An introduction to image and video coding

Luis Torres

Polytechnic University of Catalonia

Barcelona, Spain

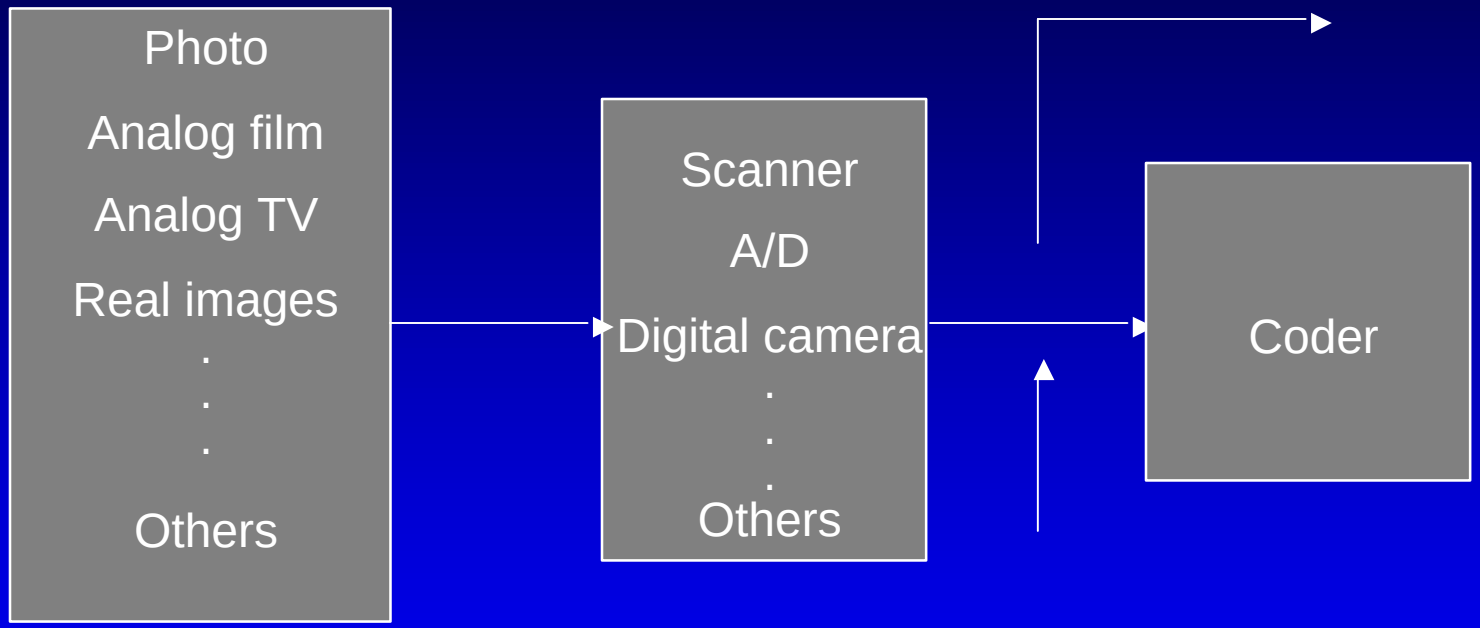
ltorres@ecn.purdue.edu

luis@gps.tsc.upc.es

Summary

- Introduction
- Signals and formats
- The need for compression
- Lossless and lossy coding
- General image coding scheme
- Measures of the compression quality
- Scalability and symmetry
- Image and video coding standards

Input video signal



Y, u, v Image

PCM 8 bits

$Y = 0.30\ R + 0.59\ G + 0.11\ B$

$u = B - Y$

$v = R - Y$

Y u v Formats

Y u v Format

Y

U

V

RGB 24 bits/pixel

YUV 4:2:0 (12 bits/pixel)

The need for image compression

- 512 x 512 pixel color image

  512 x 512 x 24bits = 786 Kbytes

- Videoconference QCIF (quarter common intermediate format)

  (176 x 144 + 88 x 72 + 88 x 72) x 8 x 25 = 7.6 Mbits/s

- Digital television

  (720 x 576 + 360 x 288 + 360 x 288) x 8 x 25 = 124 Mbits/s

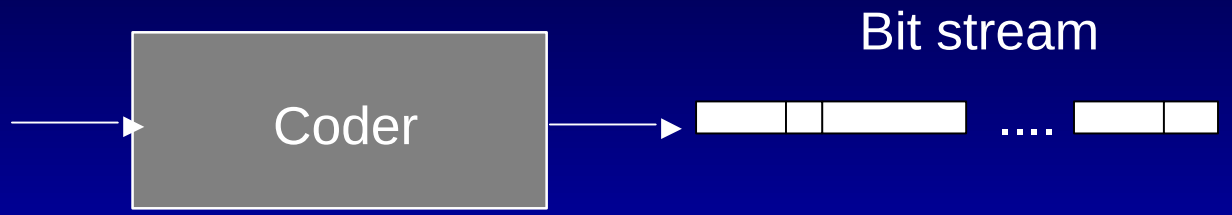
- High definition television - HDTV

  (1440 x 1152 + 720 x 576 + 720 x 576) x 8 x 25 = 497 Mbits/s

- Multispectral images (satellite)

  (6000 x 6000) x 8 x 6 = 216 Mbytes

Image coding



Objective: To find a way to represent
the original image without (?) distortion
with the minimum number of bits possible

