Video Compression Technology

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Agenda

- **Digital TV Introduction**
- **Video Compression Standards**
- **Video Formats and Quality**
- **Video Coding Concepts**

Digital Television

What is Digital Television?

Digital Television Format

- **Standard Definition Television (SDTV)**

  - **Europe**
    - 4:3 Aspect ratio, 625 lines, 50 fields/sec
    - 16:9 Aspect ratio, 625 lines, 50 fields/sec

  - **North America**
    - 4:3 Aspect ratio, 525 lines, 60 fields/sec

Digital Television Format

- **High Definition Television (HDTV) - All 16:9 Aspect Ratios**

  - 1125 (1080i) lines, 60 or 59.94 fields/sec, Interlaced
  - 750 (720p) lines, 60 or 59.54 frames/sec, Progressive
  - 525 (480p) lines, 60 or 59.94 frames/sec, Progressive
  - Others: 24 Hz p, 25 Hz p, 30 Hz p, 50 Hz i/p, 60 50 Hz i/p

Digital Video Broadcast Standard

- **Digital Video Broadcasting (DVB)**
  - DVB-S (Digital Video Broadcasting - Satellite)
  - DVB-T (Digital Video Broadcasting - Terrestrial)
  - DVB-C (Digital Video Broadcasting - Cable)
  - DVB-H (Digital Video Broadcasting - Handheld)
- **Advanced Television Systems Committee (ATSC)**
- **Integrated Services Digital Broadcasting (ISDB)**
- **Digital Multimedia Broadcasting (DMB)**

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Video Compression Standards

- **JPEG, still images (Joint Photographic Experts Group)**
  - M-JPEG; motion JPEG, not a standard, generally proprietary, JPEG 2000
- **ITU-T : H.261 (px64), H.262, H.263 (Video conference), H.264**
- **MPEG-1 (Moving Picture Experts Group), CD-ROM and multimedia**
- **MPEG-2, Broadcast entertainment/contribution and DVD**
- **MPEG-4, very low bit rate coding of objects**
- **Other formats - DV, RealVideo, VC-1, WMV, XVD**

MPEG-1

- **ISO/IEC 11172 (1993)**
- **Lossy compression of video & audio**
- **Design focused on non-interlaced (progressive)**
  Source Input Format (SIF) = 352x240, 352x288, or 320x240
- **Application was media storage e.g. CD-ROM**
  ~1.5 Mbps data rate
- **Uses most of the H.261 techniques**
- **Used in early DTV testing**

MPEG-2

- **ISO/IEC 13818 (1994)**
- **Lossy compression of video & audio**
- **Evolved out of the shortcomings of MPEG-1**
- **Applications**

  - RF Transmission
    - ATSC, DVB-T, DVB-C, DVB-S
    - Other satellite; ENG, Backhaul, Affiliate Distribution
  - Broadband Network (Telco)
  - Storage Media
  - Intra-studio
  - Internet
  - Video Conferencing
  - Education
  - Entertainment

MPEG-2 Standard Documents

MPEG-2 ISO/IEC 13818

- Part 1 Systems
- Part 2 Video
- Part 3 Audio
- Part 4 Conformance Testing (for 1, 2 and 3)
- Part 5 Software Simulation
- Part 6 System Extensions - DSM-CC
  (Digital Storage Media - Command and Control)
- Part 7 Audio Extension - NBC (Non-Backward Compatible)
- Part 9 System Extension - RTI (Real-Time Interface)
- Part 10 Conformance Extension - DSM-CC
- Part 11 Intellectual property management (IPMP)

MPEG-4

- **ISO/IEC 14496 (1998)**
- **Low bit rate video communications**
  - 2 Kbps – 10 Kbps
- **Applications**
  - AV data for web (Streaming media)
  - CD Distribution
  - Voice (Telephone, Videophone)
  - Broadcast television

MPEG-4 - Parts

MPEG-4 ISO/IEC 14496

- Part 1 Systems
- Part 2 Visual
- Part 3 Audio
- Part 4 Conformance
- Part 5 Reference Software
- Part 6 Delivery Multimedia Integration Framework (DMIF)
- Part 7 Optimized Reference Software
- Part 8 Carriage on IP networks
- Part 9 Reference Hardware
- Part 10 Advanced Video Coding (AVC)

MPEG-4 - Parts

MPEG-4 ISO/IEC 14496

- Part 11 Scene description and Application engine("*BIFS*")
- Part 12 ISO Base Media File Format
- Part 13 Intellectual Property Management and Protection (IPMP) Extensions
- Part 14 MPEG-4 File Format
- Part 15 AVC File Format
- Part 16 Animation Framework eXtension (AFX)
- Part 17 Timed Text subtitle format
- Part 18 Font Compression and Streaming (for OpenType fonts)
- Part 19 Synthesized Texture Stream
- Part 20 Lightweight Application Scene Representation (LASeR)

MPEG-4 - Parts

MPEG-4 ISO/IEC 14496

- Part 21 MPEG-J Graphics Framework eXtensions (GFX)
- Part 22 Open Font Format
- Part 23 Symbolic Music Representation (SMR)
- Part 24 Audio and systems interaction
- Part 25 3D Graphics Compression Model
- Part 26 Audio Conformance
- Part 27 3D Graphics conformance

Overview of MPEG-4 Visual

- **MPEG-4 Visual (Part 2, “Coding of Visual Objects”)**
- **Support many different application**
  - “Legacy” video application
  - Rendered computer graphics
  - Streaming video
  - High-quality video editing
- **Block-based video CODEC, Quantization, Entropy coding**
- **Introduction - Overview**
- **Section 1-5 Technical detail**
- **Section 6 Syntax & Semantics**
- **Section 7 Processes for decoding**
- **Section 8 Objects**
- **Section 9 Profiles & Levels**
- **15 Annexes**

Overview of H.264

- Designed primarily to support efficient and robust coding and transport of rectangular video frames
- Target applications include two-way video communication
- Introduction – Application, Concept of Profiles and Levels
- Section 1-5 Preamble to the detail, terminology and definitions, abbreviations
- Section 6 input and output data formats
- Section 7 syntax and semantics
- Section 8 processes involved in decoding slices
- Section 9 how a coded bitstream
- 4 Annexes

