



Laurea Magistrale in *Ingegneria delle Telecomunicazioni*

## Lossy Image Coding: JPEG

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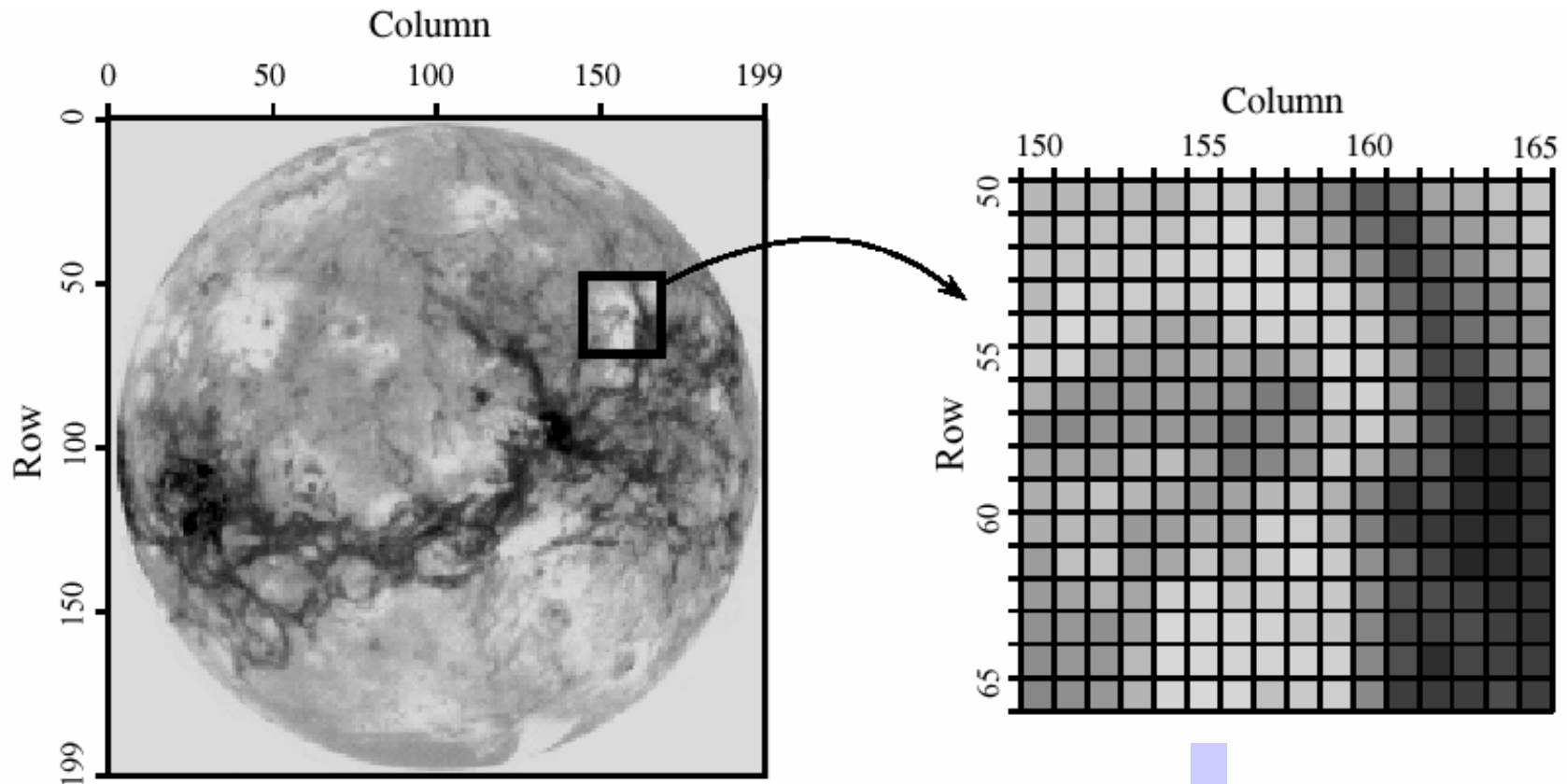
*marco.luise@unipi.it*

*<http://www.iet.unipi.it/m.luise/>*

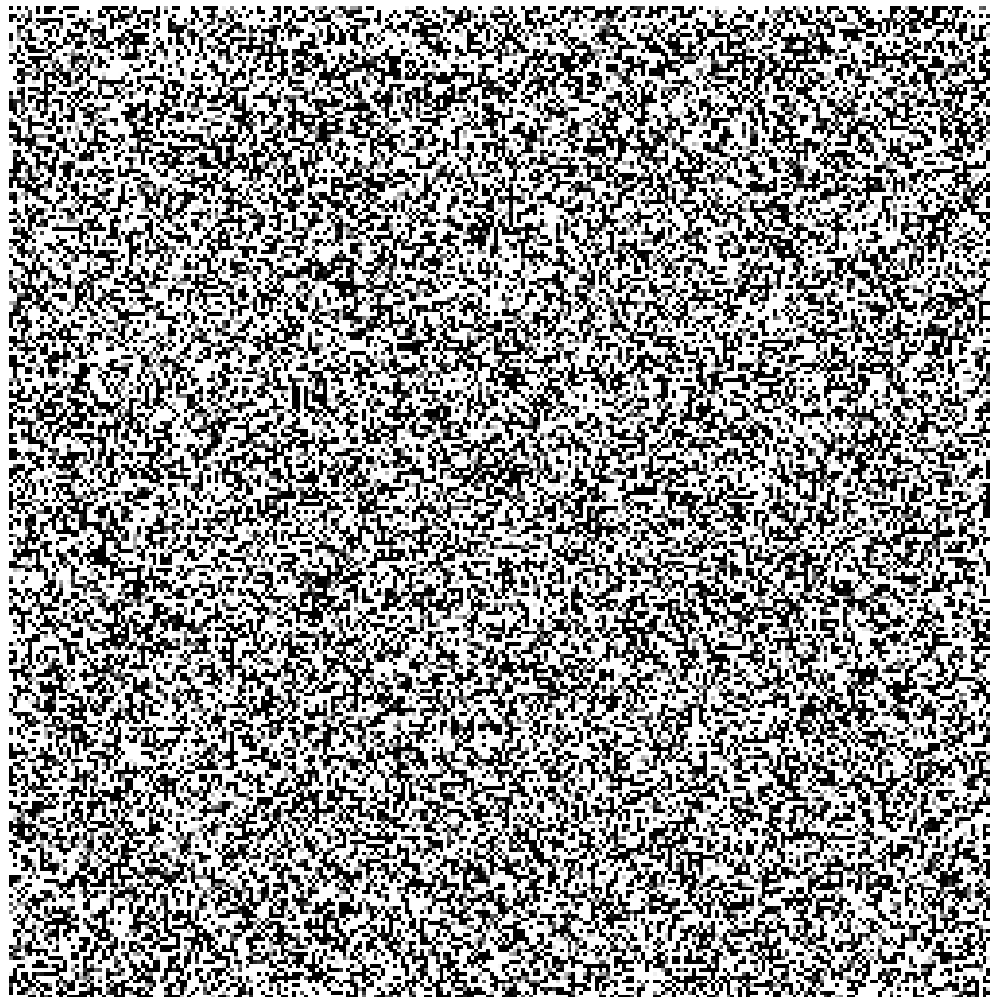


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# Immagine: Sorgente di informazione