Lossless image coding

Lossy image coding

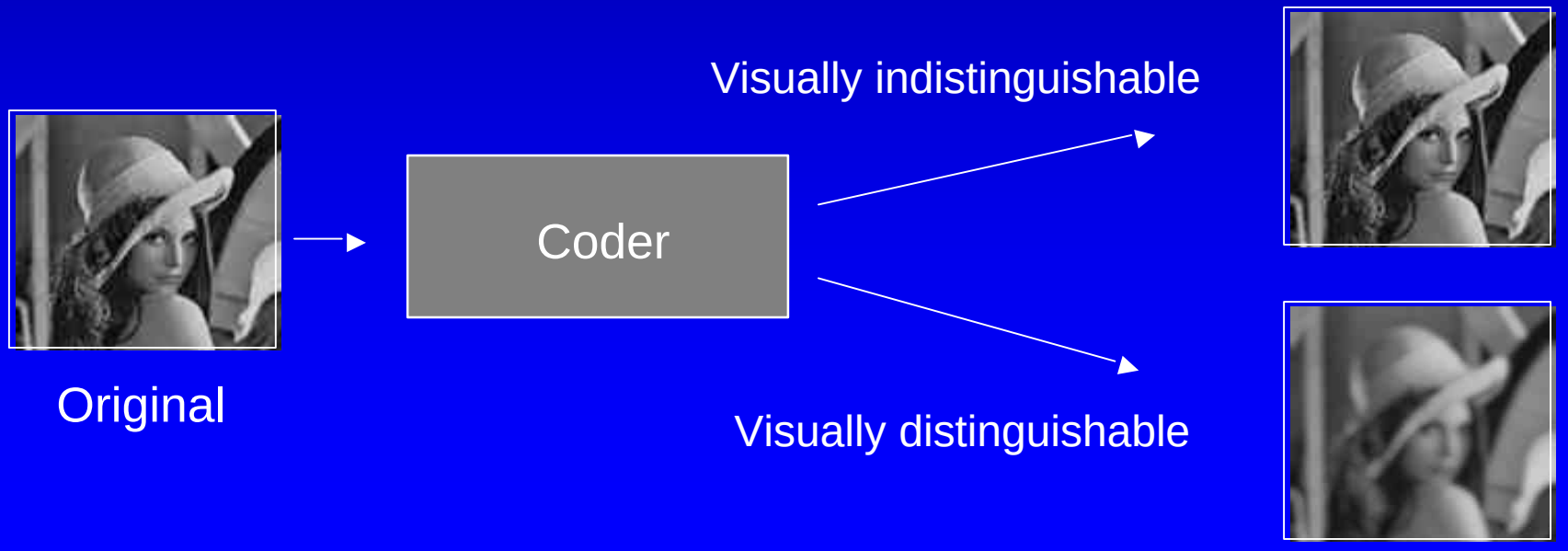
Lossless and lossy image coding

- Lossless image coding :

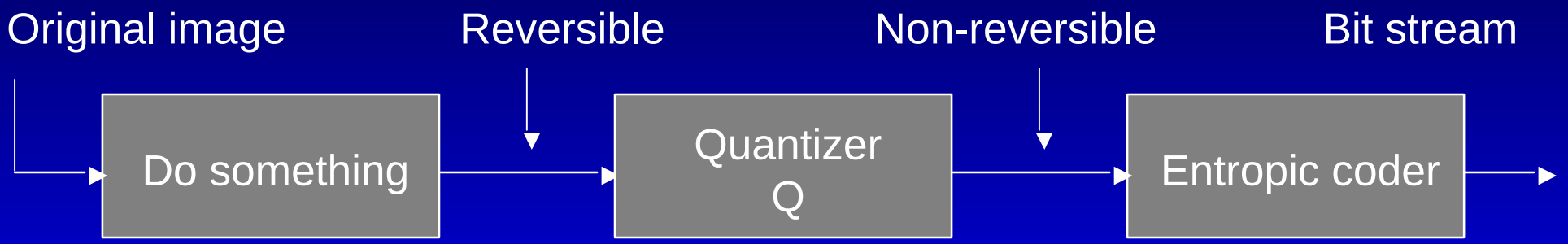
  The decoded image is pixel by pixel identical to the original

- Lossy image coding :

  The decoded image is NOT pixel by pixel identical to the original



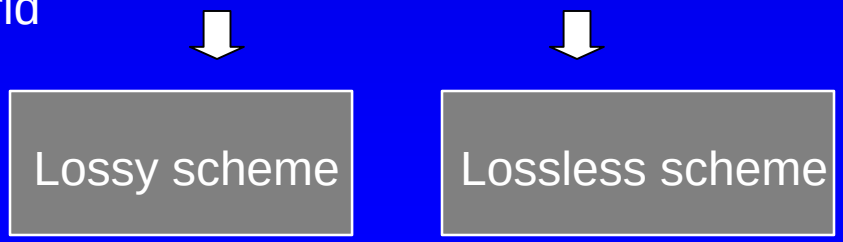
General scheme of image coding (compression)



- *To prepare* the image
- To remove redundancy
- This an optional block. Although almost always exists
- DCT, wavelets, hybrid

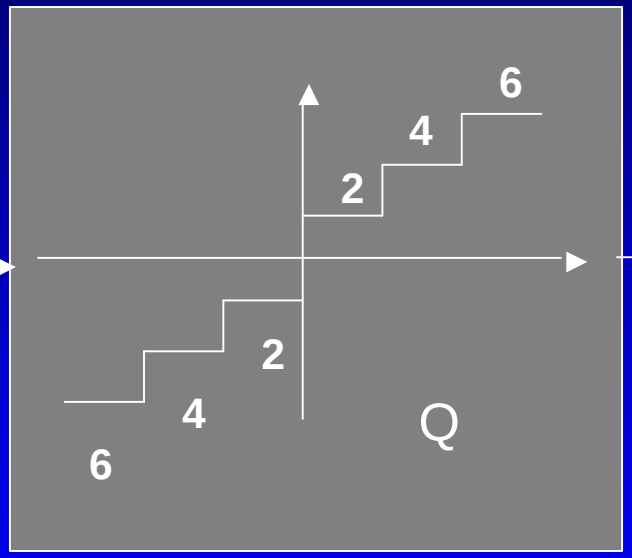
- Quantizer
- Scalar or vectorial
- This an optional block. Although almost always exists