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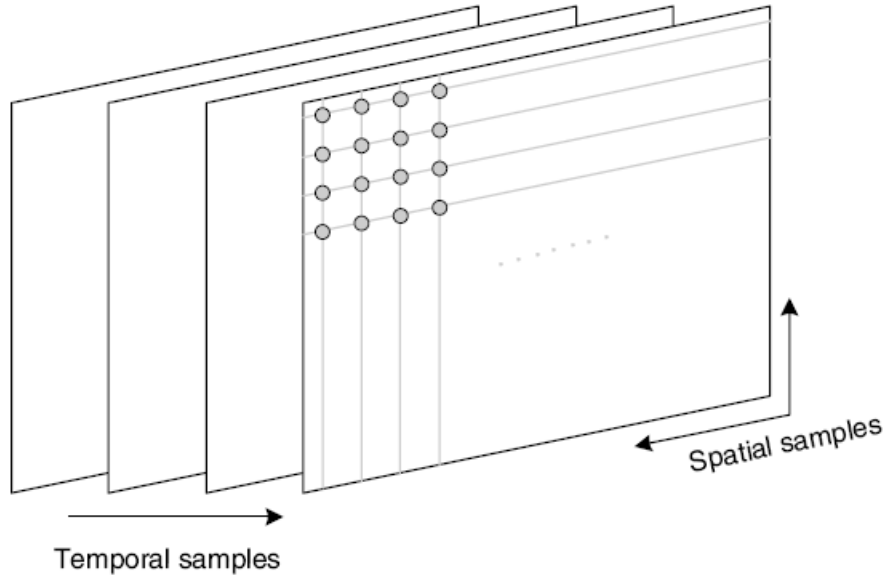
Natural Video Scenes

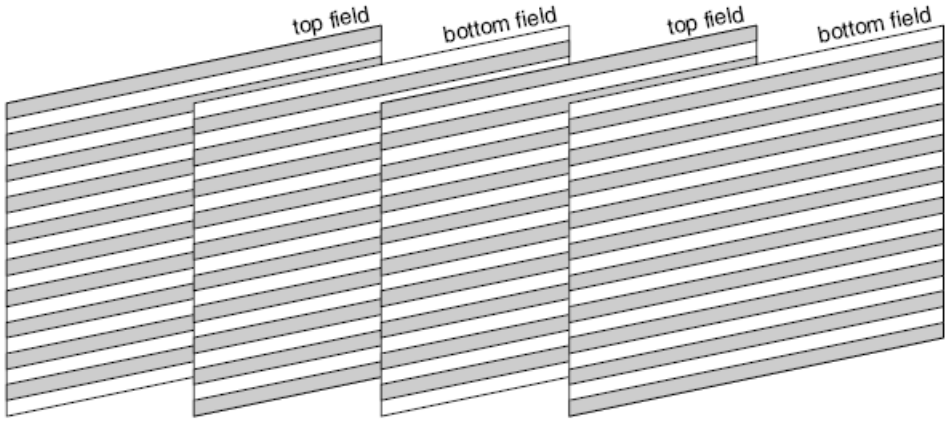
- **Composed of multiple objects each with their own characteristic shape, depth, texture and illumination.**
- **Spatial Characteristics & Temporal Characteristics**

Spatial & Temporal

- **Temporal Compression (IntER-frame)**
  - Compresses the data from multiple frames
- **Spatial Compression (IntRA-frame)**
  - Compresses the data within one frame
  - (Similar to JPEG)



