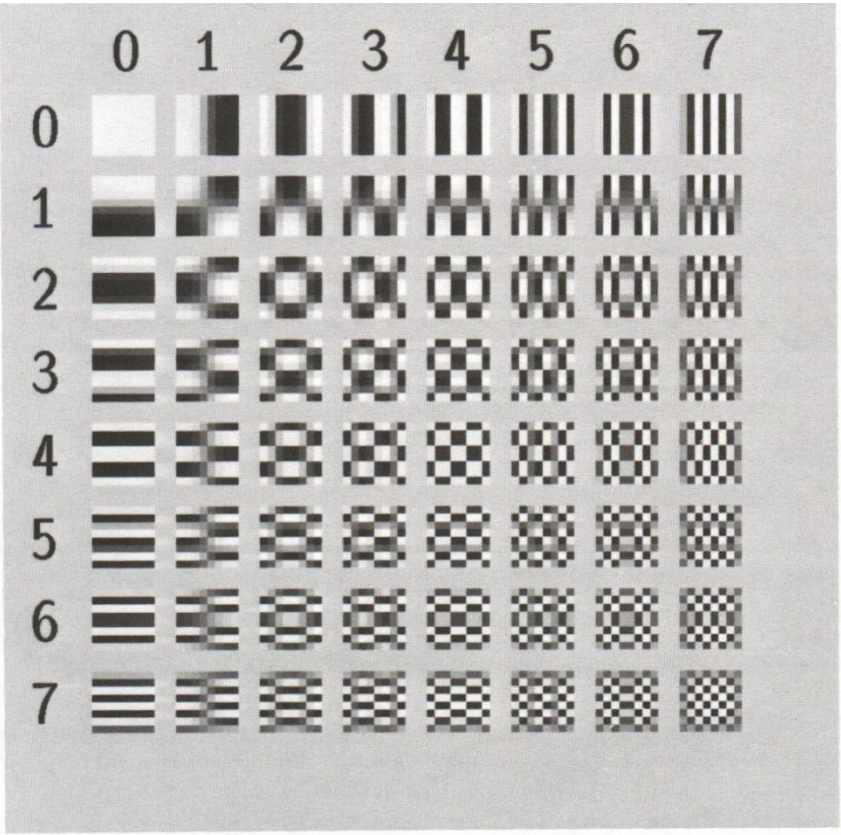
DCT Transform and quantization

Prediction error

Prediction image, motion compensated at MB level from previous decoded image

Created from previous decoded image with motion compensation

Bidimensional DCT Basis Functions (N=8)



Exploiting Spatial Redundancy ...

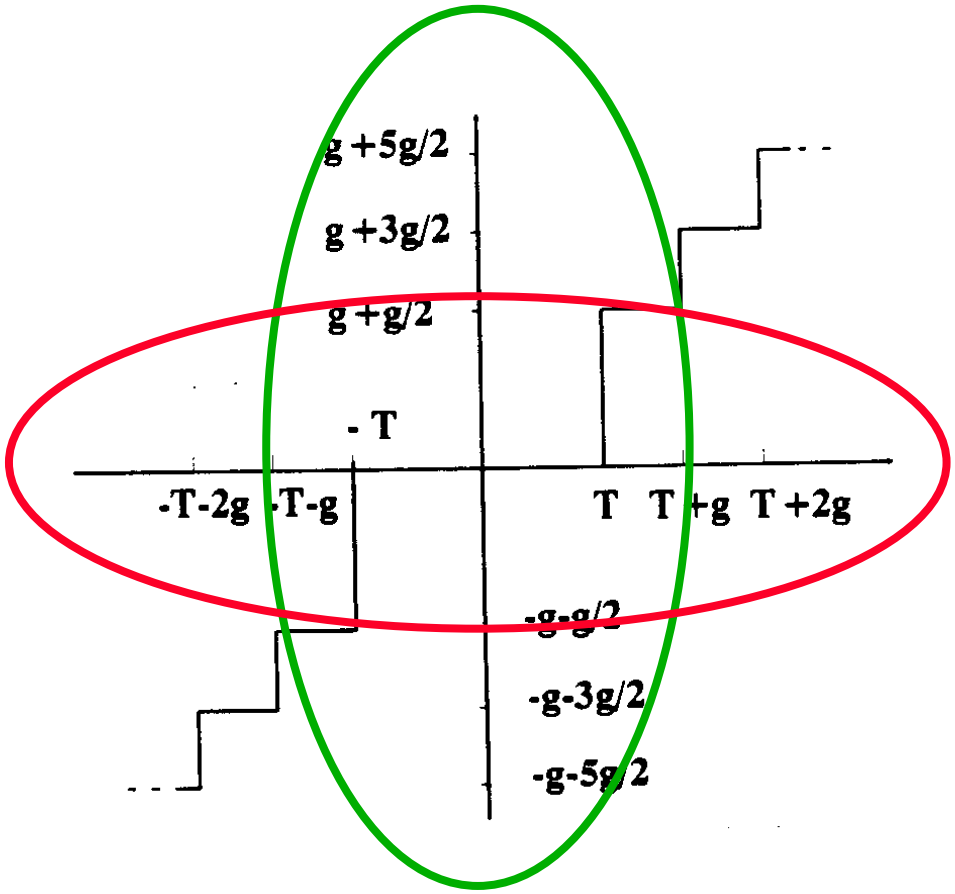
in the usual way ...

