Analog Compression on NTSC

NTSC Color Signal 26 MHz

- 13.5 MHz for Luminance (Y)
- 6.75 MHz for Chrominance
  - Two signals of 6.75 MHz
    - Cb for the color difference R - Y
    - Cr for the color difference B - Y
  - Information for Red, Blue, Green
- 26 MHz >> 6 MHz

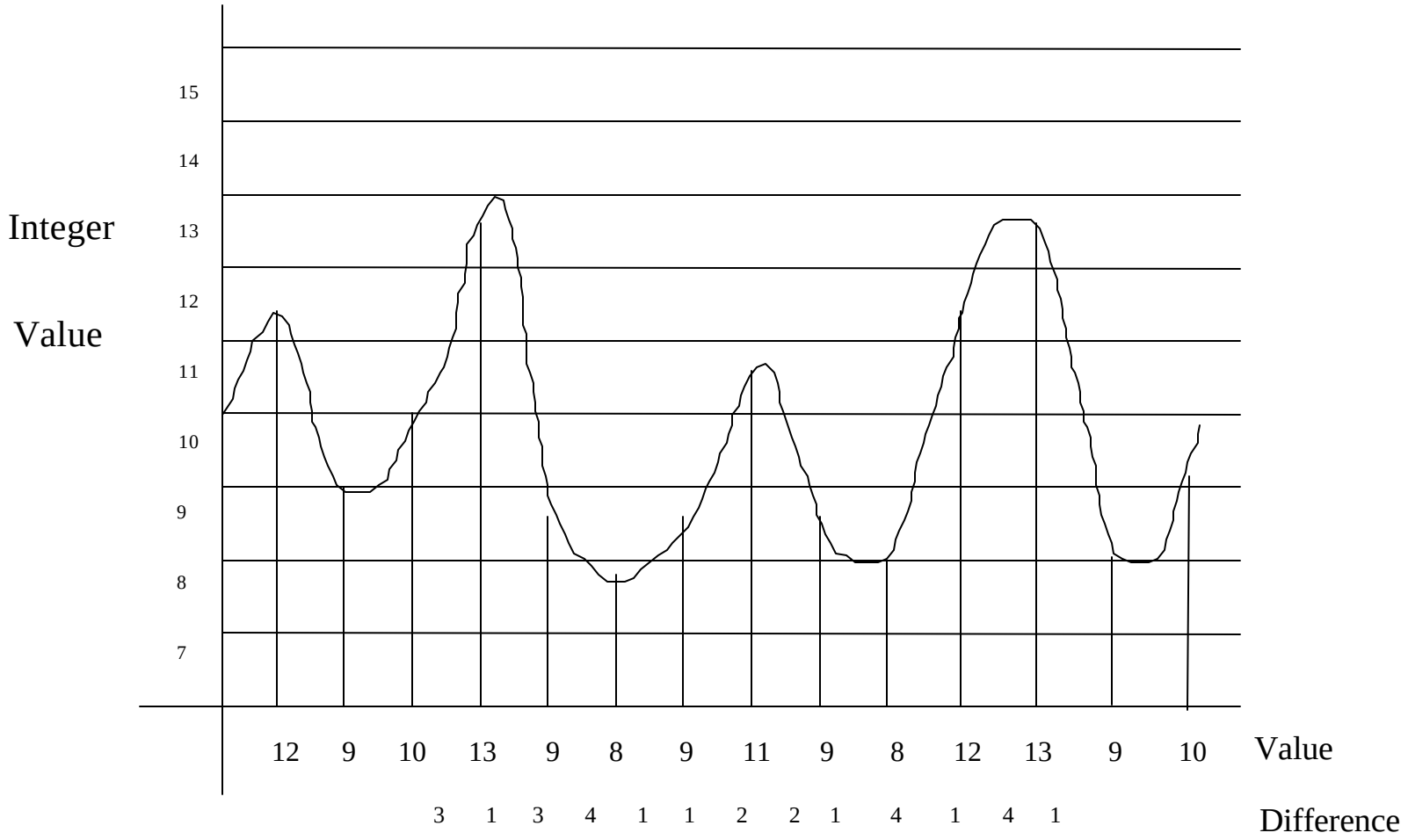
Lossless Compression

- Output = Input, guaranteed
- Critical Data Communications
  - Numerical Data
  - Financial matters
- Methods
  - Variable Length Coding (VLC)
    - PKZIP is an example
    - Huffman Coding a type of VLC
  - Run Length Coding
    - Replaces long repeating patterns with shorter character set