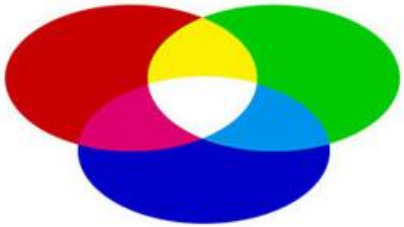
Frames & Fields



Top field

Bottom field

RGB Color Spaces



Red, Green and Blue components of color image

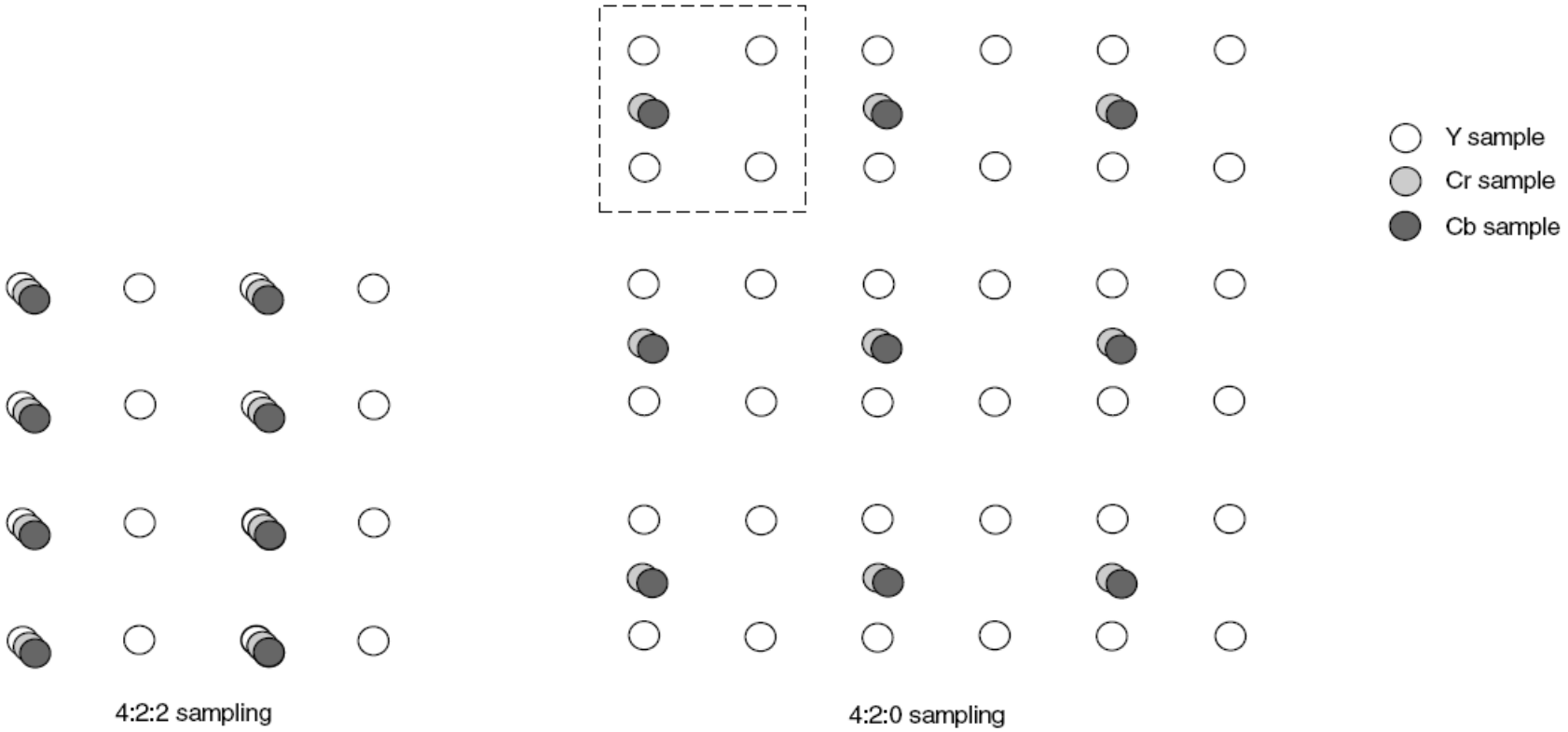
YCbCr

- **ITU-R recommendation BT.601**

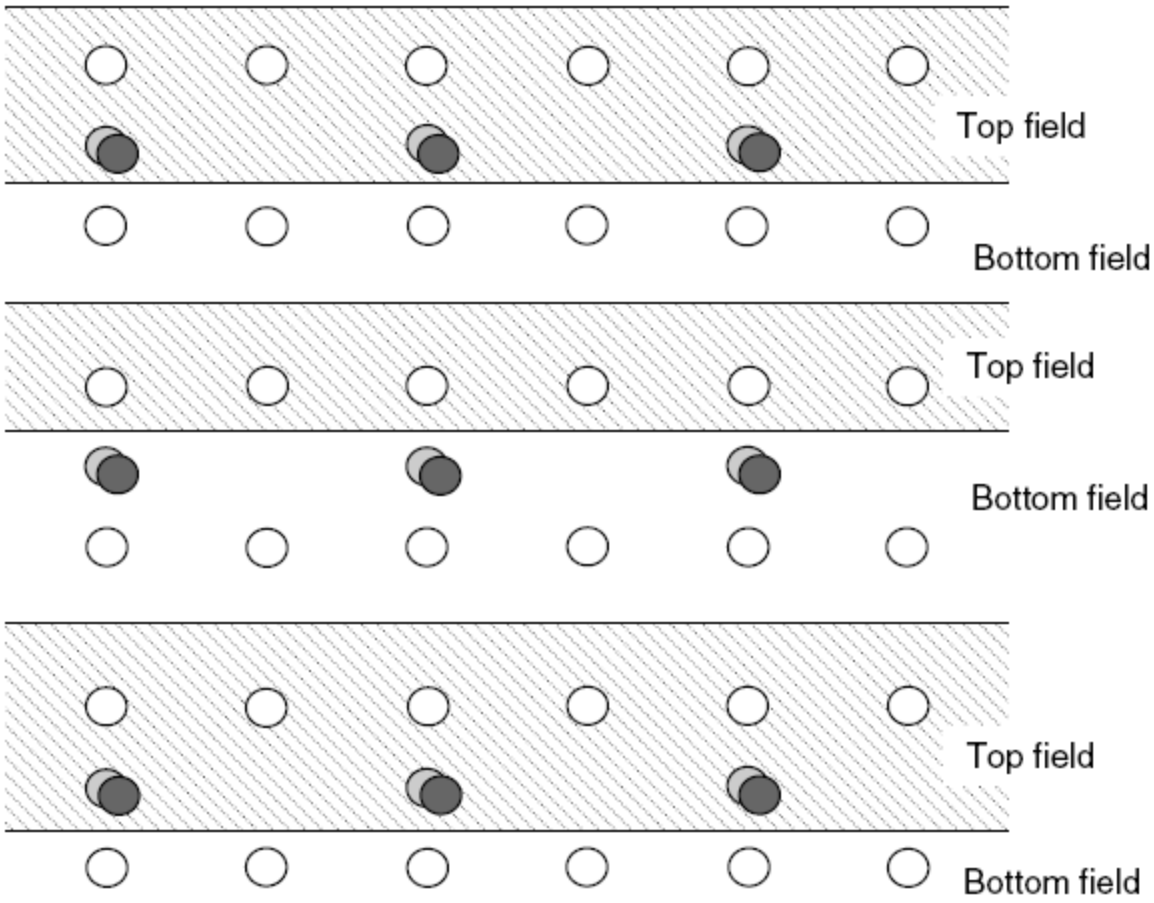
$$Y = 0.299R + 0.587G + 0.114B$$
$$Cb = 0.564(B - Y)$$
$$Cr = 0.713(R - Y)$$