# Chi porta più informazione? 1/2



## Chi porta più informazione? 2/2



# Il disturbo 1/3



## Il disturbo 2/3



# Il disturbo 3/3



# La sorgente





# Disturbo di canale e codifica con perdita



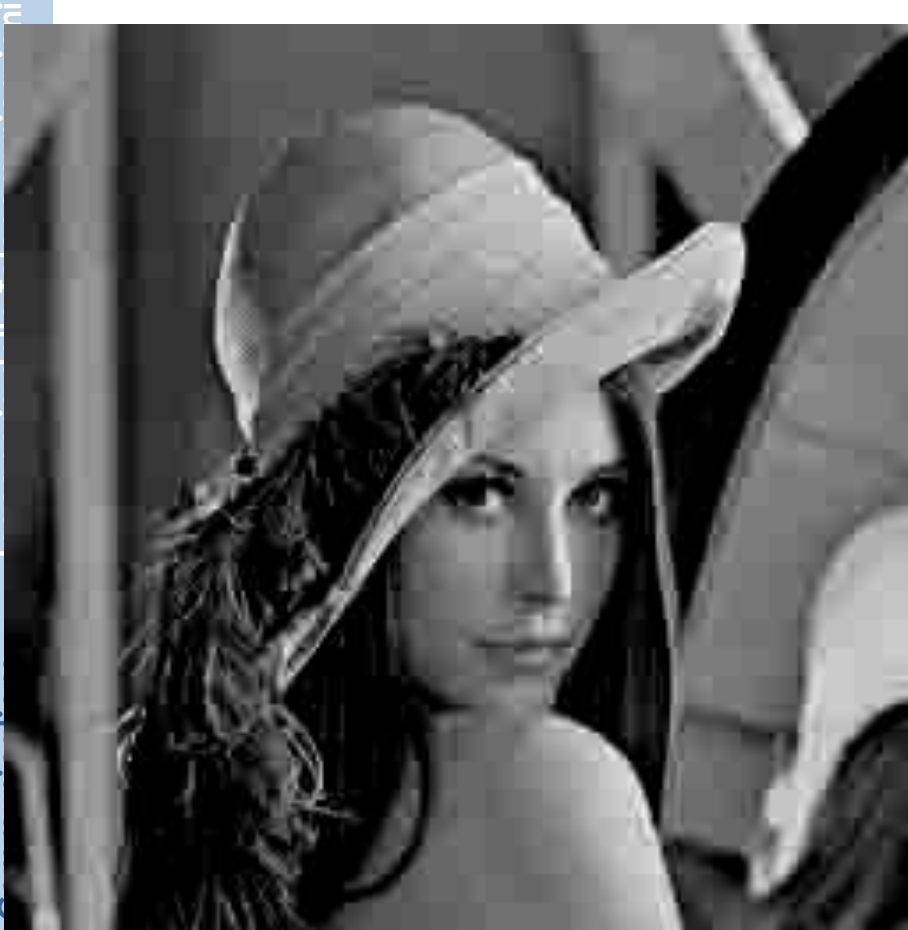
# Quantizzazione Rozza



**4 bit/pixel**



**2 bit/pixel**



**codifica con  
perdita (JPEG)**



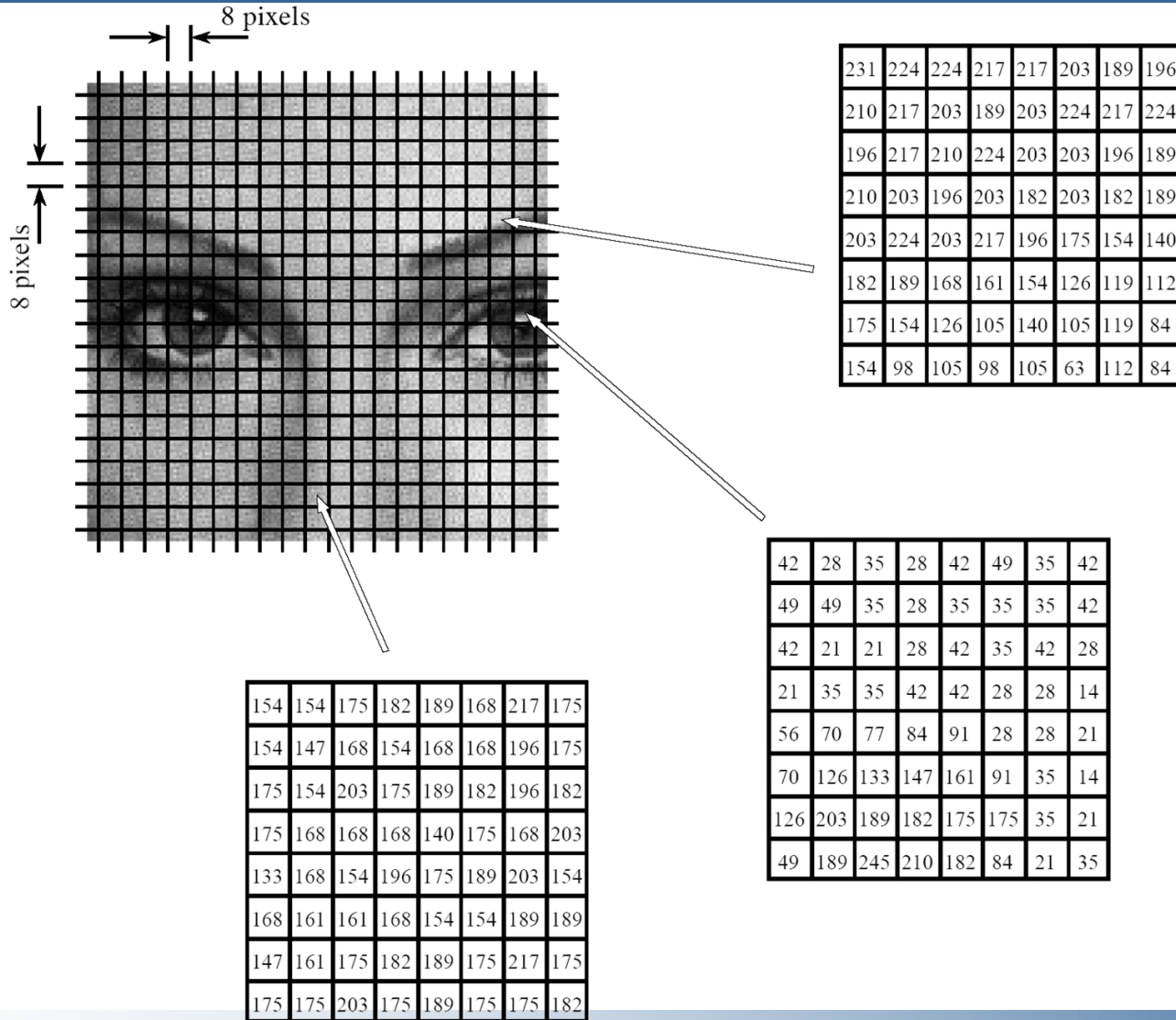
**quantizzazione  
rozza 2 bit/pixel**



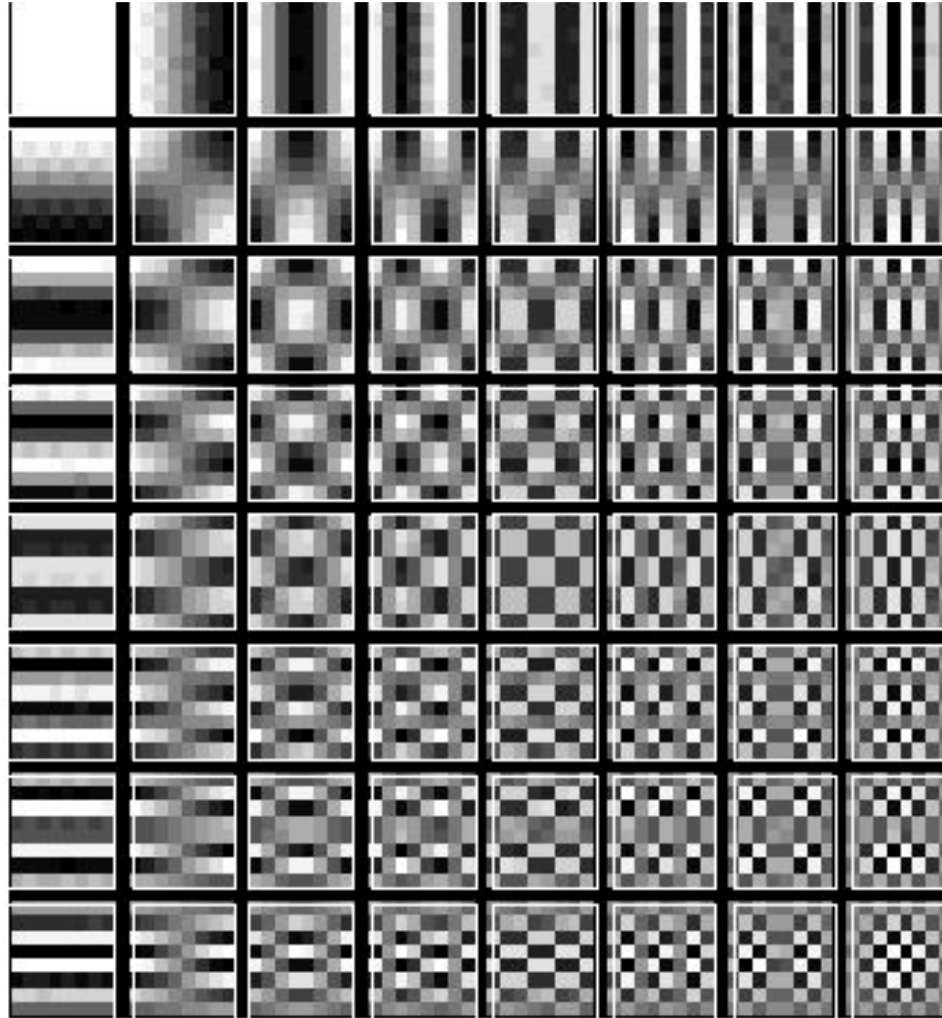
# La sorgente



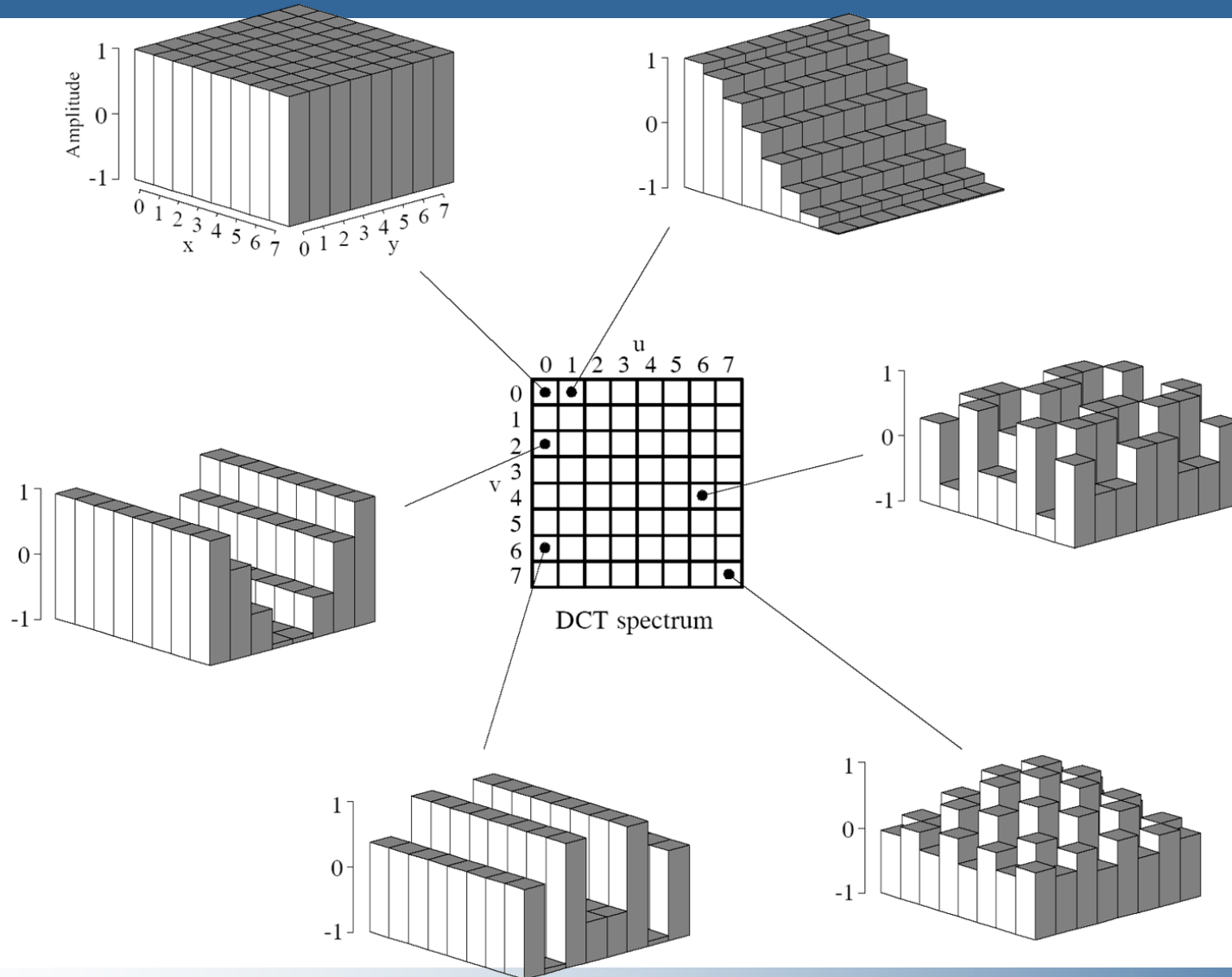
# Segmentazione dell'Immagine



# Le funzioni della base DCT (1)



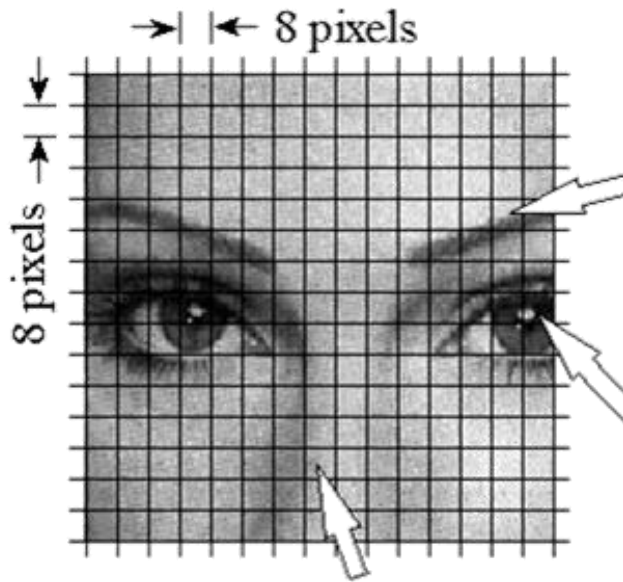
# Le funzioni della base DCT (2)





Codifica con  $\bar{S}[0,0]$ 

# Andamenti della DCT



## Original Group

a. Eyebrow

231	224	224	217	217	203	189	196
210	217	203	189	203	224	217	224
196	217	210	224	203	203	196	189
210	203	196	203	182	203	182	189
203	224	203	217	196	175	154	140
182	189	168	161	154	126	119	112
175	154	126	105	140	105	119	84
154	98	105	98	105	63	112	84

b. Eye

42	28	35	28	42	49	35	42