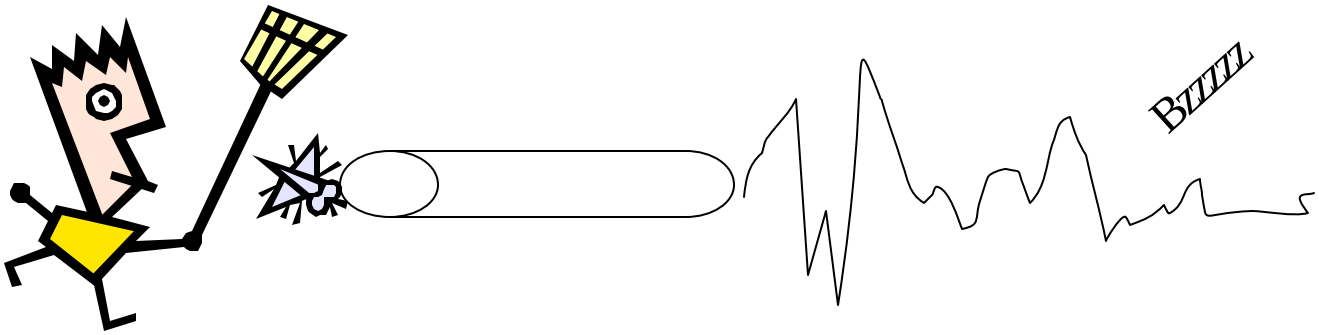
Lossy Compression

- Output ≠ Input
- Bandwidth required only 25% of Lossless Compression
- Non-Critical Communications
  - CATV
  - Audio/Video
- "Receiver" not that sensitive
  - Human ear ~300 to 16,000 Hz
  - Human eye
    - Transmit detectable changes
    - Color differences and brightness

Adaptive Pulse Code Modulation
ADPCM



Linear Predictive Coding
LPC

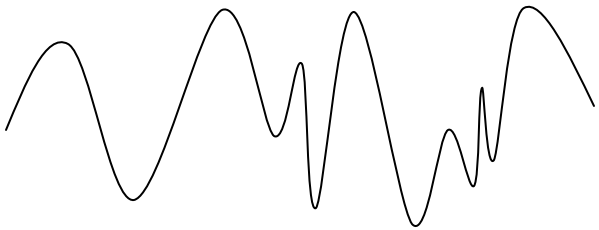


Encode differences
Differences use fewer “bits” then original signal
Each difference sample is a linear combination of ALL previous samples
This results in an equation called a linear predictor
Reconstruct signal in decoder’s filter

Audio versus Video Compression

Audio

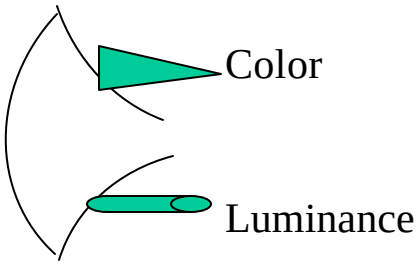
300 - 16,000 Hz



Video

4,000,000 Hz

Luminance
Colors



GIF
Graphics Interchange File

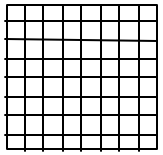
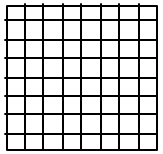
- Still pictures
- Limited colors (2^7)
- Can compress up to 5:1