Cr, Cg and Cb components

Sampling Formats

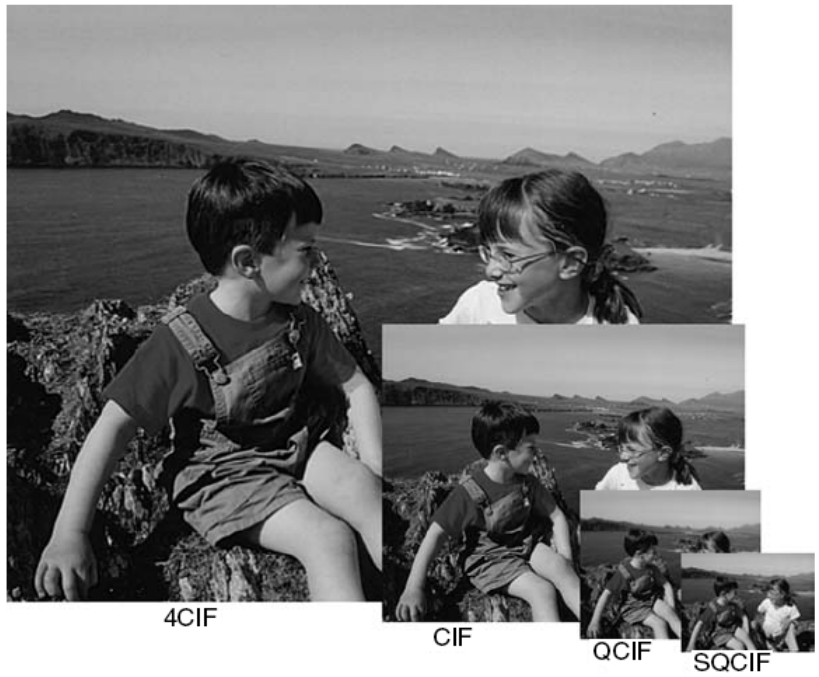


YCbCr 4:2:0 Samples



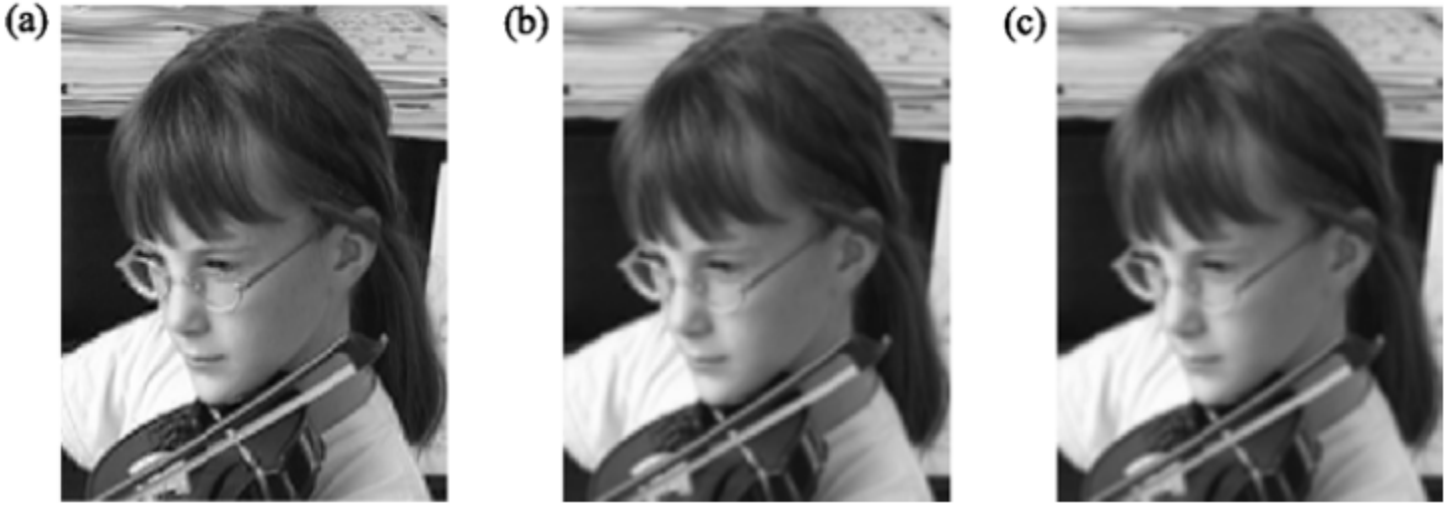
Video Formats

Format	Luminance resolution (horiz. × vert.)	Bits per frame (4:2:0, eight bits per sample)
Sub-QCIF	128 × 96	147456
Quarter CIF (QCIF)	176 × 144	304128
CIF	352 × 288	1216512
4CIF	704 × 576	4866048



Quality

- **Subjective Quality Measurement**
  - DSCQS (Double Stimulus Continuous Quality Scale)
- **Objective Quality Measurement**
  - PSNR (Peak Signal to Noise Ratio)



PSNR examples: (a) original; (b) 30.6 dB; (c) 28.3 dB

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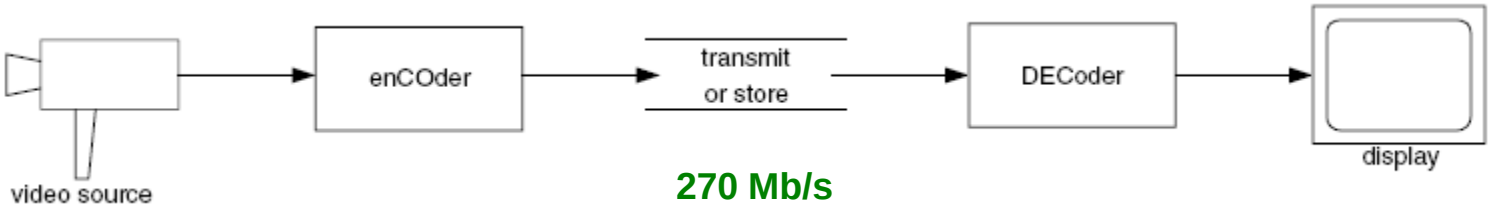
Video Compression - Purpose Of

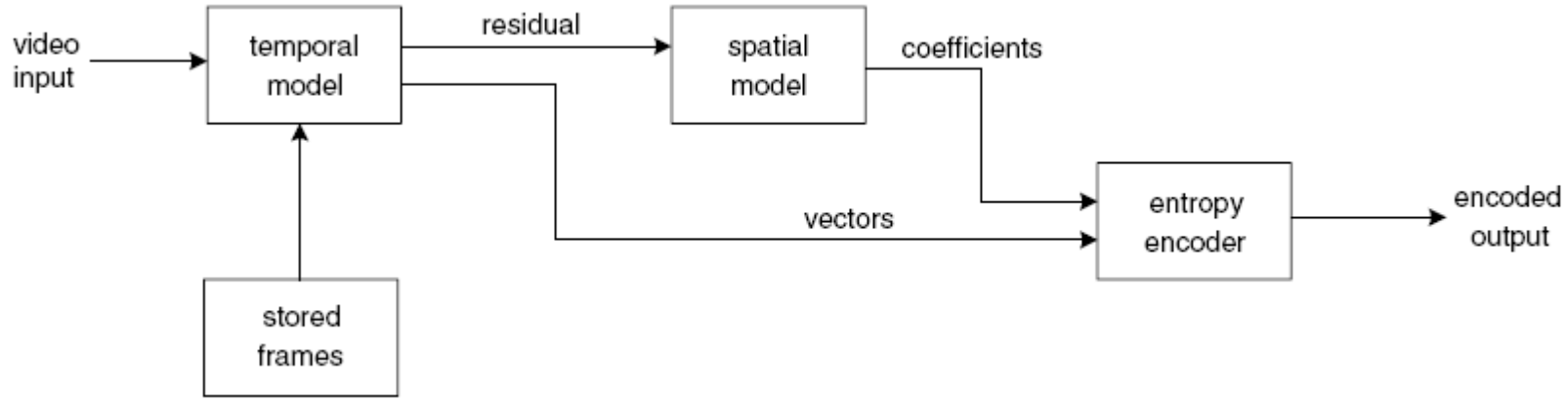
- **What is the purpose of video compression?**
  - Reduce the amount of data required to be transmitted to create the picture at the receiver.