49	49	35	28	35	35	35	42
42	21	21	28	42	35	42	28
21	35	35	42	42	28	28	14
56	70	77	84	91	28	28	21
70	126	133	147	161	91	35	14
126	203	189	182	175	175	35	21
49	189	245	210	182	84	21	35

## DCT Spectrum

d. Eyebrow spectrum

174	19	0	3	1	0	-3	1
52	-13	-3	-4	-4	-4	5	-8
-18	-4	8	3	3	2	0	9
5	12	-4	0	0	-5	-1	0
1	2	-2	-1	4	4	2	0
-1	2	1	3	0	0	1	1
-2	5	-5	-5	3	2	-1	-1
3	5	-7	0	0	0	-4	0

e. Eye spectrum

70	24	-28	-4	-2	-10	-1	0
-53	-35	43	13	7	13	1	3
23	9	-10	-8	-7	-6	5	-3
6	2	-2	8	2	-1	0	-1
-10	-2	-1	-12	2	1	-1	4
3	0	0	11	-4	-1	5	6
-3	-5	-5	-4	3	2	-3	5
3	0	4	5	1	2	1	0

# Frequency-selective (Variable) Quantization

a. Low compression

1	1	1	1	1	2	2	4
1	1	1	1	1	2	2	4
1	1	1	1	2	2	2	4
1	1	1	1	2	2	4	8
1	1	2	2	2	2	4	8
2	2	2	2	2	4	8	8
2	2	2	4	4	8	8	16
4	4	4	4	8	8	16	16

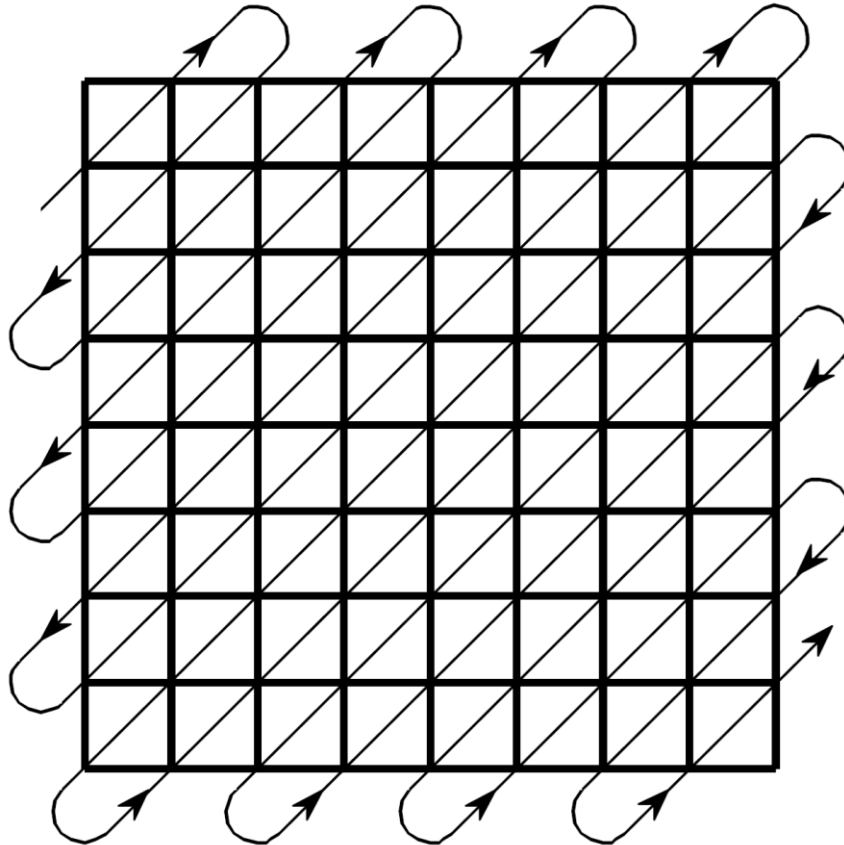
b. High compression

1	2	4	8	16	32	64	128
2	4	4	8	16	32	64	128
4	4	8	16	32	64	128	128
8	8	16	32	64	128	128	256
16	16	32	64	128	128	256	256
32	32	64	128	128	256	256	256
64	64	128	128	256	256	256	256
128	128	128	256	256	256	256	256