JPEG
Joint Photographic Group

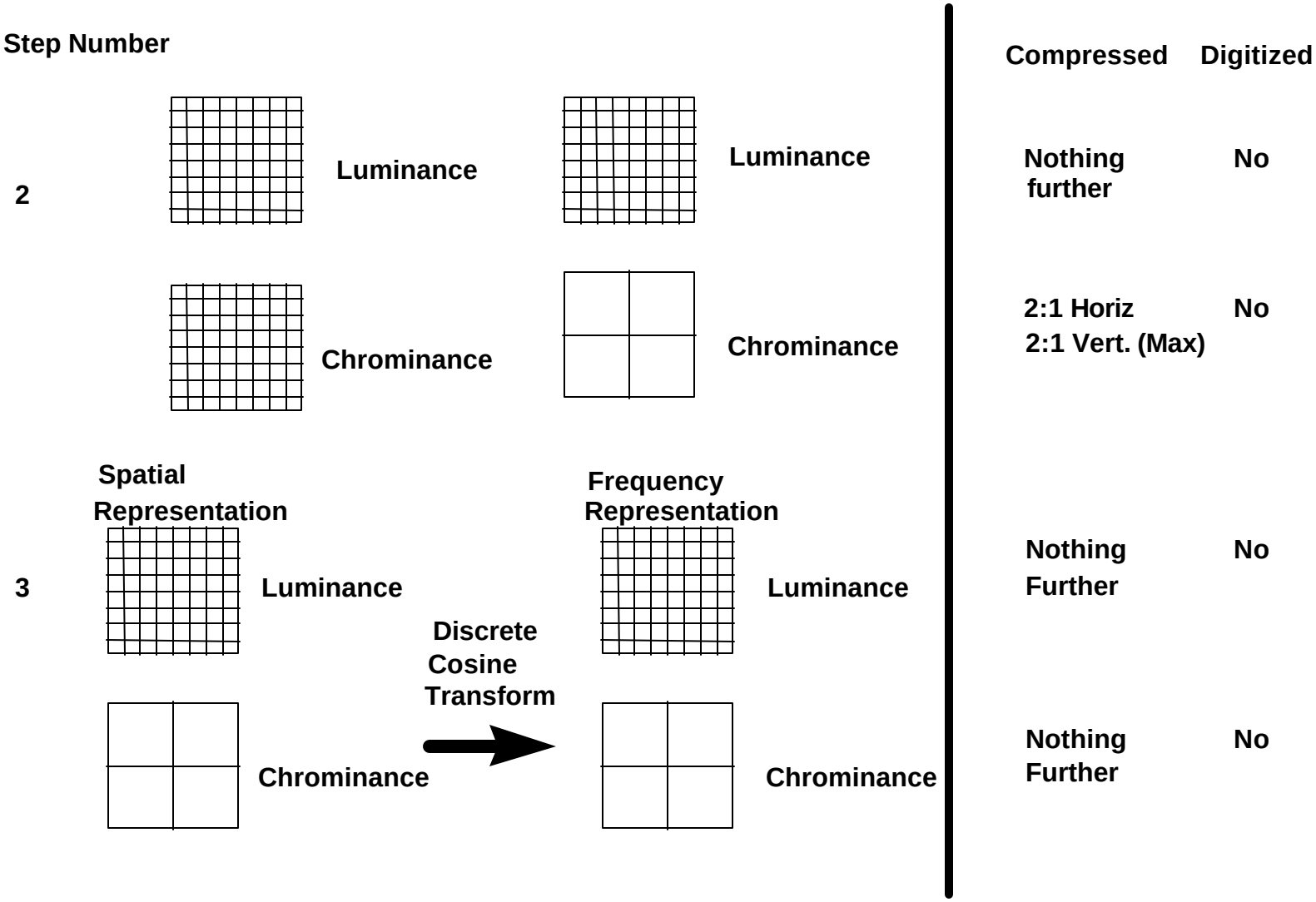
7-Step Process

1. Transform Image
2. Process Pixels in Groups
3. Group pixels in 8x8 blocks & transform to frequency domain
4. Divide by Quantization Coefficient
5. Convert integers to binary digits
6. Compress 0 strings with Huffman coding
7. Attach header

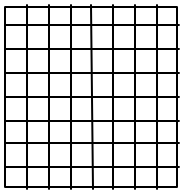
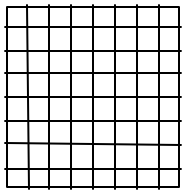
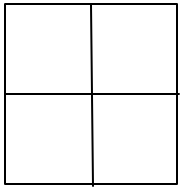
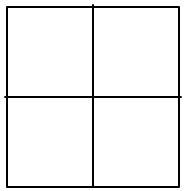
The JPEG Process - Sampling Steps

Step Number	Image	Recorded Image		Compressed	Digitized
0			RGB	Yes, at Pixel Level	No
1		Numerical Coefficients 	Luminance	Nothing further	No
			Chrominance		