270 Mb/s
1.485 Gb/s

Video Codec

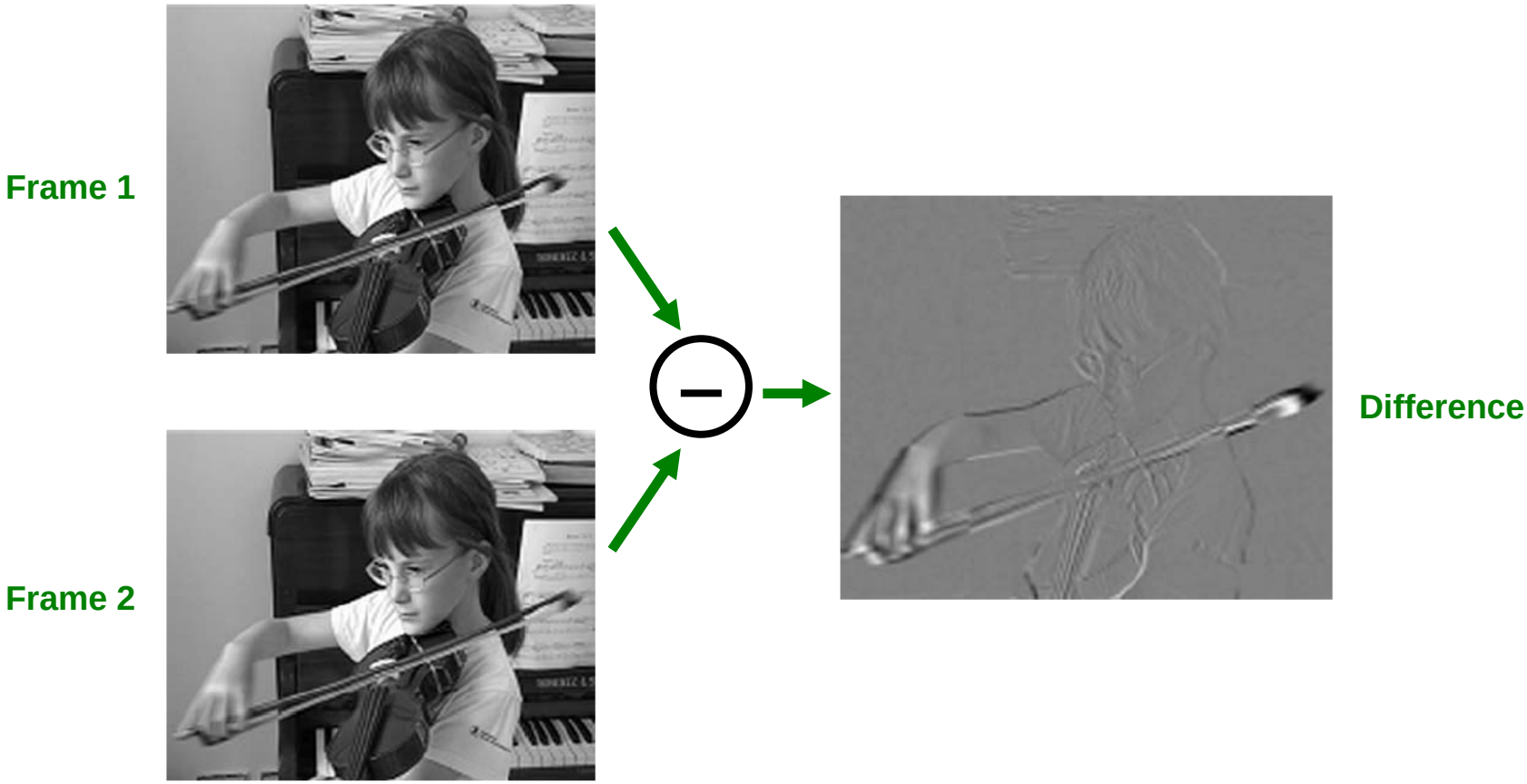
- Encodes a source image/video sequence into a compressed form
- Lossless and Lossy
- Three main functional units: *Temporal model, Spatial model, Entropy encoder*



Encoder Block Diagram

Temporal Model

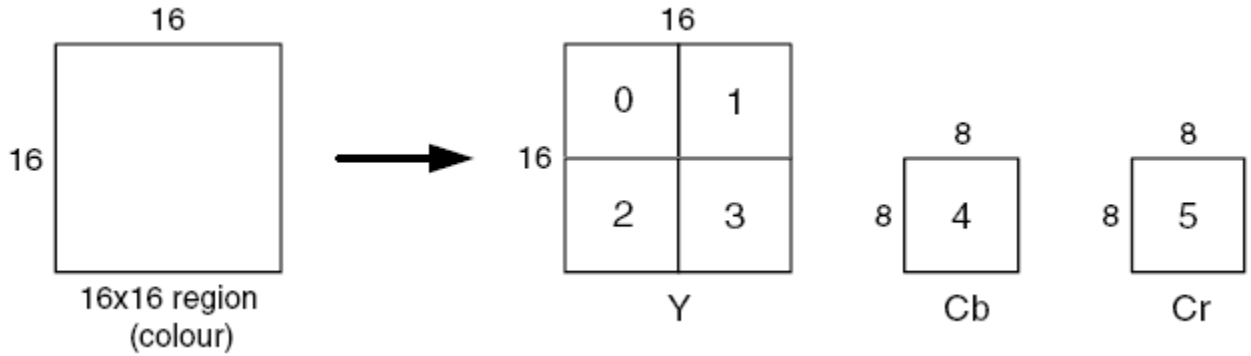
- Reduce redundancy between transmitted frames by forming a predicted frame and subtract this form the current frame