now also for the MB prediction error ...

$$F(u,v)=\frac{2}{N}\,C(u)C(v)\sum_{x=0}^{N-1}\sum_{y=0}^{N-1}f(x,y)\cos\frac{(2x+1)u\pi}{2N}\cos\frac{(2y+1)v\pi}{2N}$$

$$f(x,y)=\frac{2}{N}\sum_{u=0}^{N-1}\sum_{v=0}^{N-1}C(u)C(v)F(u,v)\cos\frac{(2x+1)u\pi}{2N}\cos\frac{(2y+1)v\pi}{2N}$$

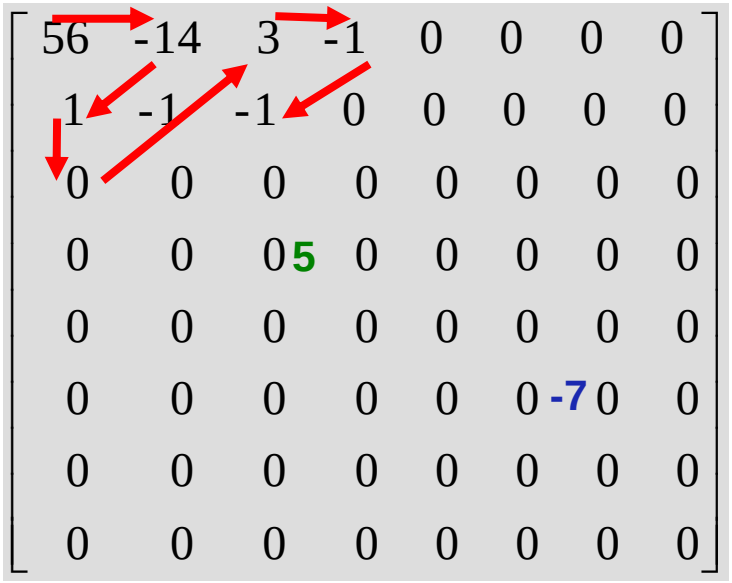
H.261 Quantization



Example quantization function

- H.261 uses as quantization steps all even values between 2 and 62 (31 quantizers available).
- Within each MB, all DCT coefficients are quantized with the same quantization step with the exception of the DC coefficient for Intra MBs which are always quantized with step 8.
- The usage of a same constant quantization step for all the AC DCT coefficients is motivated by the fact that a prediction error (and not absolute sample values) is being coded.
- H.261 normatively defines the reconstruction values for the quantized coefficients but not the decision values which may be selected to implement different quantization characteristics (uniform or not).

Serializing the Residual DCT Coefficients



(0, 56), (0, -14), (0, 1),
(1, -1), (0, 3), (0, -1),
(0, -1),
(10, 5)
(X, -7)
EOB

- **The transmission of the quantized DCT coefficients requires to send the decoder two types of information about the coefficients: their position and quantization level (for the selected quantization step).**

- **For each DCT coefficient to transmit, its position and quantization level are represented using a bidimensional symbol**

(run, level)

where the *run* indicates the number of null coefficients before the coefficient under coding, and the *level* indicates the quantized level of the coefficient.