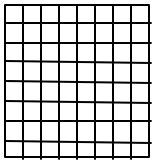
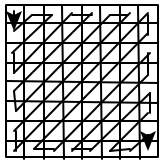
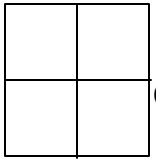
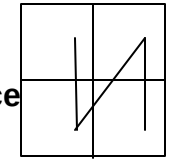
The JPEG Process - Sampling Steps



The JPEG Process - Quantizing Steps

Step Number					Compressed	Digitized
4		Luminance	Division by Quantizing Coefficients →	 Luminance	Some, at Highest Frequencies	No
		Chrominance		 Chrominance	Some, at Highest Frequencies	No

The JPEG Process - Encoding Steps

Step Number	Rounded Frequencies	Sequence Digits	Binary String	Compressed	Digitized
5	 Luminance	 Luminance		Nothing Further	Yes
	 Chrominance	 Chrominance	1011 0111 1111 0101	Nothing Further	Yes
6	Binary String 1011 0111 1111 0101	Huffman Coding	Compressed Binary String 1 00 10 101	Reduced Number of Digits	Yes
7	Compressed Binary String 1 00 10 101	Add Header With Information About Quantization Coefficients, Type of Sequencing, and Specifics of Huffman Code	Ready for Transmission 1011 0111 1111 0101	Nothing Further	Yes

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HUFFMAN CODING TABLE

7 bit code	1100001	1100010	1100011	1100100	1100101	1100110
Frequency in thousands	45	13	12	16	9	5
Fixed length codeword	000	001	010	011	100	101
Variable length codeword	0	101	100	111	1101	1100

MPEG
Motion Pictures Experts Group

- MPEG-1
  - 1.5 Mb/s Video & .25 Mb/s Audio
  - Optimized for CD ROMs
- MPEG-2
  - 100 Mb/s
  - CATV Standard
  - 5 Audio Channels Available
- MPEG-3
  - Merged into MPEG-2
- MPEG-4
  - Evolving
  - Low bit rates - telephony applications

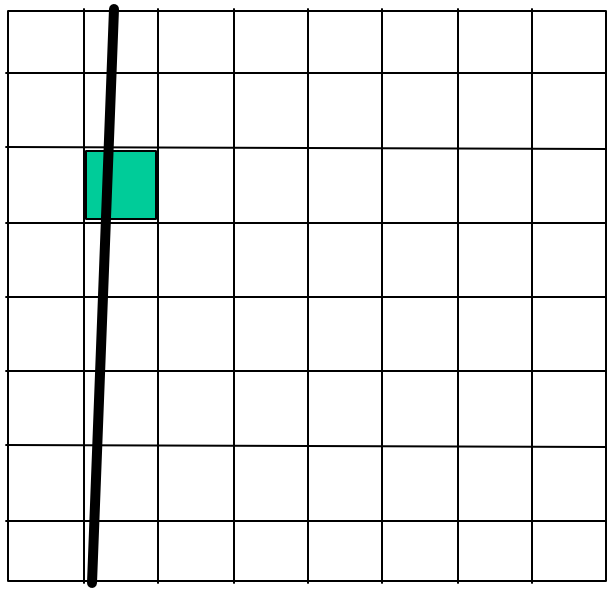
MPEG-2

Interframe Motion Compression

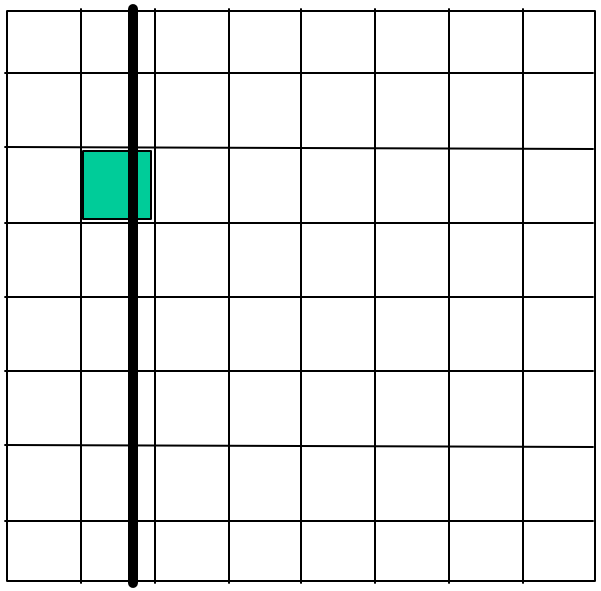
- Frames processed in groups
- Motion simulated
- Successive frames have redundancies
- 3-Types of Frames
  - I-Frame
  - P-Frame
  - B-Frame