- Entropic coder
- This block always exists



Quantization

Do something



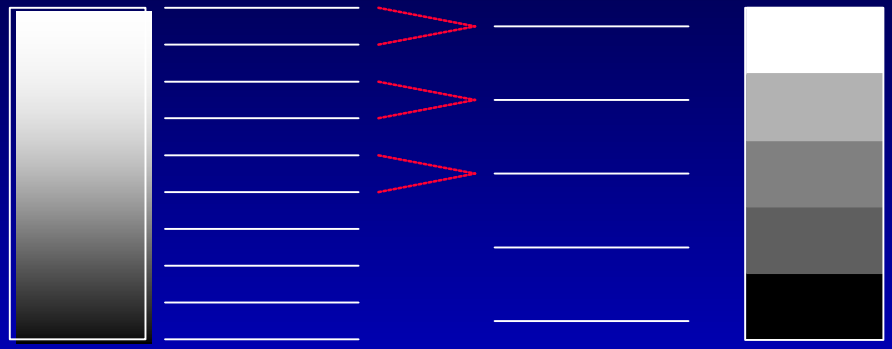
Entropic coder

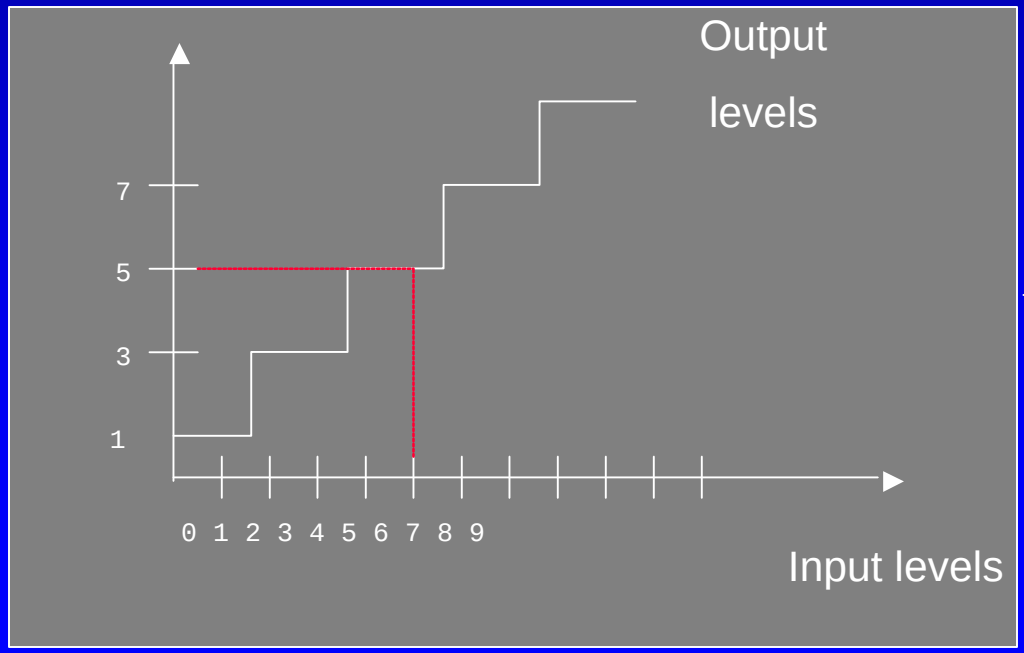
Code

Quantization (1)