$$\Delta(u, v)$$

$$S_q(u, v) = \text{int} \left( \frac{S(u, v)}{\Delta(u, v)} \right)$$

# Percorso di scansione



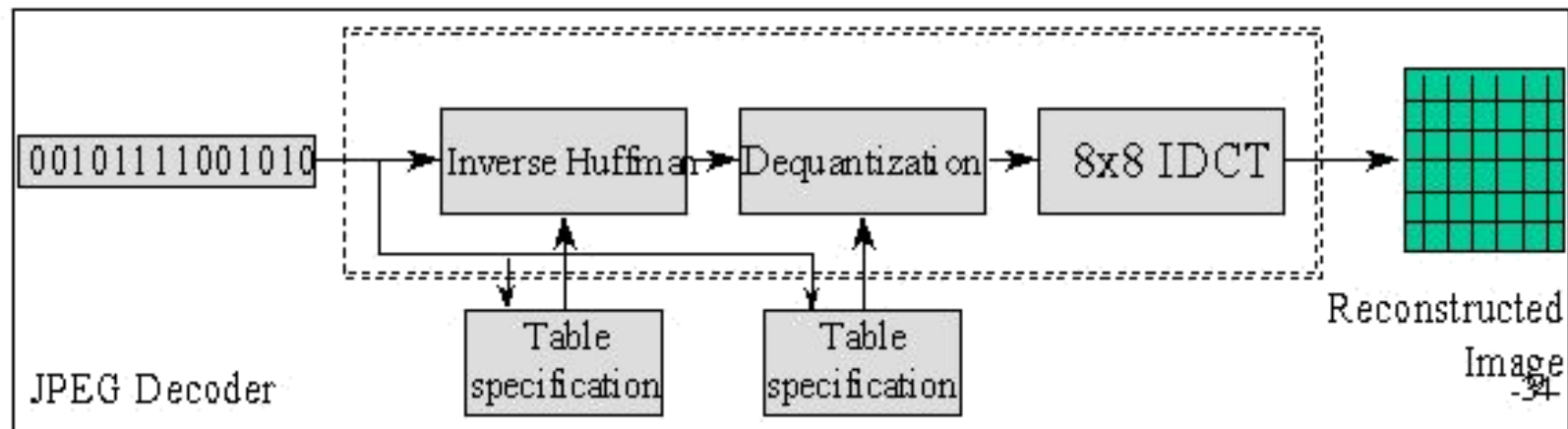
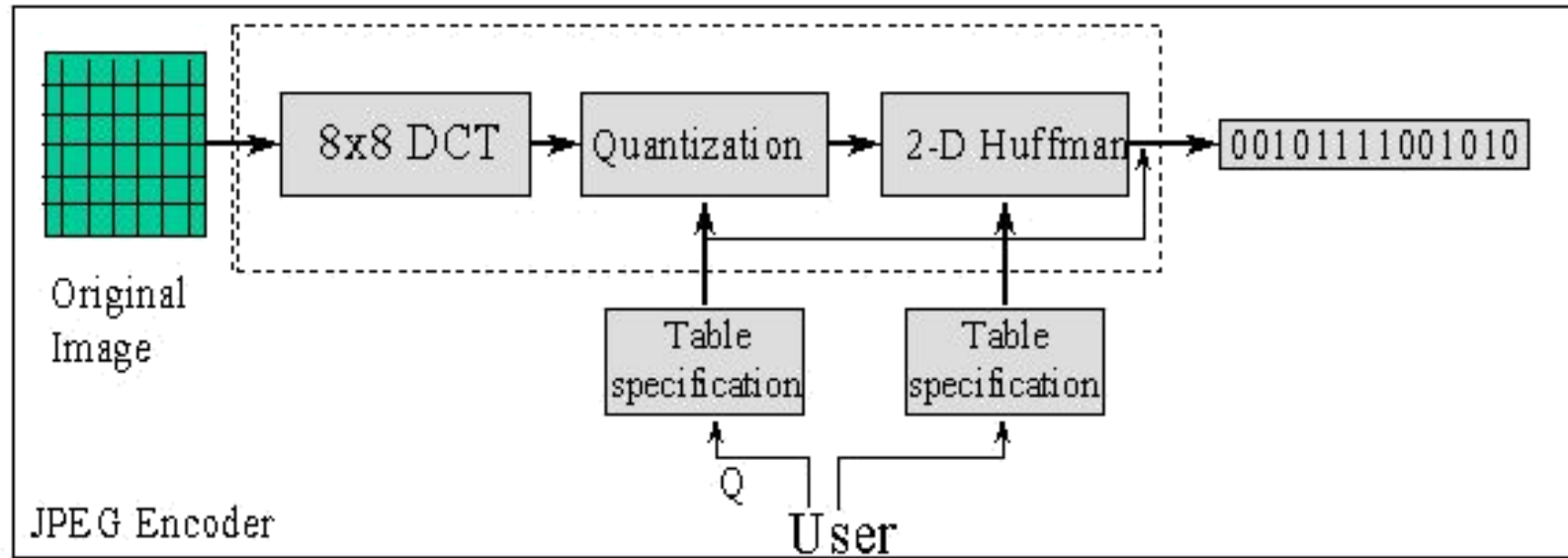
```

00 01 05 06 14 15 27 28
02 04 07 13 16 26 29 42
03 08 12 17 25 30 41 43
09 11 18 24 31 40 44 53
10 19 23 32 39 45 52 54
20 22 33 38 46 51 55 60
21 34 37 47 50 56 59 61
35 36 48 49 57 58 62 63

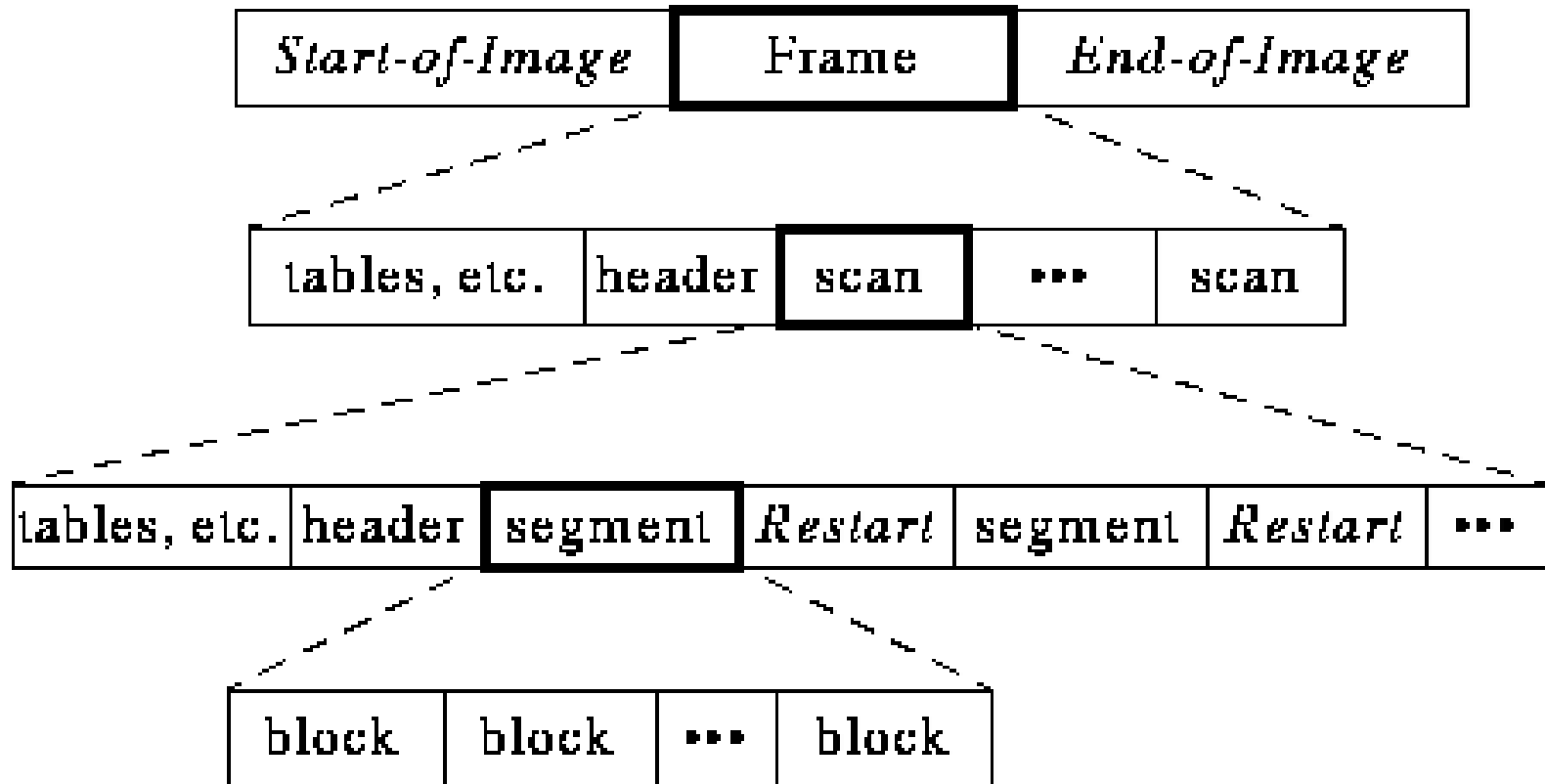
```