MPEG-2

I and P Frames



I - Frame



P - Frame

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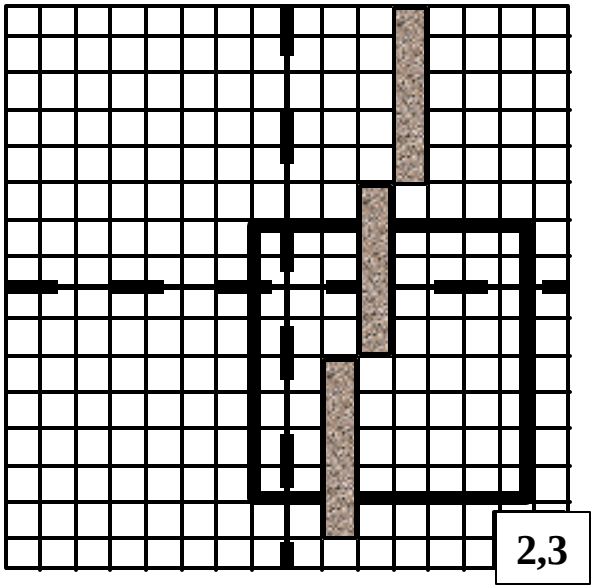
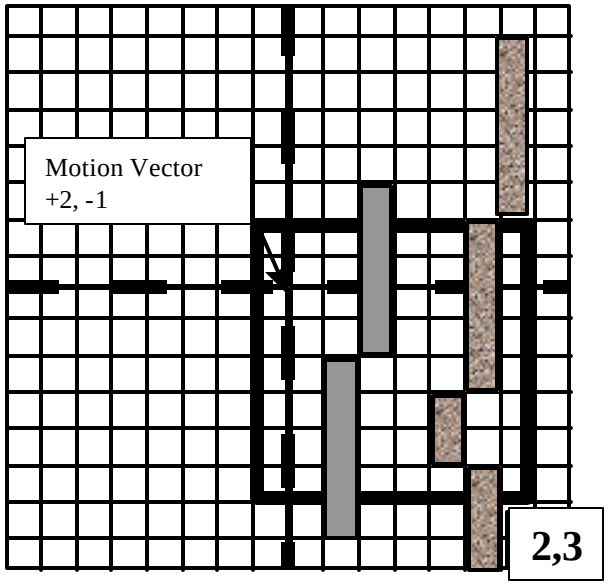
MPEG-2