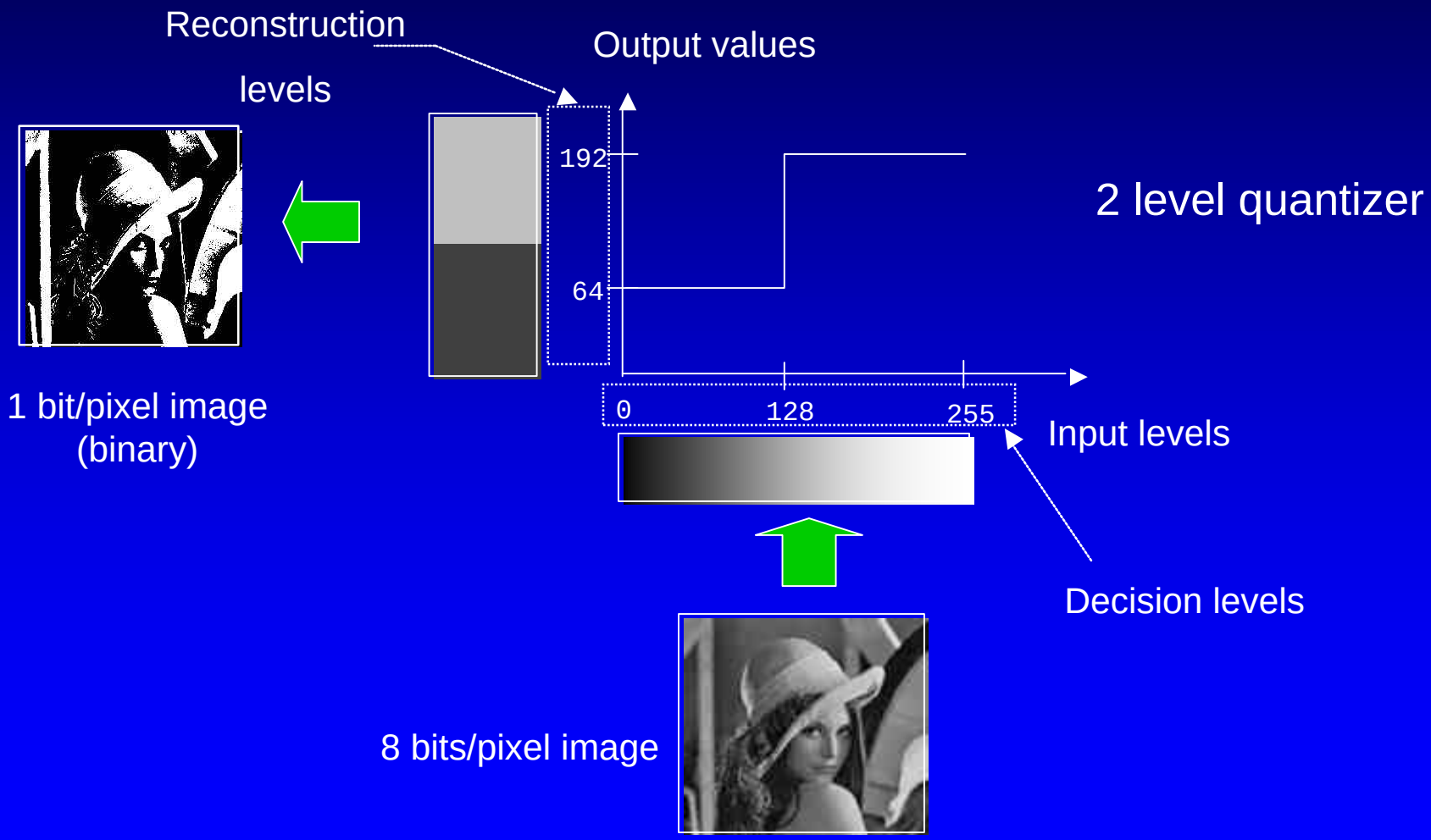
Input digital levels

Output levels

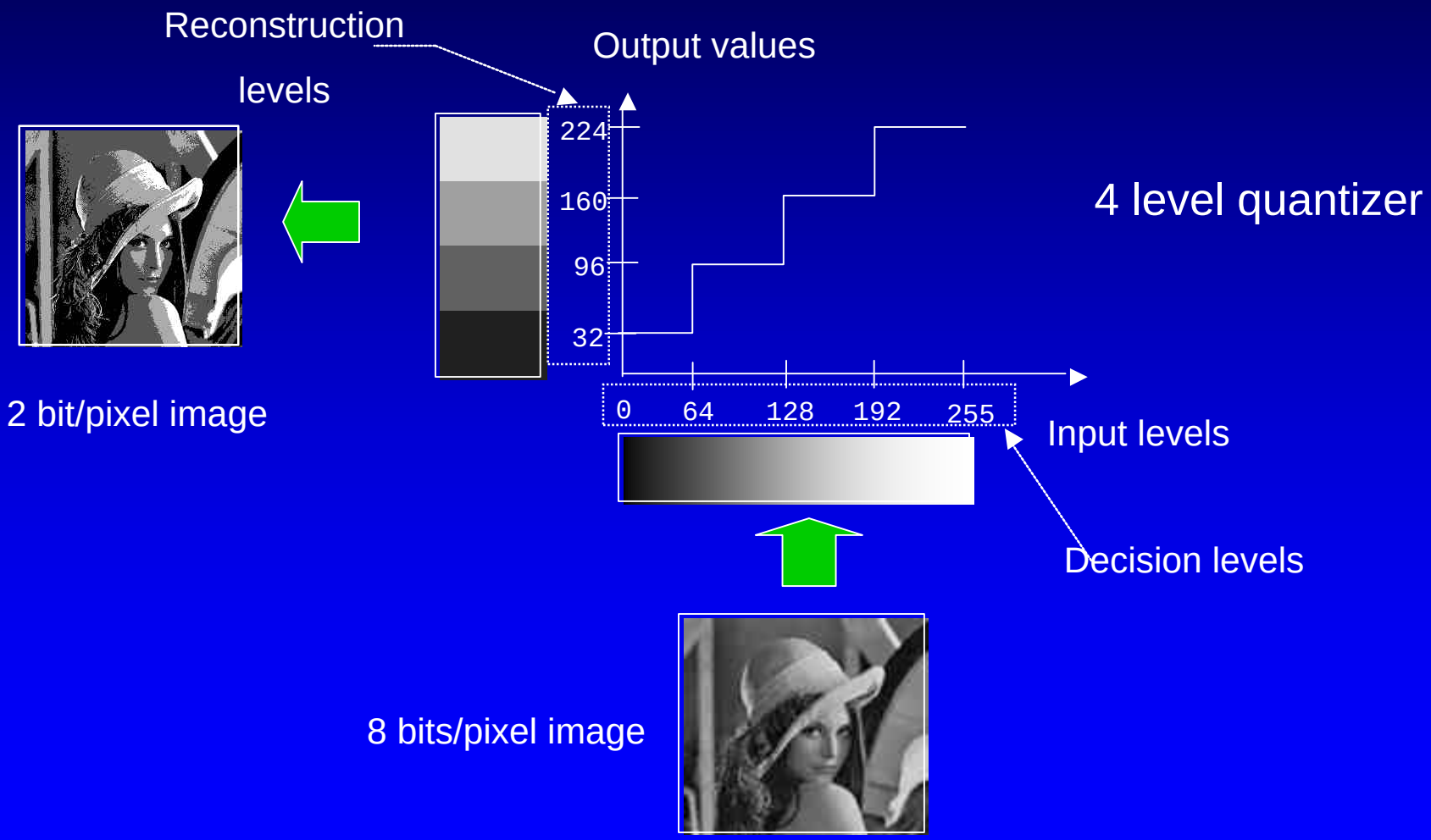




Quantization (2)



Quantization (3)



Uniform quantizer

4 bits

2 bits

3 bits

1 bit

Image formats

	ITU - 601	CIF
Sampled signals	Y, u, v	Y, u, v
Sampling frequency Mhz.	(Y) 13.5 - (u,v) 6.75	(Y) 6.75 - (u,v) 3.375
Sampling structure	orthogonal 1:1	orthogonal 1:1
Pixels / image	(Y): 720 x 576 (u,v): 360 x 288	(Y): 352 x 288 (u,v): 176 x 144
Bits/pixel	8	8