# Codifica “entropica”

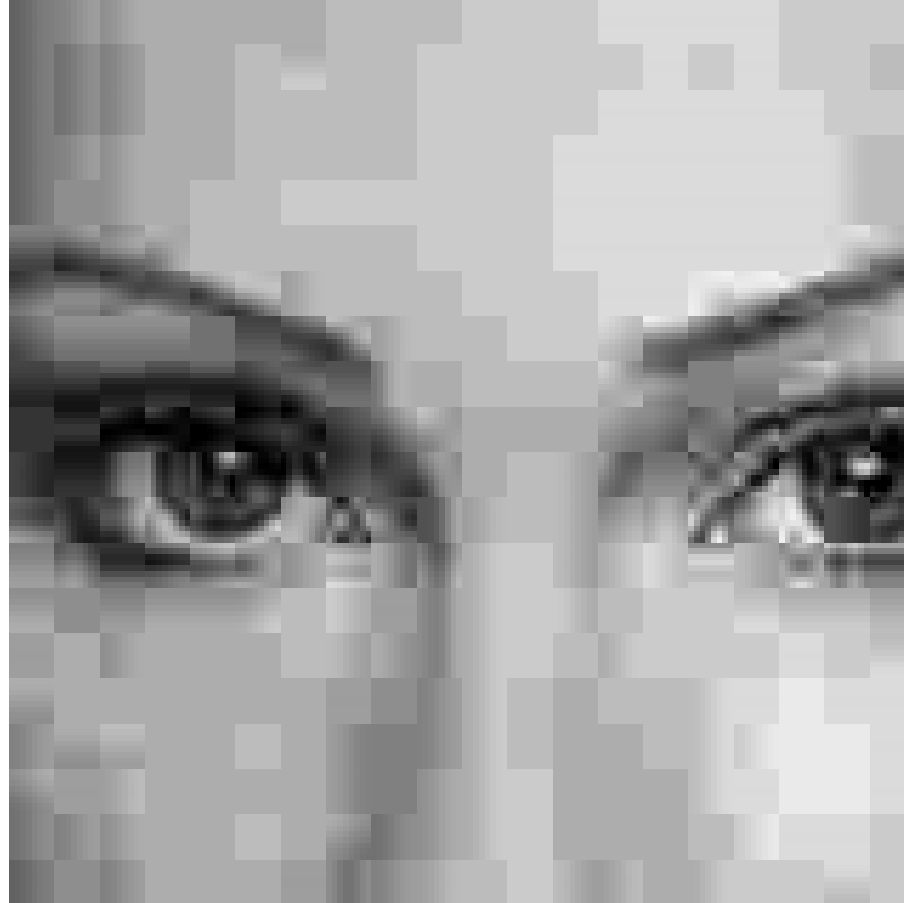
1. Run-length encoding: ( $R$  (*lunghezza della sequenza, su 4 bit*),  $B$  (*valore non-zero, variabile, tipicamente su 8 bit*))
2. Codice di Huffman “doppio”: si codificano separatamente  $R$  e i primi 4 bit di  $B$  (*256 entry, non più di 16 bit di parola*) e poi i restanti di  $B$