Computing the Motion Vector



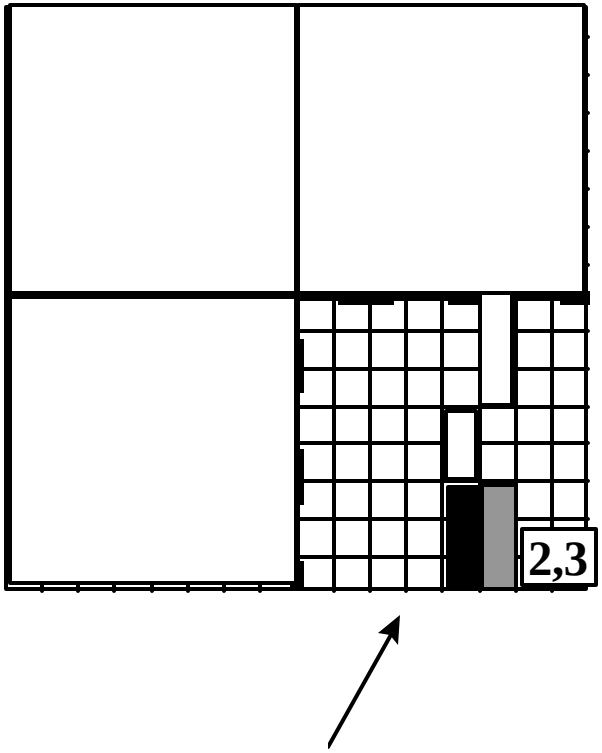
Reference I-Frame



Forward Predicted P-Frame

MPEG-2

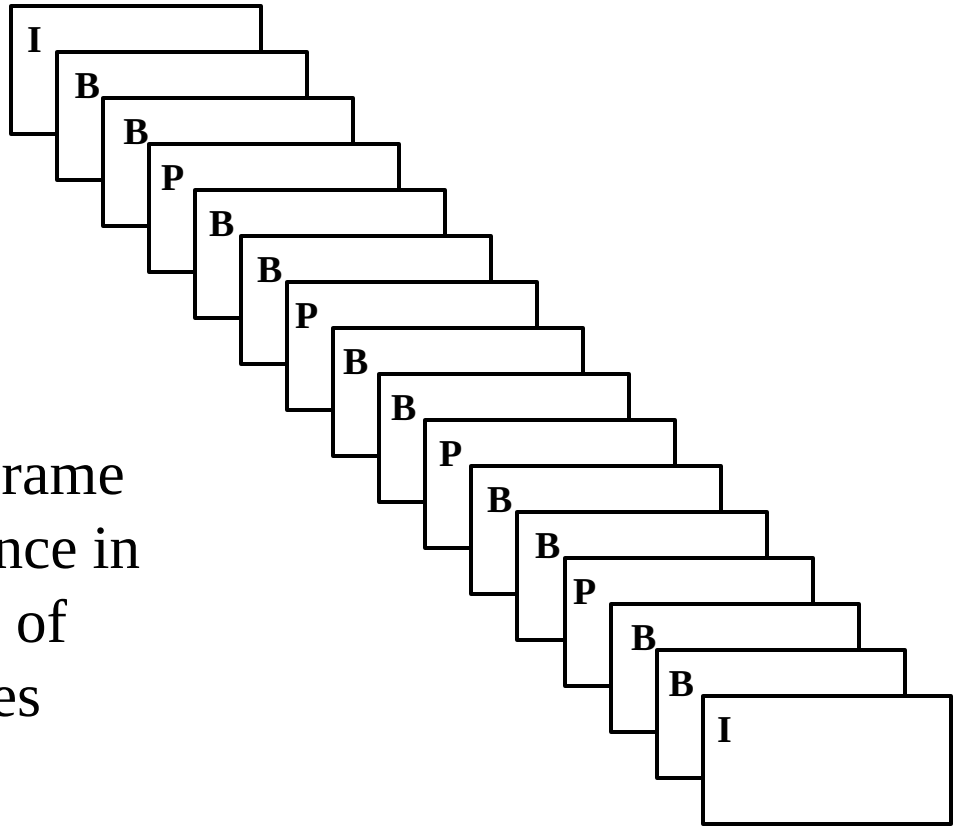
The Error Block



Error Block

MPEG-2

Group of Pictures (GOP)



15/3 Frame Sequence in Group of Pictures

MPEG-2
Audio Encoding and Compression

Multichannel Audio

- Surround sound
- 7-Commentary/bi-lingual channels

Transport Layer

- Used in error prone environments
- Fixed length 188 byte packet

Discrete Cosine Transform (Definition)

The NxN two dimensional DCT is defined as:

Encoder:

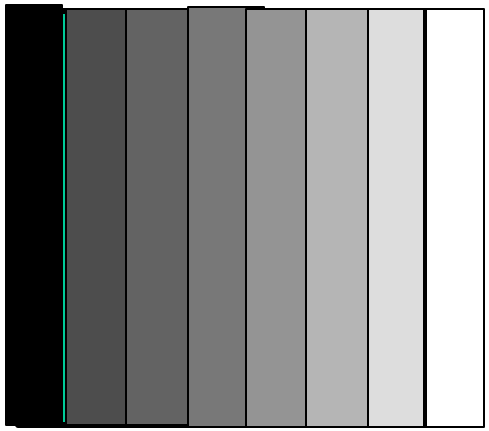
$$F(u,v) = \frac{2}{N} C(u)C(v) \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} f(x,y) \cos\frac{(2x+1)u\pi}{2N} \cos\frac{(2y+1)v\pi}{2N}$$

Decoder:

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

$$C(u), C(v) = \begin{cases} \frac{1}{\sqrt{2}} & \text{for } u,v = 0 \\ 1 & \text{otherwise} \end{cases}$$