Measure of the compression (1)

$$\text{Compression factor} = \frac{\text{Bits original image}}{\text{Bits compressed image}}$$

$$\text{Bits/pixel} = \frac{\text{Bits compressed image}}{\text{Number of pixels}}$$

Measure of the compression (2)

Original image
256 x 256 x 8 bits

Compressed image
40.000 bits

$$\text{Bits/pixel} = \frac{40.000}{256 \times 256} = 0.61 \text{ bpp}$$

$$\text{C. F.} = \frac{8 \text{ bpp}}{0.61 \text{ bpp}} = 13.1$$

Measures of the compression quality

Coder

X(m,n)

Y(m,n)

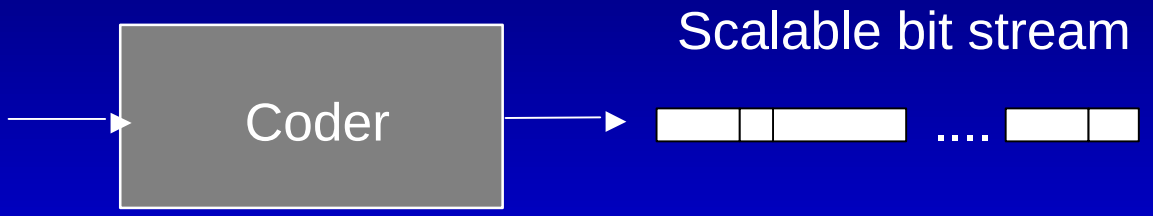
Subjective measure → Opinions over a scale of 5

Objective measure →

$$\mathrm{PSNR(dB)} = 10\log_{10}\frac{255^2}{\mathrm{MSE}}$$

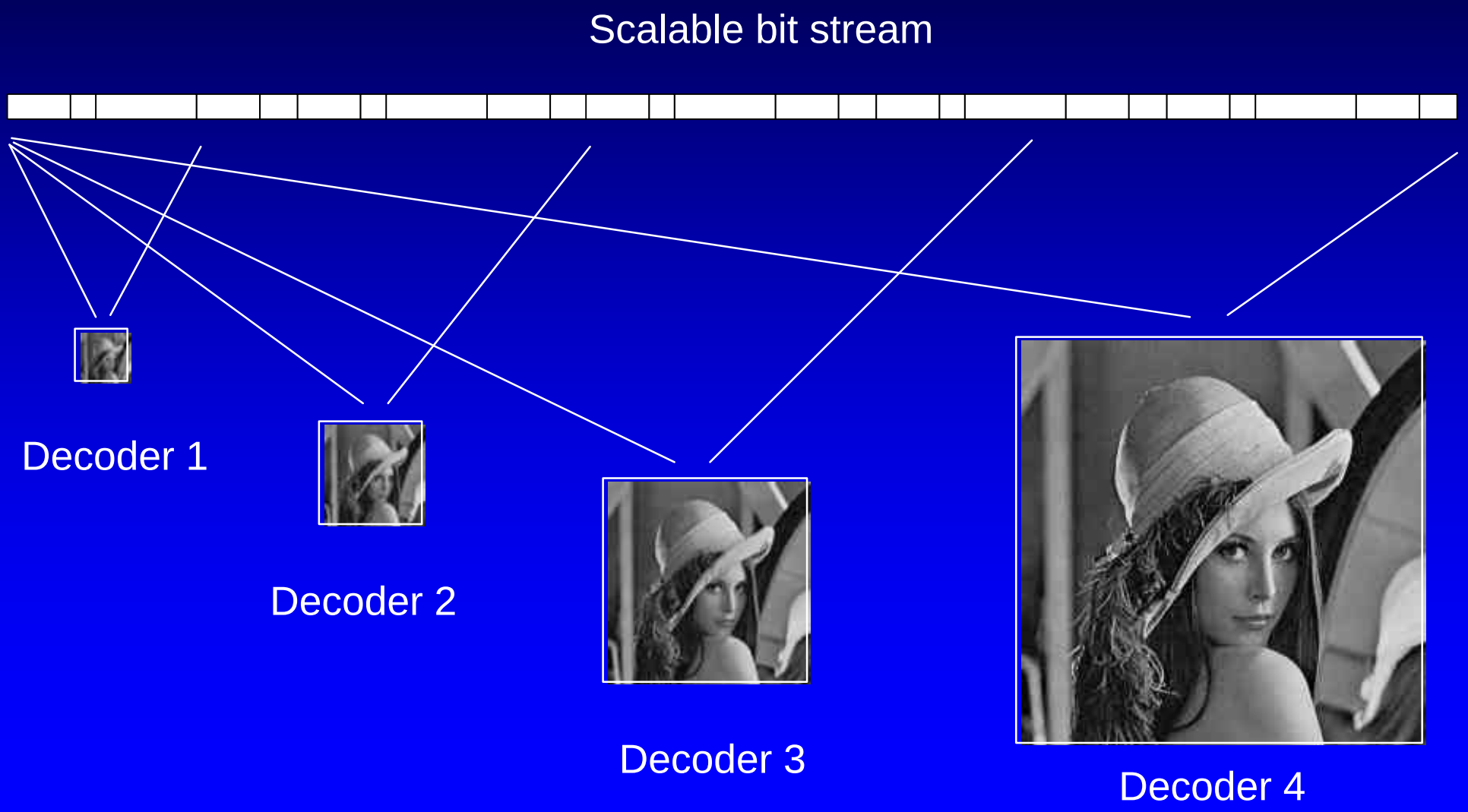
$$\mathrm{MSE} = \frac{1}{\mathrm{MN}}\sum_{i=1}^{M}\sum_{j=1}^{N}(y_{ij} - x_{ij})^2$$