# Formato del file JPEG

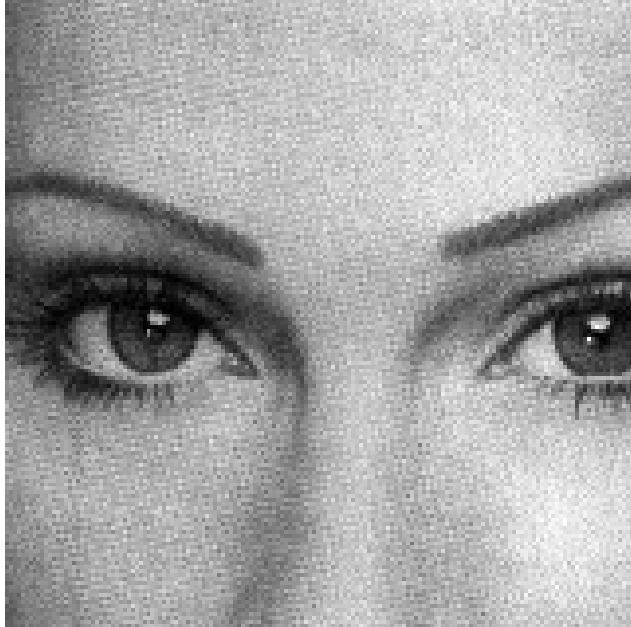


## Confronto 1/5





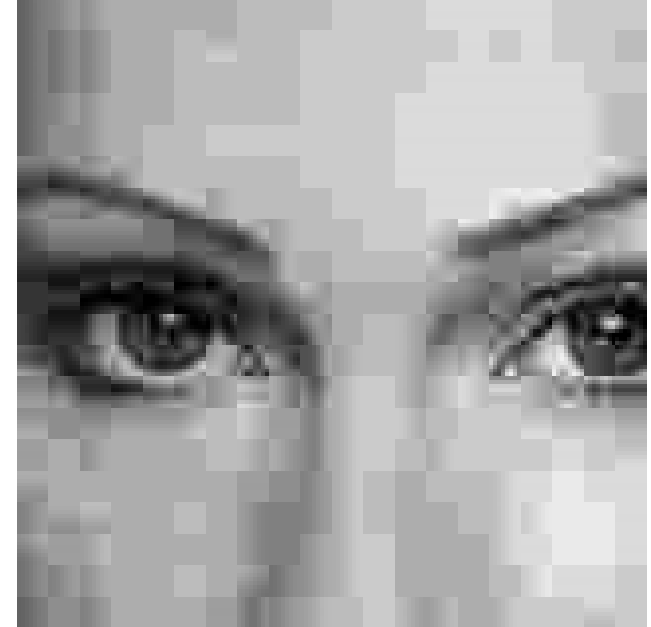
# Confronto 2/5



**8 bit/pixel**

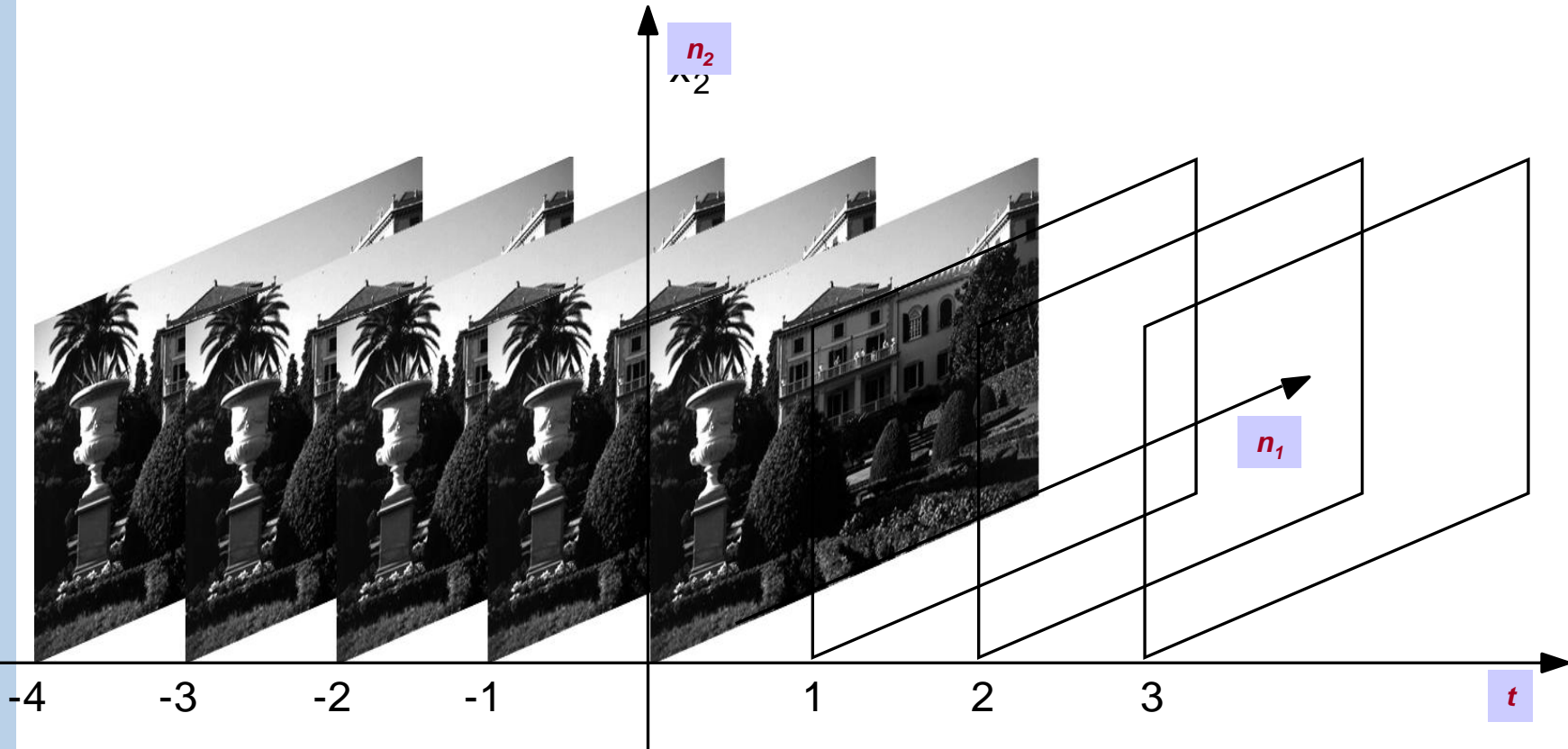


**0.8 bit/pixel**



**0.18 bit/pixel**

# Segnale video $S[n_1, n_2; t]$



CCIR 601: 25 quadri al secondo con risoluzione 720x576 pixel

## Bit-rate del segnale video

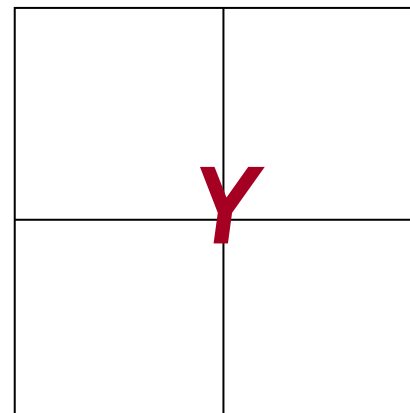
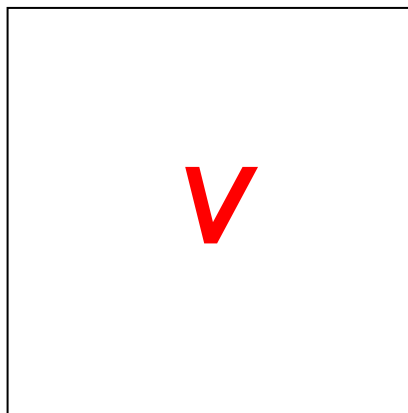
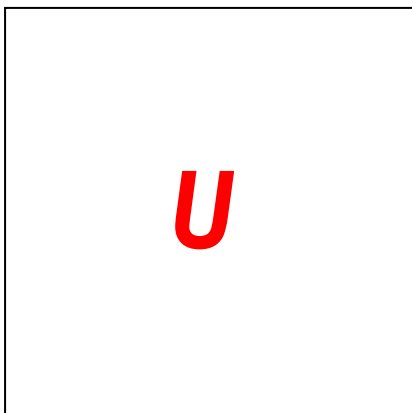
- **CCIR 601**
- **3 colori (R,G,B)**
- **profondità 8 bit/colore**
- **$R_b = 25 \times 720 \times 576 \times 3 \times 8 = 248.832 \text{ Mbit/s}$**
  
- **HDTV: risoluzione 1920x1152 pixel**
- **$R_b = 1.33 \text{ Gbit/s}$**

$$Y = 0.299R + 0.587G + 0.114B$$

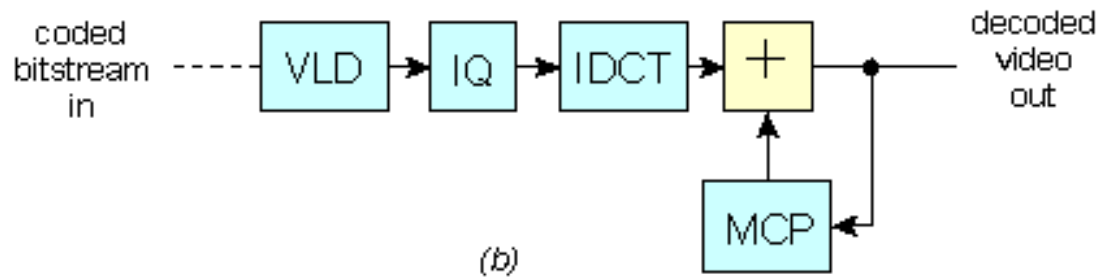
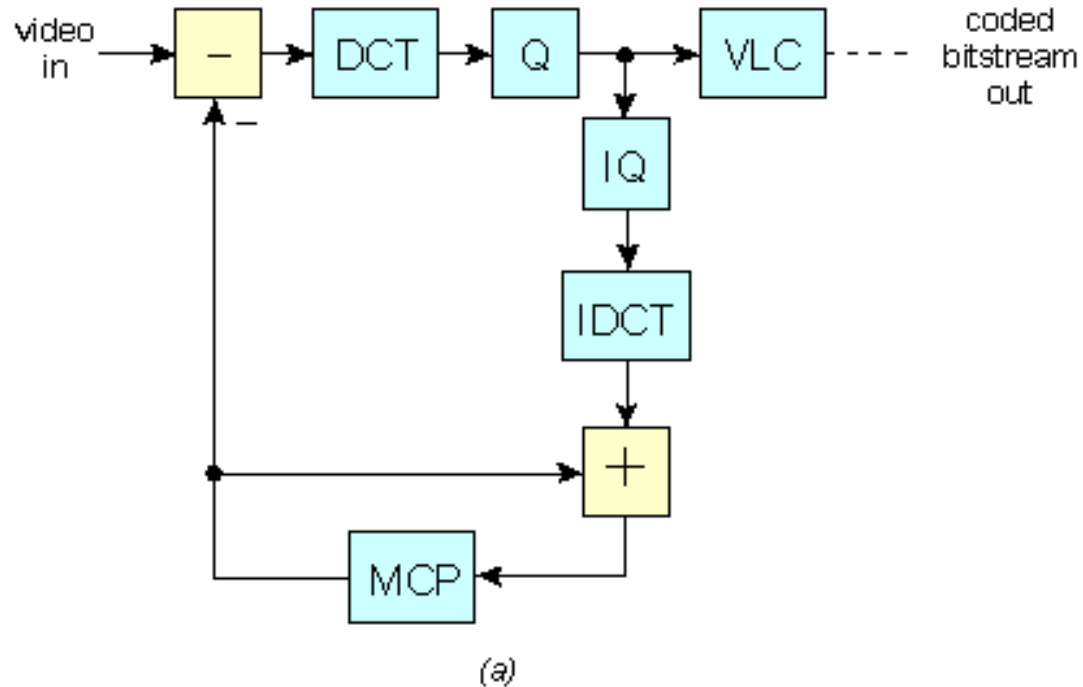
$$U = 0.493(B - Y)$$