Macroblock

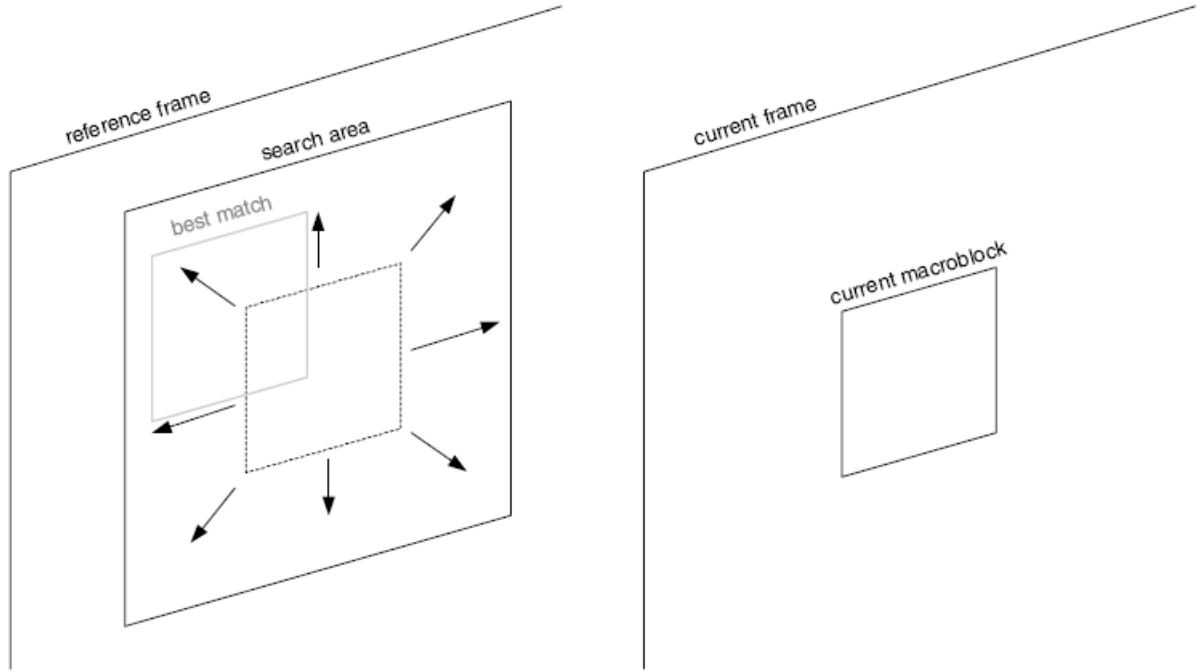
- represents a block of 16 by 16 pixels
- contains 4 Y (luminance) block, 1 Cb (blue color difference) block,

1 Cr (red color difference)



Motion Estimation & Compensation

- Motion Estimation – Sample region in a reference frame that closely matches the current macroblock
- Motion Compensation – The selected “best” matching region in the reference frame is subtracted from the current macroblock to produce a residual macroblock



Residual (Block Size)

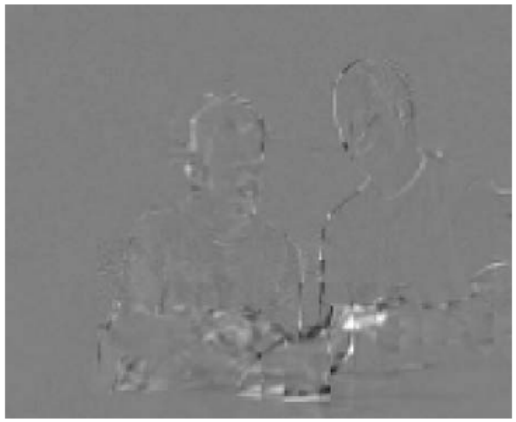
Frame 1

Frame 2

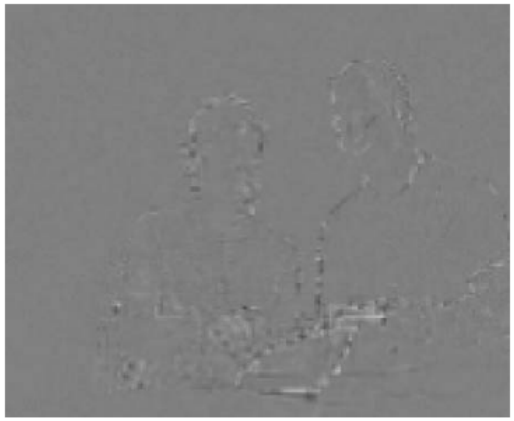
Residual
(No Motion)

Residual (Block Size)

Residual
(16x16 Block Size)