Scalability



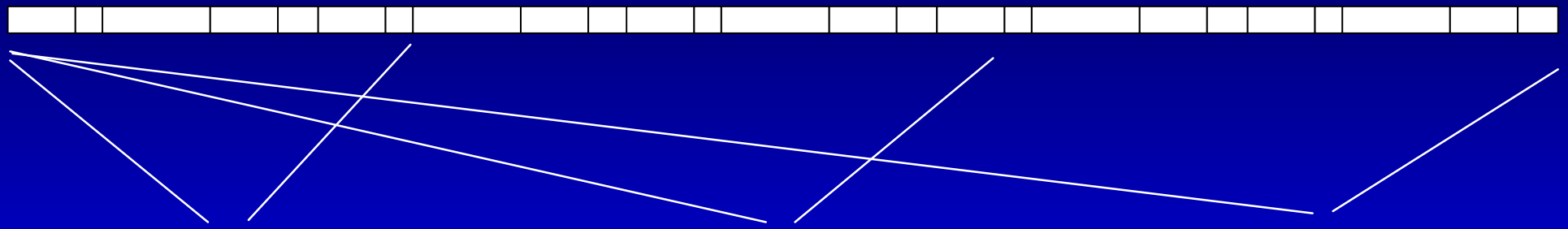
- Spatial scalability
- PSNR scalability (quality)
- Non-scalable

Spatial scalability



PSNR scalability (quality)