$$V = 0.877(R - Y)$$

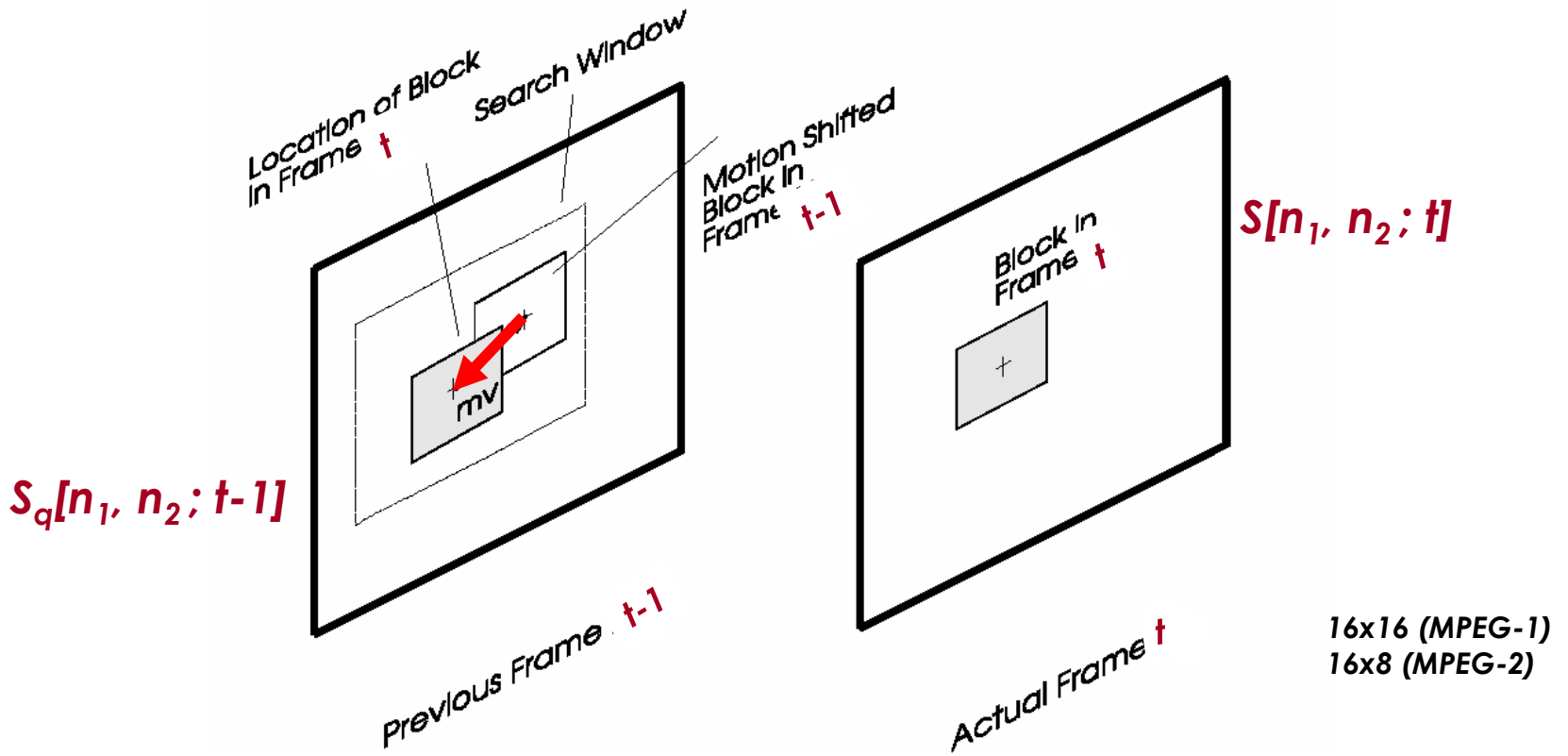
**Sottocampionamento 4:2:0**



# Codec MPEG



# Predizione del moto



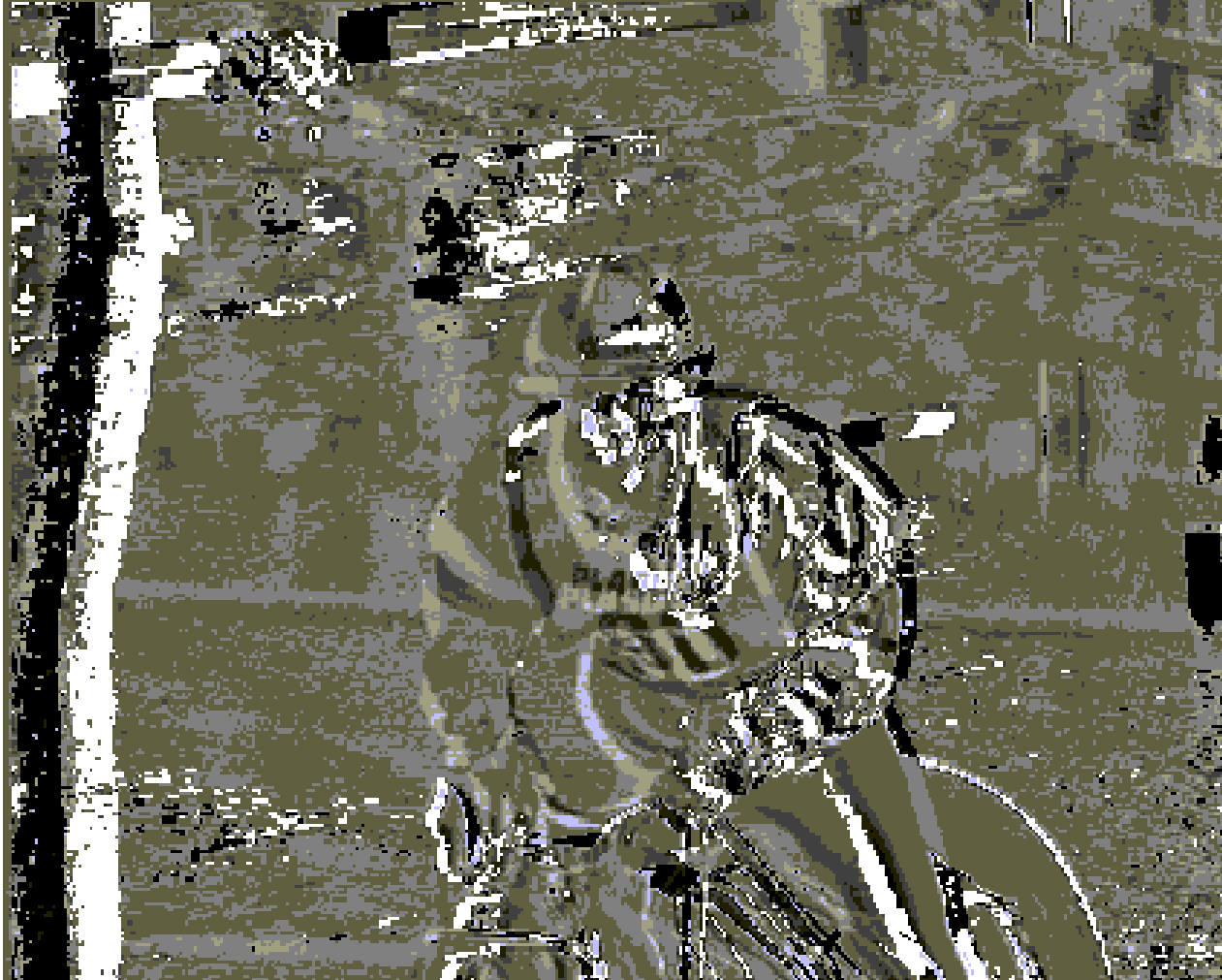
Quadro  $S[n_1, n_2; t-1]$ 

# Vettori di moto

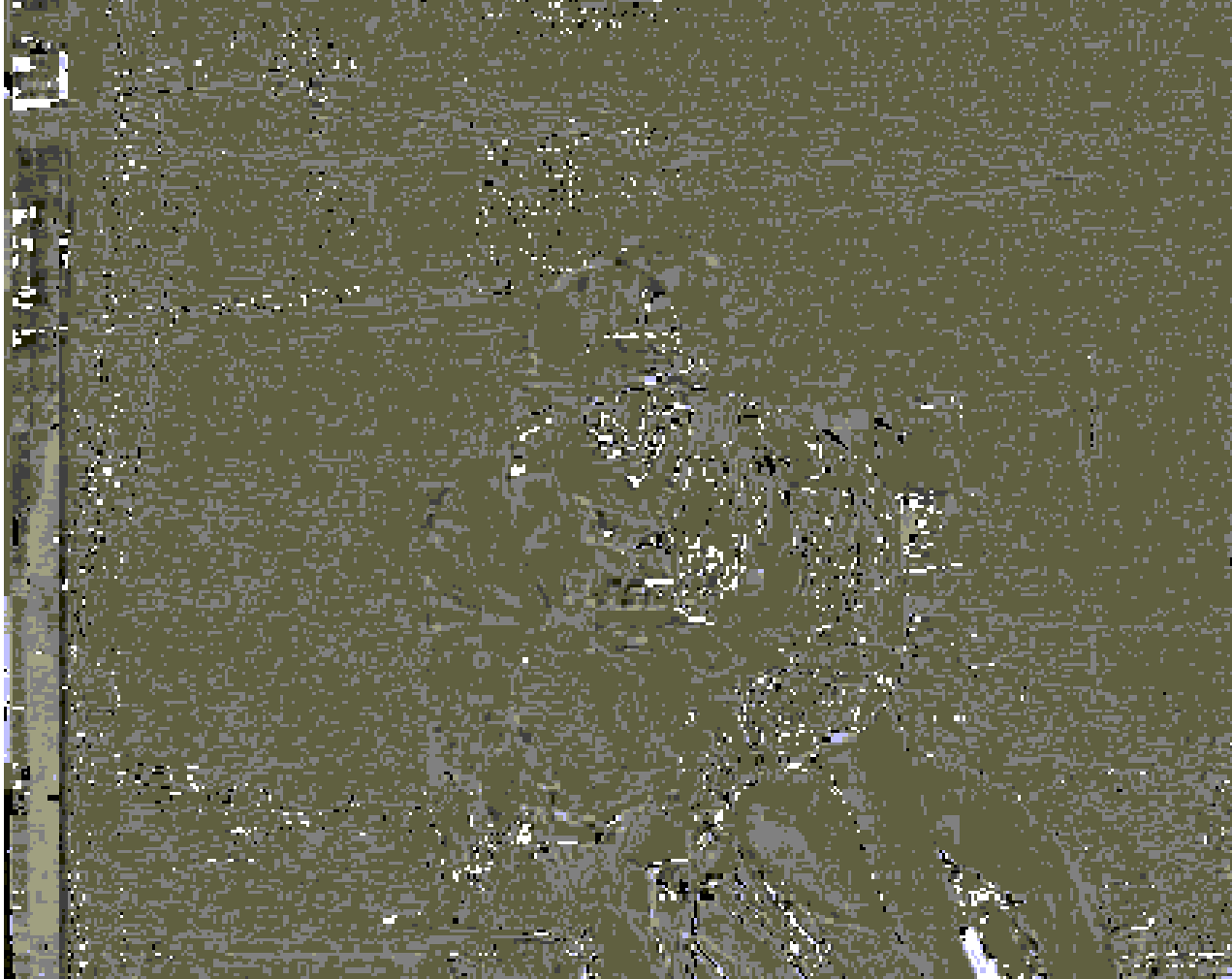




# Errore $S[n_1, n_2; t] - S[n_1, n_2; t-1]$ senza MC



# Errore $S[n_1, n_2; t] - \hat{S}[n_1, n_2; t]$ con MC



# GOP e predizione bidirezionale

**Source order and encoder input order:**

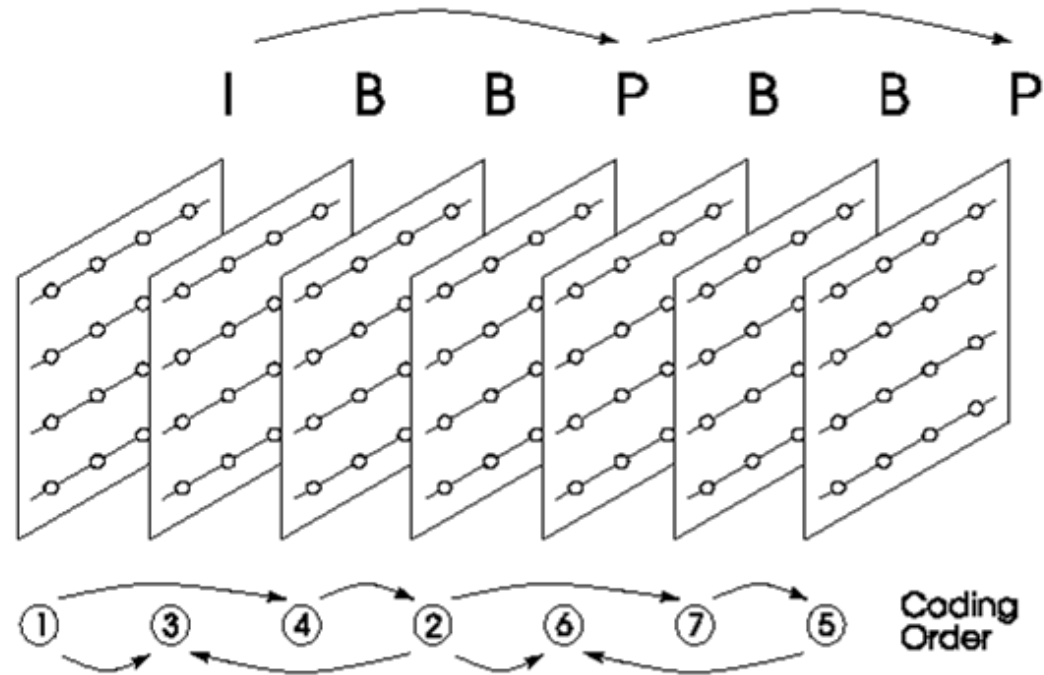