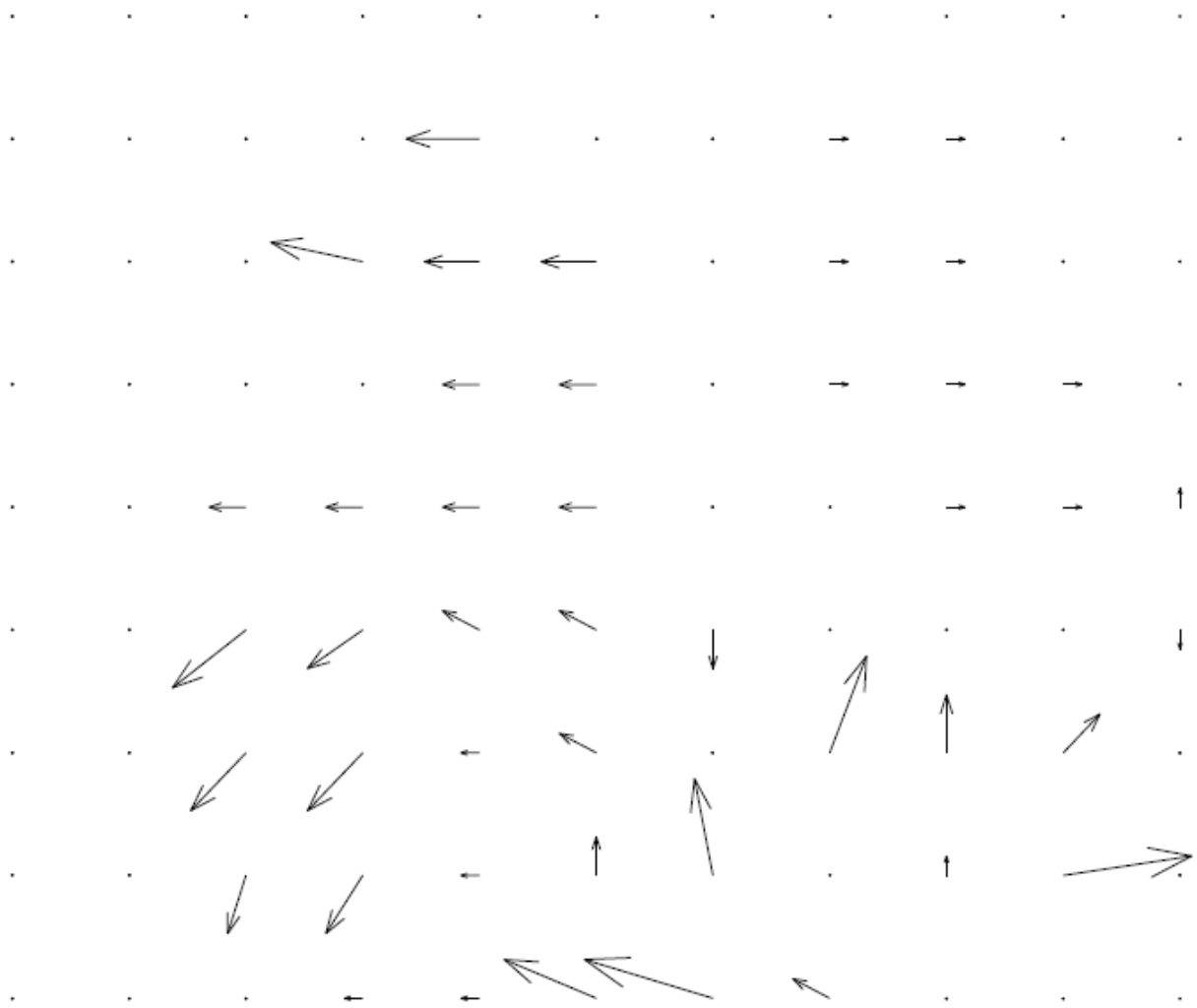


Residual
(8x8 Block Size)

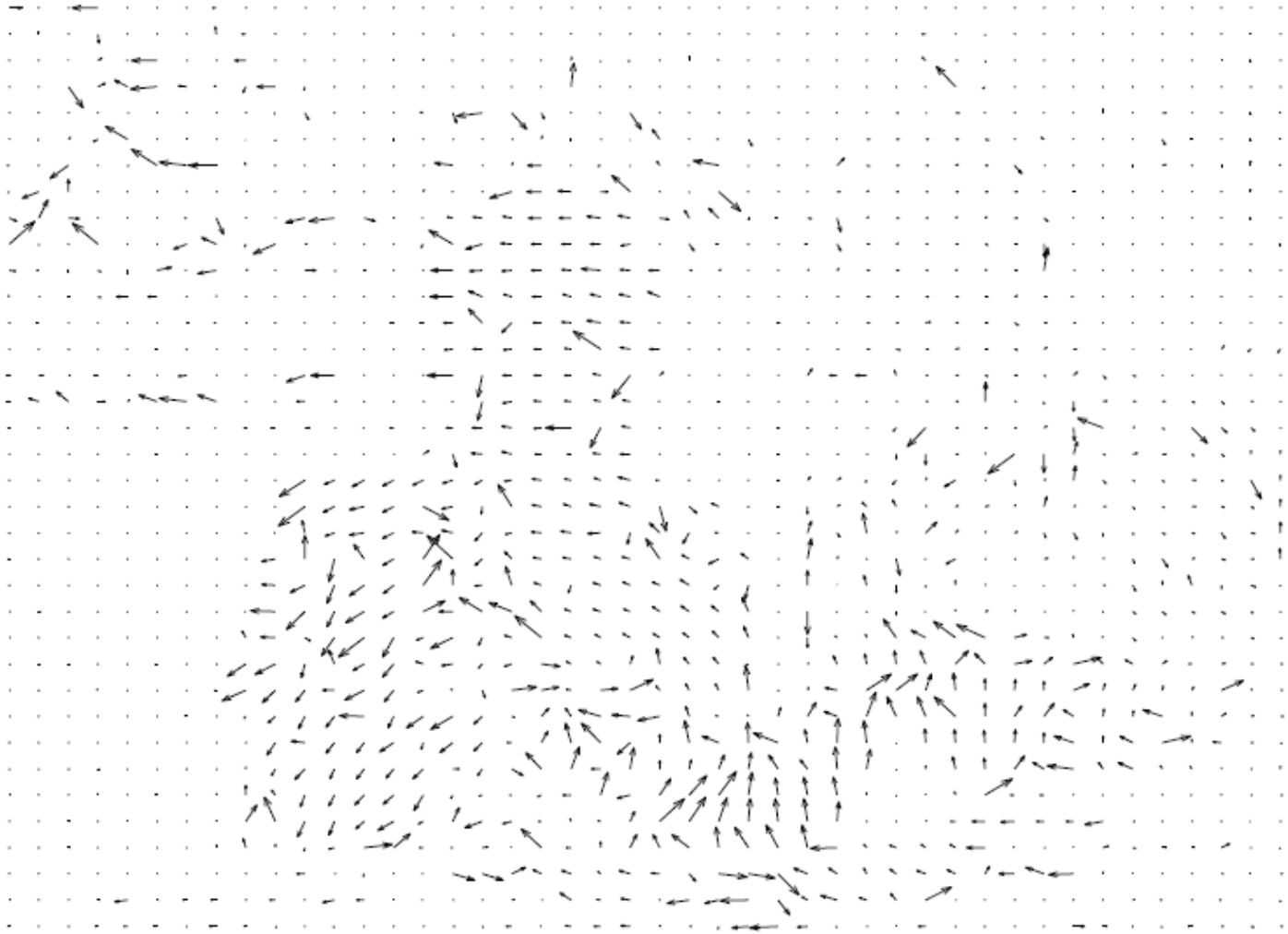


Residual
(4x4 Block Size)