Scalable Bit stream

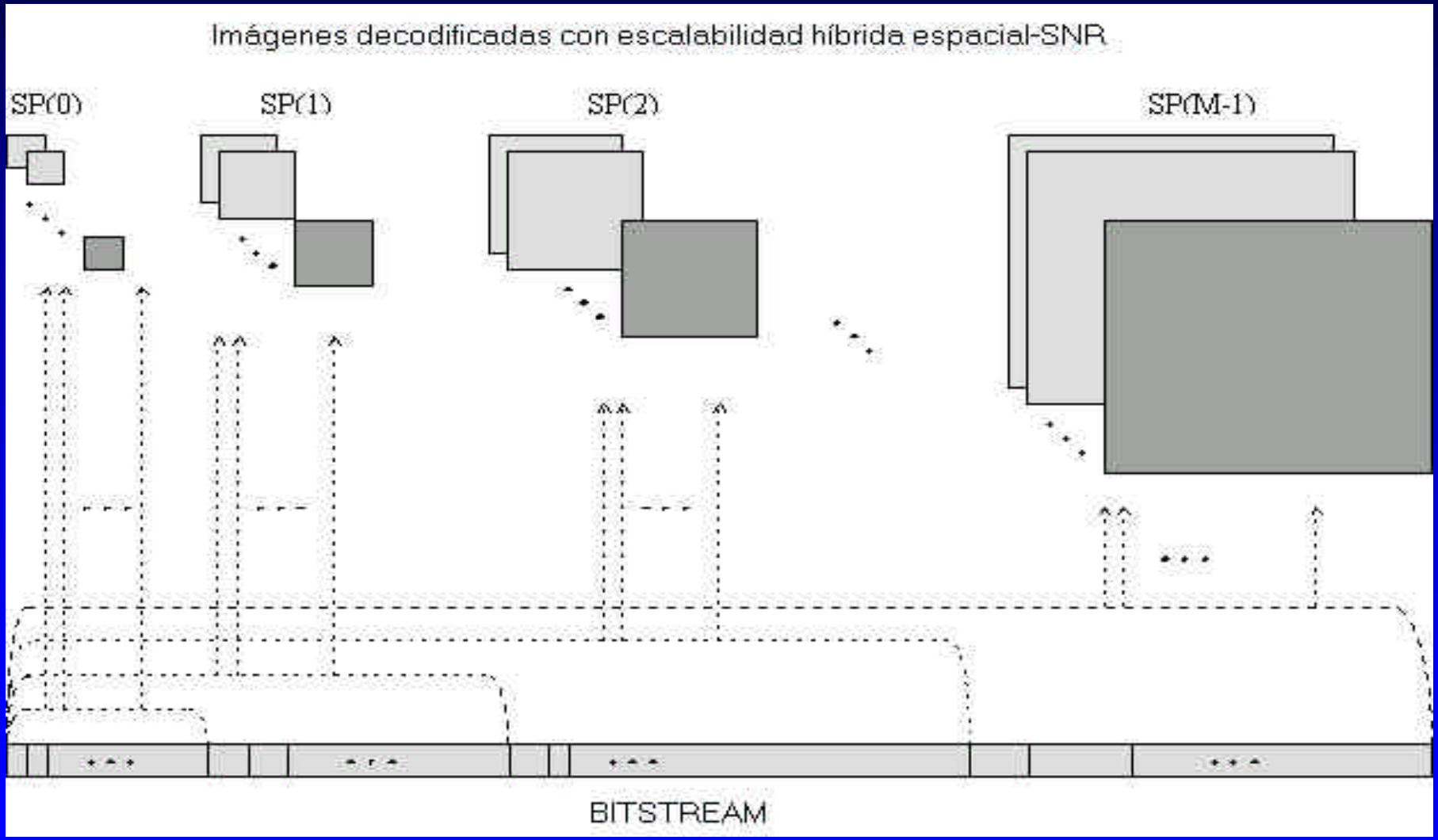


Decoder 1

Decoder 2

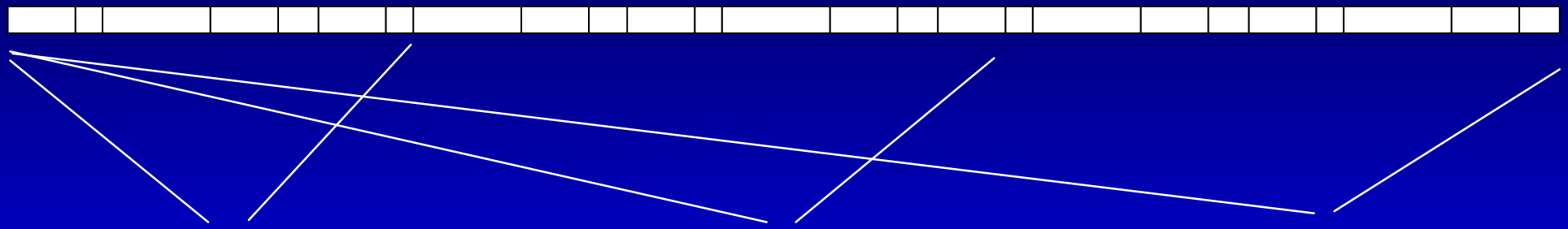
Decoder 3

Spatial – PSNR scalability



Non-scalable

Non-scalable Bit stream



Decoder 1

Decoder 2

Decoder 3

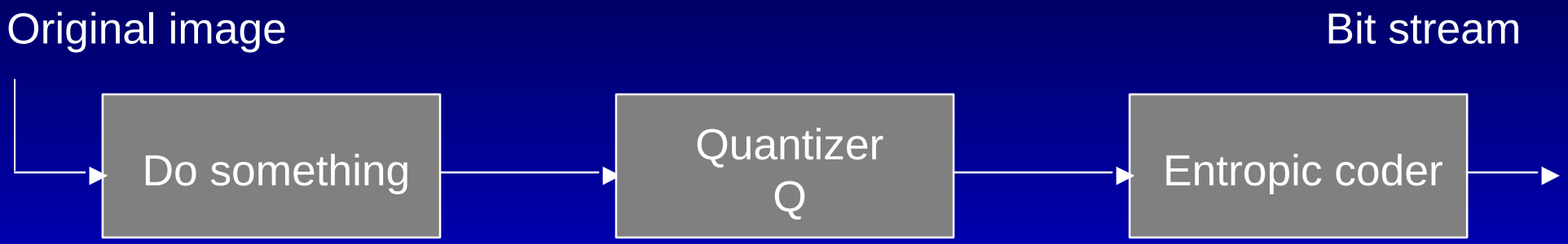
Asymmetric coder

- Coder complexity different than decoder complexity
- The decoder should be as simple as possible

JPEG: Symmetric

MPEG 1- 2: Very asymmetric

Examples of coding schemes



Transform coding – JPEG

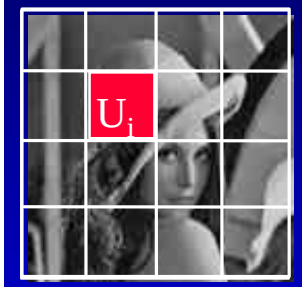
Wavelets – JPEG 2000

Still image coding

Hybrid coding – H.26x, MPEG-1, MPEG-2, MPEG-4

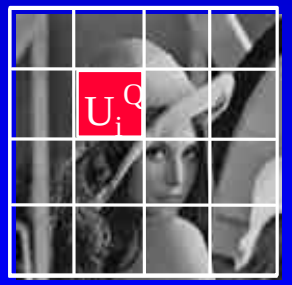
Video

Transform coding - JPEG

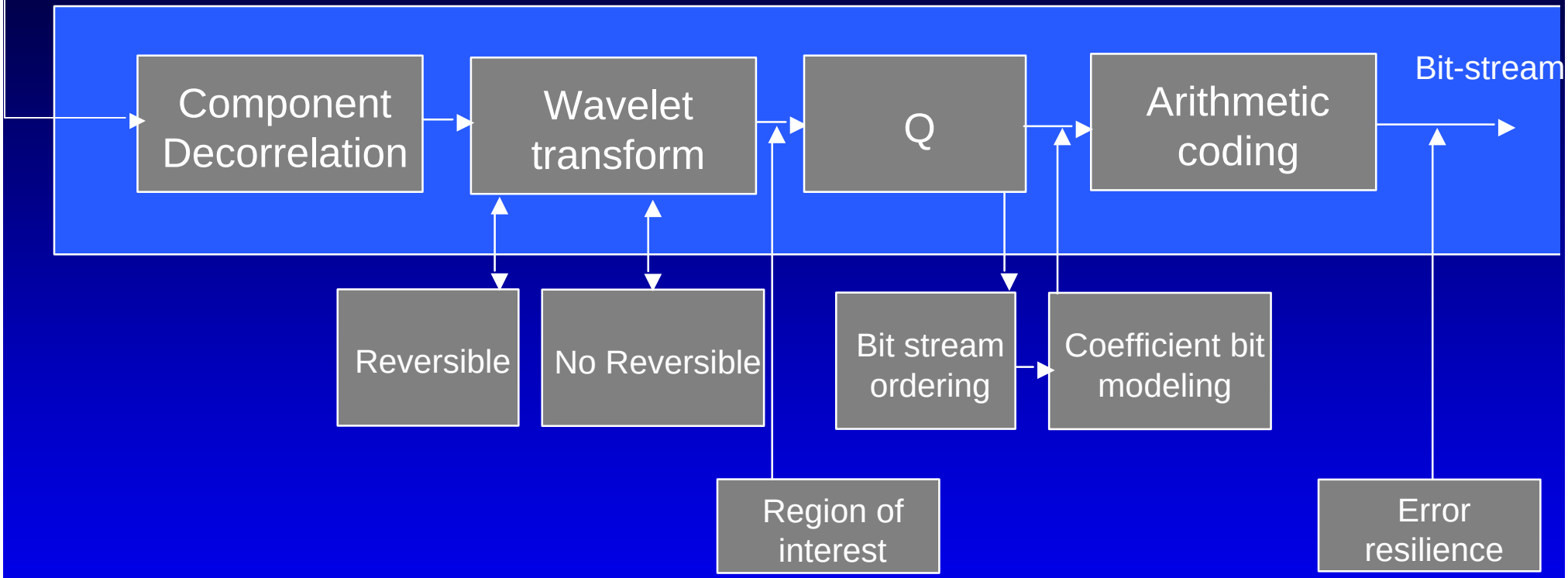


U_i → AU_iA^T → V_i → Quantizer Q → V_i^Q → Entropy coder → Channel

Channel → Entropy decoder → V_i^Q → $A^TV_i^QA$ → U_i^Q



JPEG 2000



- Error resilience
- Arbitrarily shaped region of interest
- Random access
- Lossless and lossy coding
- Fully scalable bit stream