DCT Process



Picture

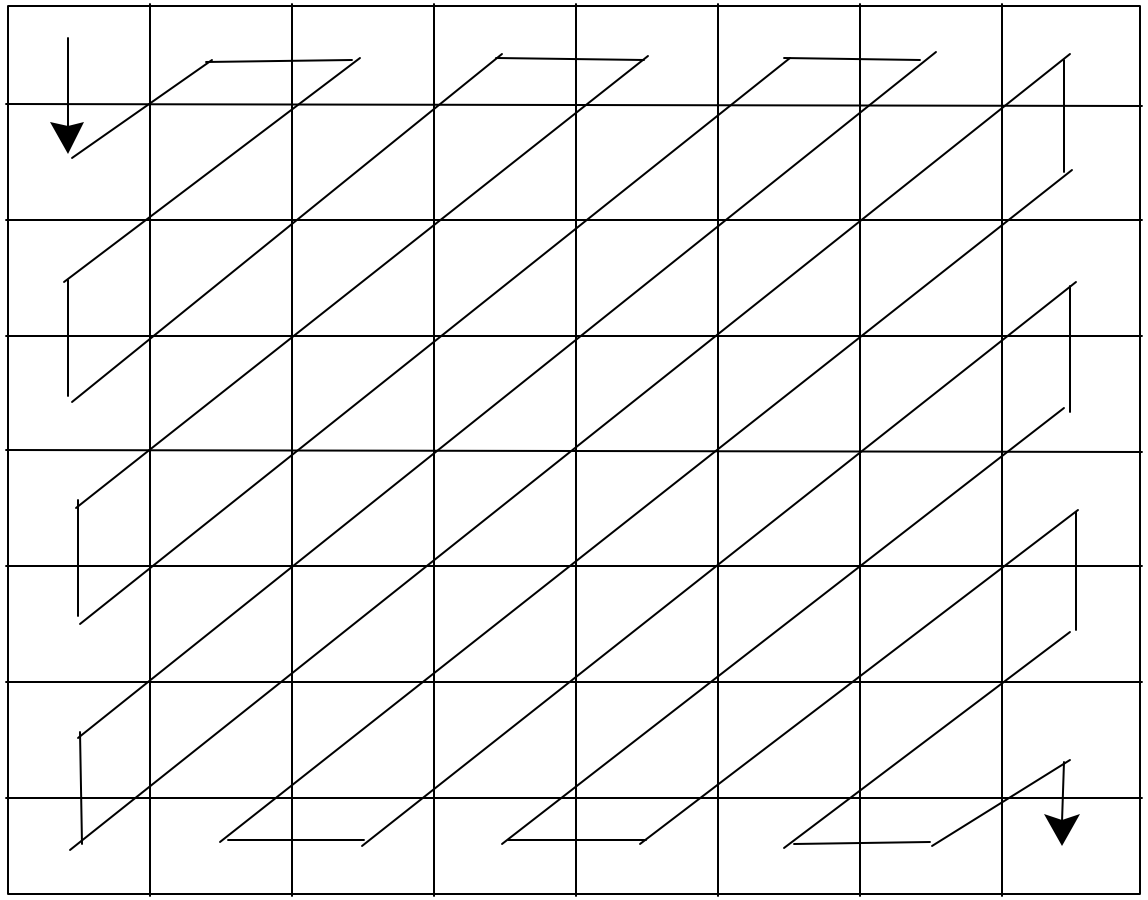
0	12.5	25.0	37.5	50.0	62.5	75.0	87.5
0	12.5	25.0	37.5	50.0	62.5	75.0	87.5
0	12.5	25.0	37.5	50.0	62.5	75.0	87.5
0	12.5	25.0	37.5	50.0	62.5	75.0	87.5
0	12.5	25.0	37.5	50.0	62.5	75.0	87.5
0	12.5	25.0	37.5	50.0	62.5	75.0	87.5
0	12.5	25.0	37.5	50.0	62.5	75.0	87.5
0	12.5	25.0	37.5	50.0	62.5	75.0	87.5

Sample Values

43.8	-40	0	-4.1	0	-1.1	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

DCT Coefficients

DCT Coefficient Processing Order



SUMMARY

Lossy versus Lossless compression

Audio Compression

- ADPCM
- LPC

Video Compression

- GIF
- JPEG
- MPEG
  - I, P, and B Frames
  - Error Block
  - Group of Pictures
- H.261

Discrete Cosine Transform