Small runs and small absolute levels are more probable and entropy coding will exploit that.

Channel and Coding Bitrates ...

Channel bitrate

The channel limits the coding bitrate

1st

Motion vectors

Lossless

2nd

Residual and Intra DCT Coefficients (with quantization)

Lossy

Encoder: the Winning Tools Cocktail !

PCM frames

Originals

MB original

MB residue

\+ −

DCT

Quantiz.

Quantized DCT coeffs

Symbols Gener.

(run, level)

Entropy coder

bits

Buffer

bits

Inverse Quantiz.

Inverse DCT

Entropy coder

bits

MB prediction from previous decoded frame

Decoded MB residue

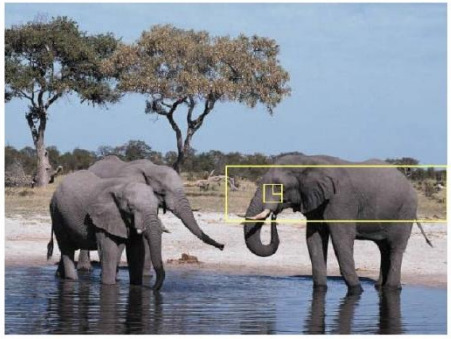
\+

Motion det./comp.

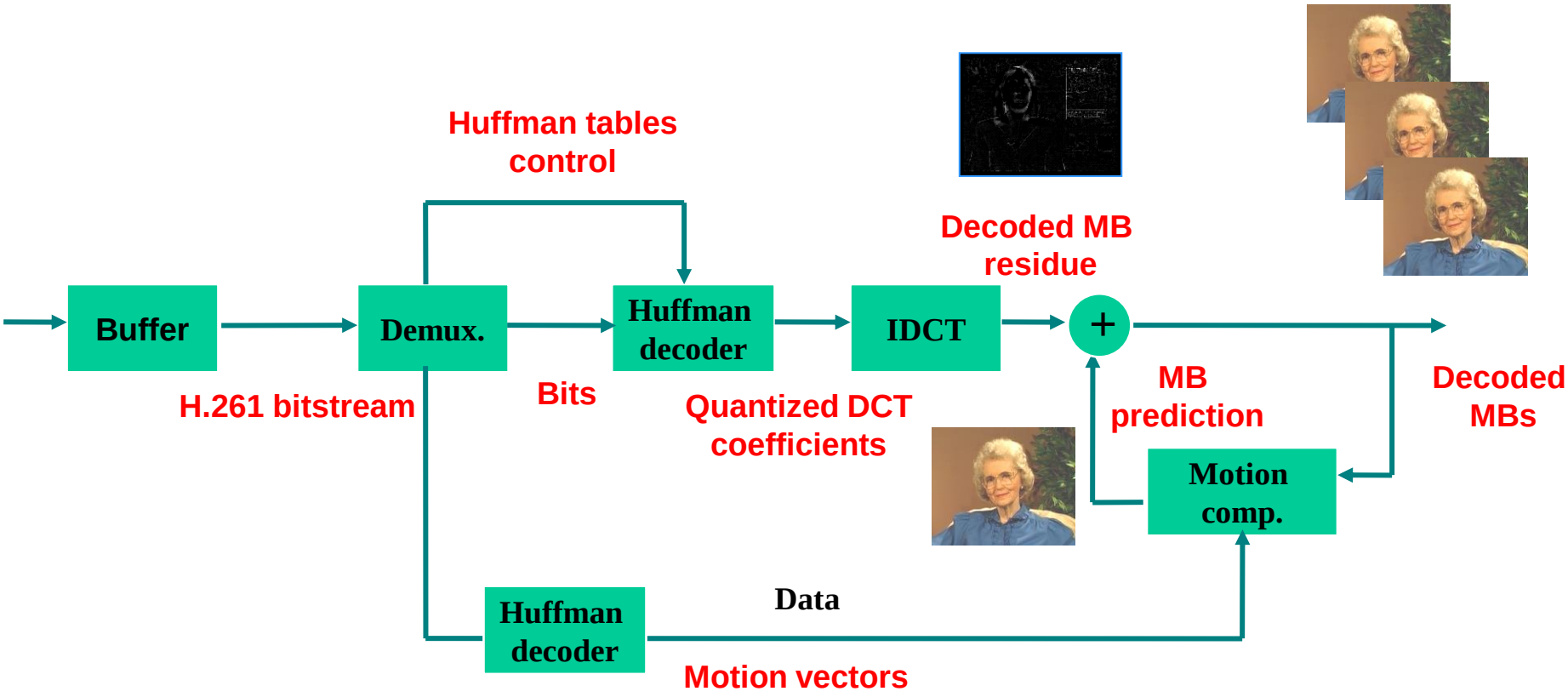
Previous frame

MB from current, original frame

Motion vectors to be entropy coded



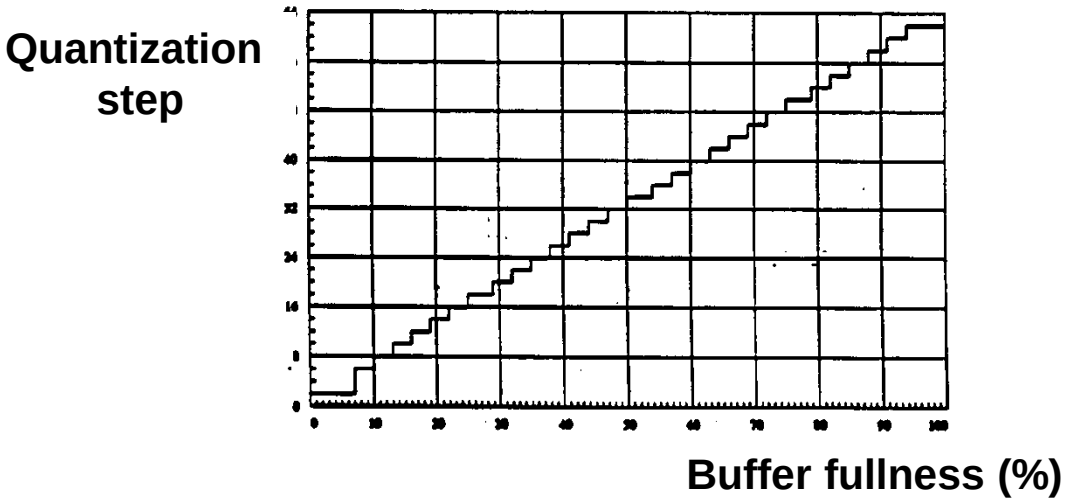
Decoder: the Slave !



Quantization Step versus Buffer Fullness

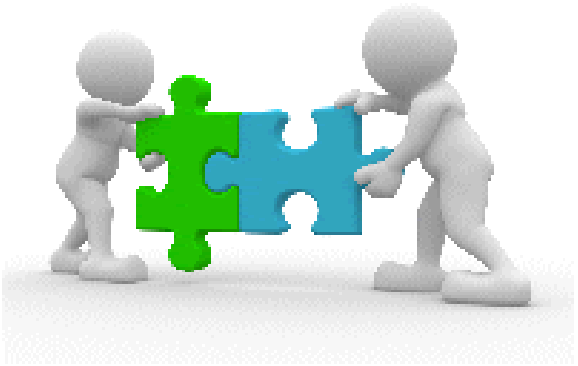
The bitrate control solution recognized as most efficient controls the MB quantization step, e.g. as a function of the output buffer fullness.