Wavelets

JPEG 2000

1 bits/pixel

0.5 bits/pixel

0.25 bits/pixel

JPEG 2000 - JPEG

JPEG 2000 - JPEG

General hybrid scheme

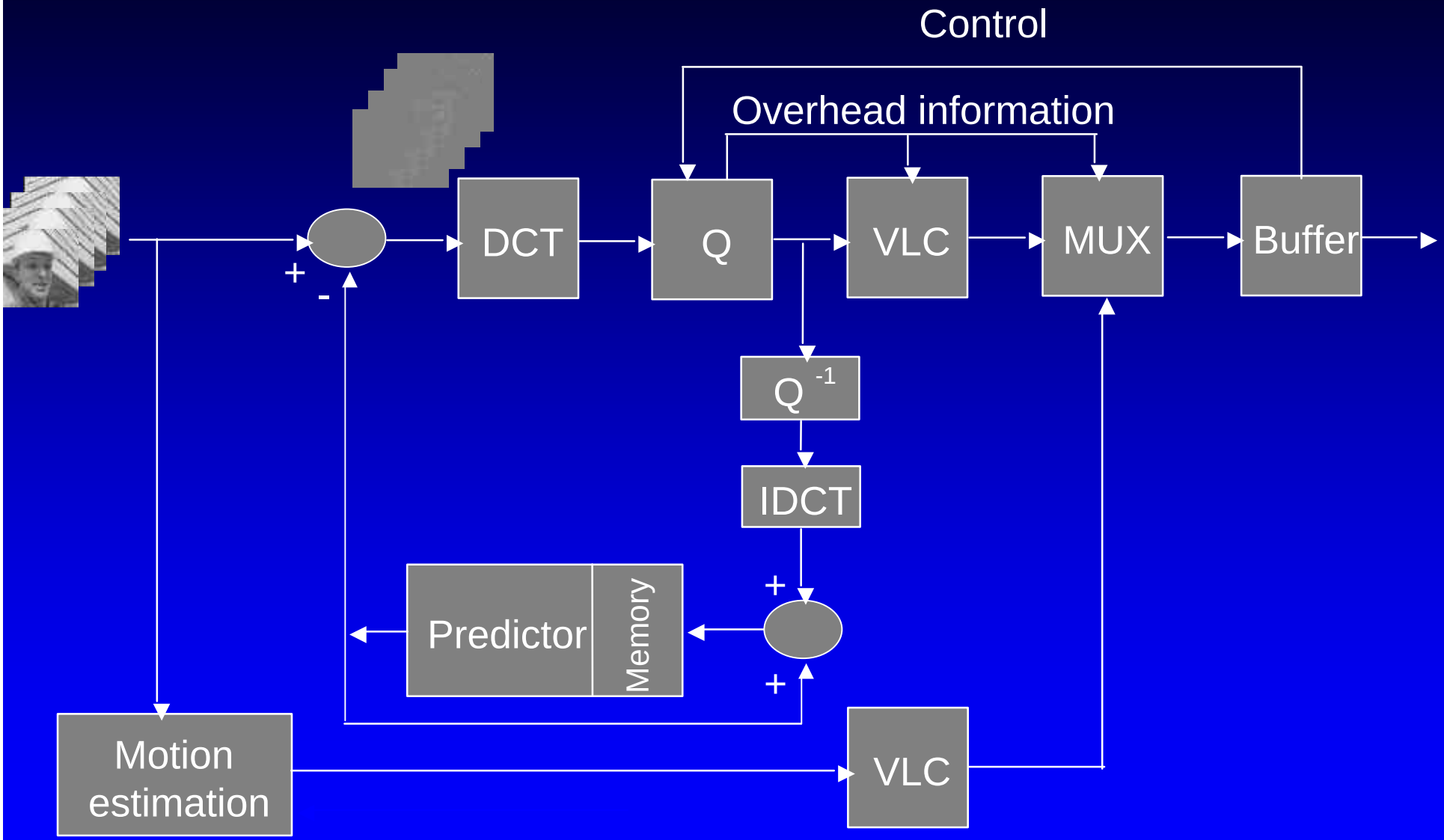
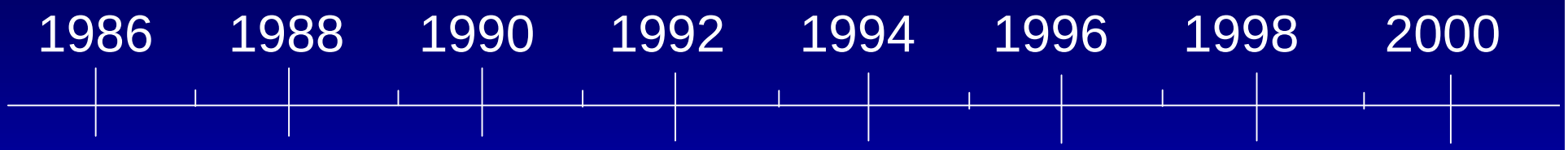


Image coding standards



JPEG

JPEG 2000

0.15 bits / pixel : Recognizable

0.25 bits / pixel : Useful

0.75 bits / pixel: Excellent

1.50 bits / pixel: Indistinguishable

20% more compression than JPEG for same quality

More functionalities

Video coding standards