**I(1) B(2) B(3) P(4) B(5) B(6) P(7) B(8) B(9) P(10) B(11) B(12) I(13)**

**Encoding order and order in the coded bitstream:**

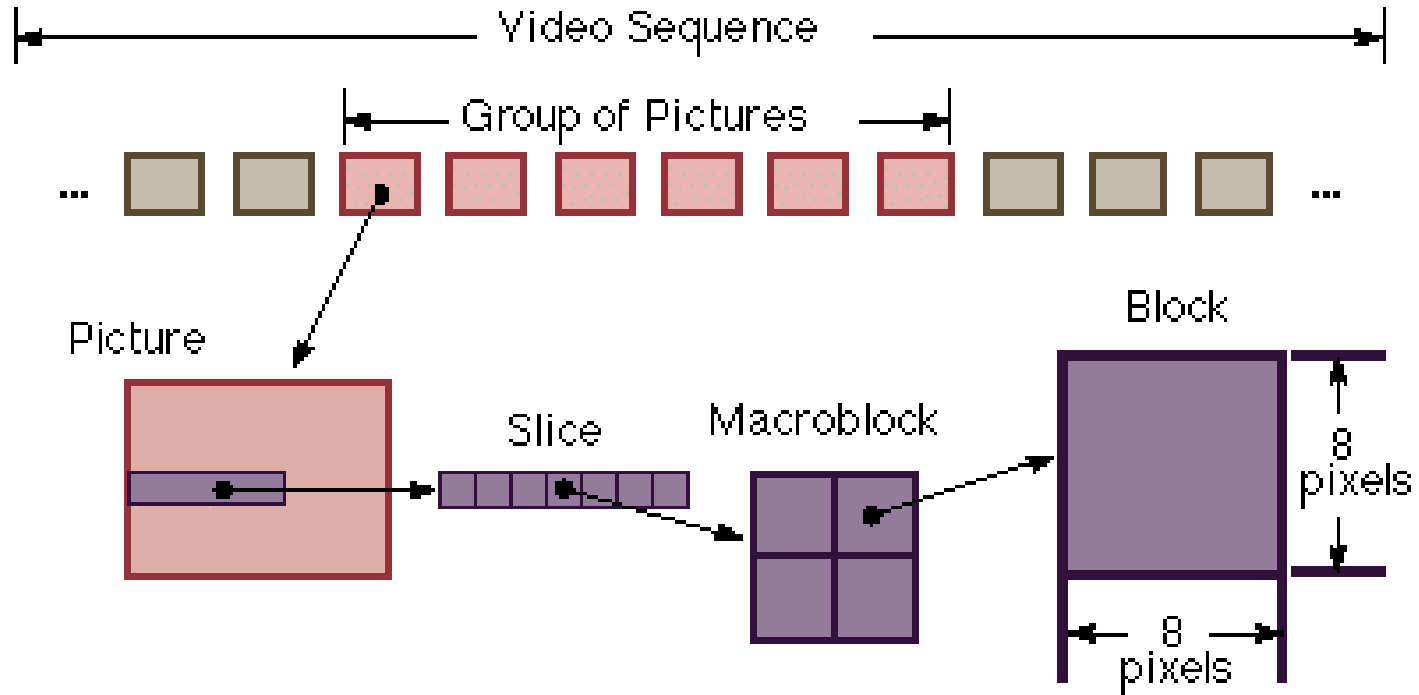
**I(1) P(4) B(2) B(3) P(7) B(5) B(6) P(10) B(8) B(9) I(13) B(11) B(12)**

**Decoder output order and display order (same as input):**

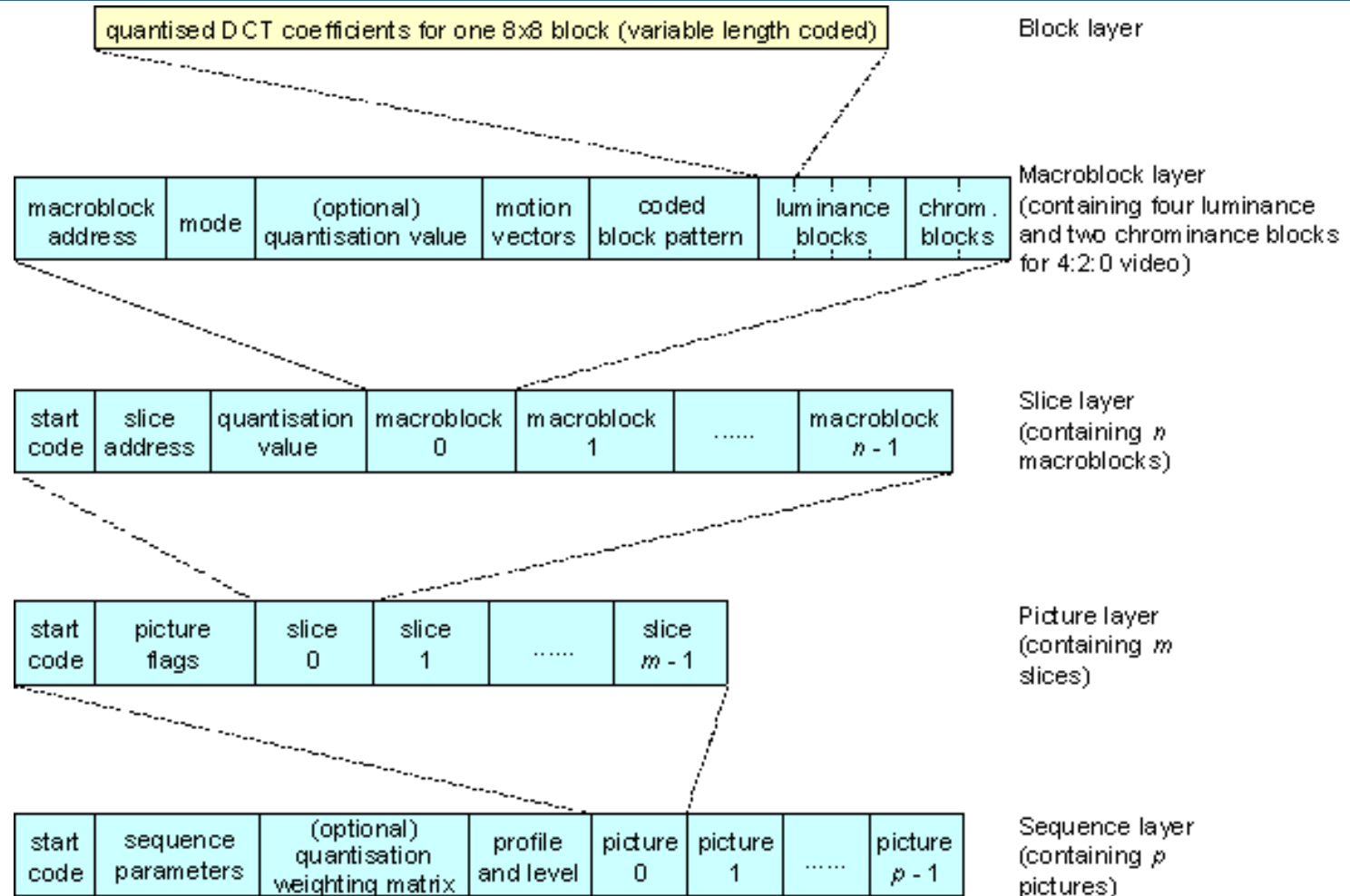
**I(1) B(2) B(3) P(4) B(5) B(6) P(7) B(8) B(9) P(10) B(11) B(12) I(13)**



# Gerarchia MPEG



# Formato MPEG



Each picture is divided into  $m$  horizontal slices, each comprising  $n$  macroblocks. For 4:2:0 video, each macroblock contains four luminance and two chrominance 8x8 blocks of quantised DCT coefficients.