The granularity of this control is associated to the *31 quantization step values available;* the frequency of change may be at *MB level.*



Matching the Encoder Variable Rate with the Channel Constant Rate

Variable content
Variable rate
Need to adapt

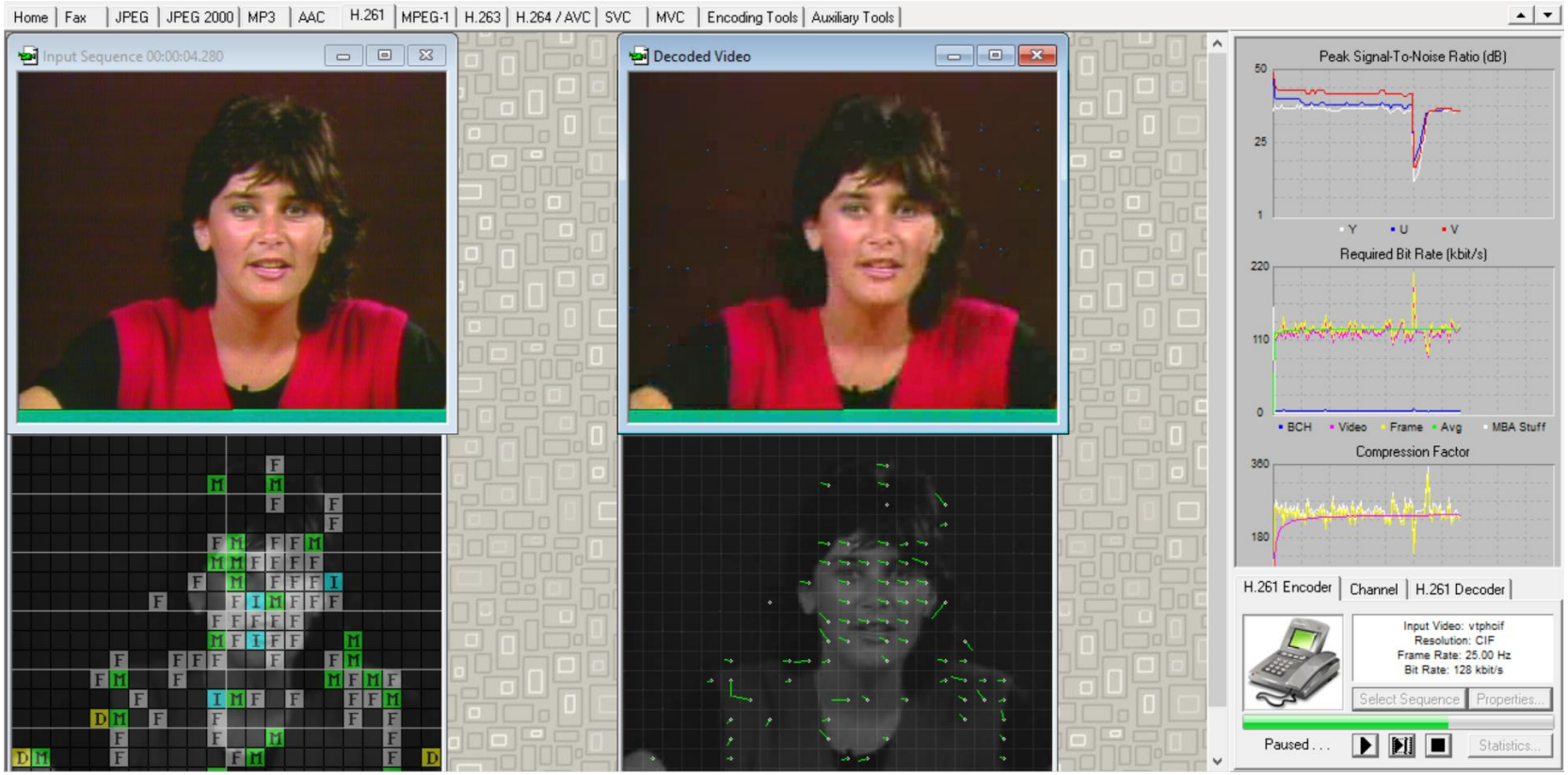


Constant rate channel
Uniform resources

The final video quality depends on:

- **The (constant) channel rate**
- **The (spatially and temporally varying) content**
- **The quantization selection algorithm**
- **The (limited) buffer size (for the critical moments)**

Let's Play and See …



I – Intra coding;
D – Inter coding without motion compensation (only error differences);
M – Inter coding with motion compensation;
F – Inter coding with motion compensation and the in-loop filter;
O - Overflow (indicating that the output buffer is too full and no bits may be sent).

TÉCNICO LISBOA