Motion Vector 16x16



Motion Vector 4x4



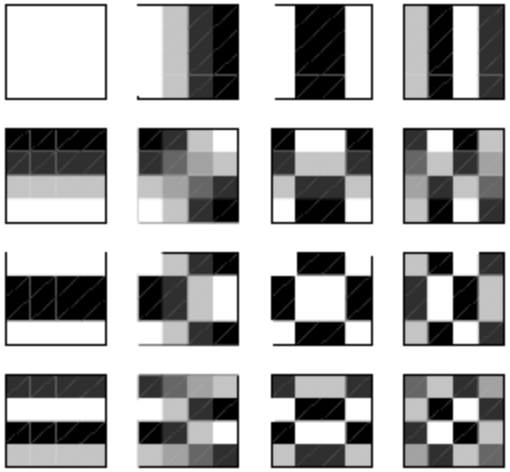
Transform Coding

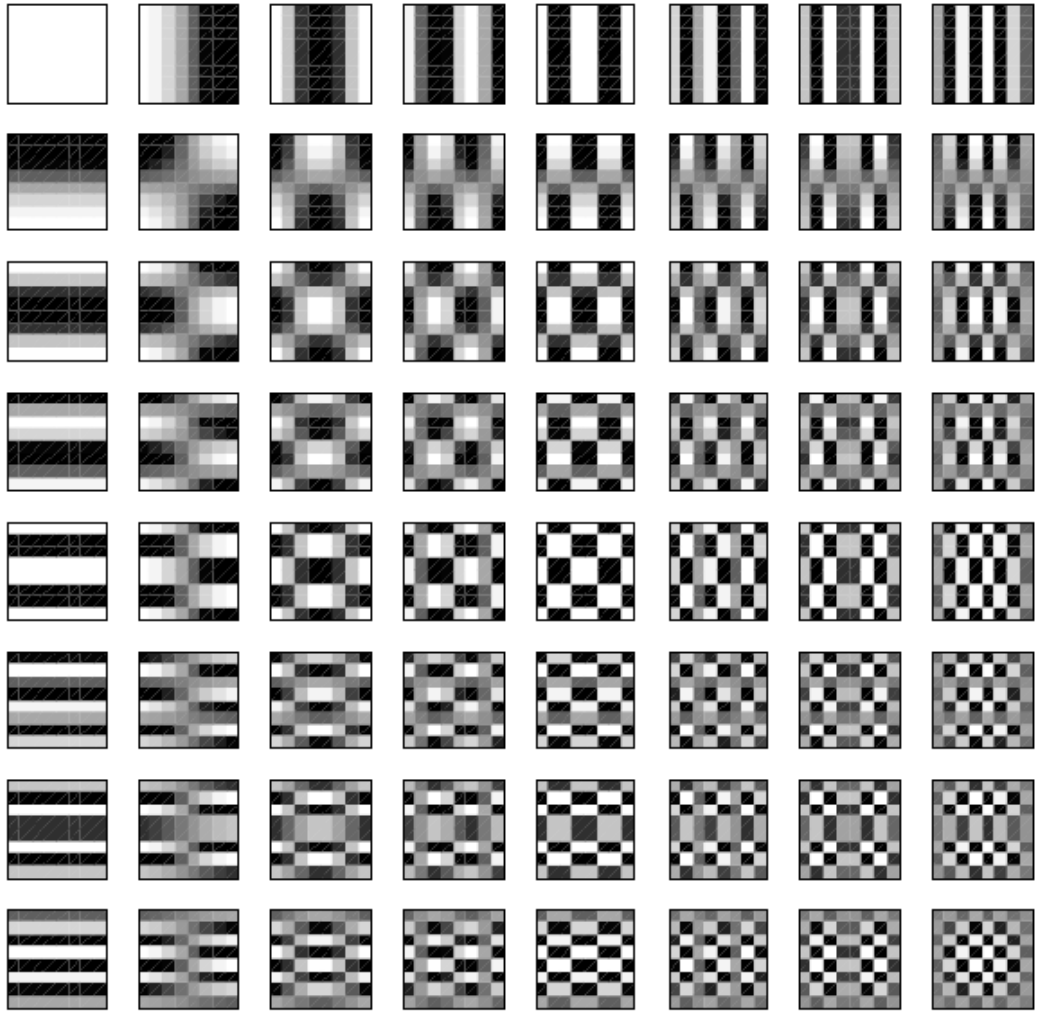
- **What is the purpose of “Transform” ?**

- **Block-Based Transform; KLT (Karhunen-Loeve Transform), SVD (Singular Value Decomposition), DCT (Discrete Cosine Transform)**

- **Image-Based Transform; DWT (Discrete Wavelet Transform)**

DCT Basis Patterns





DCT Coefficients

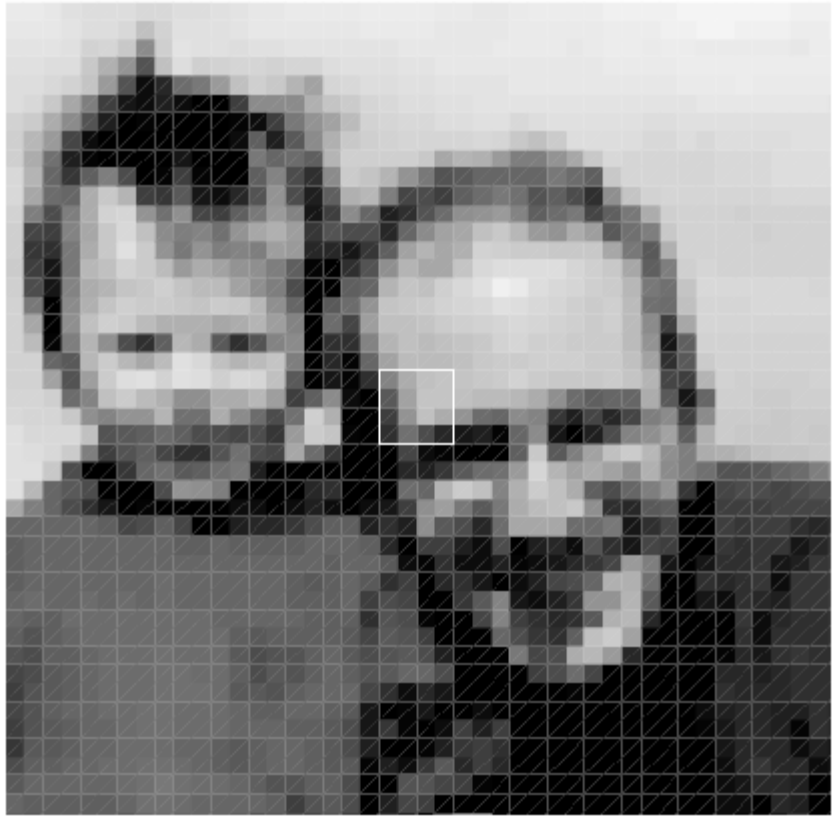


Image section 4x4 block

Original Block

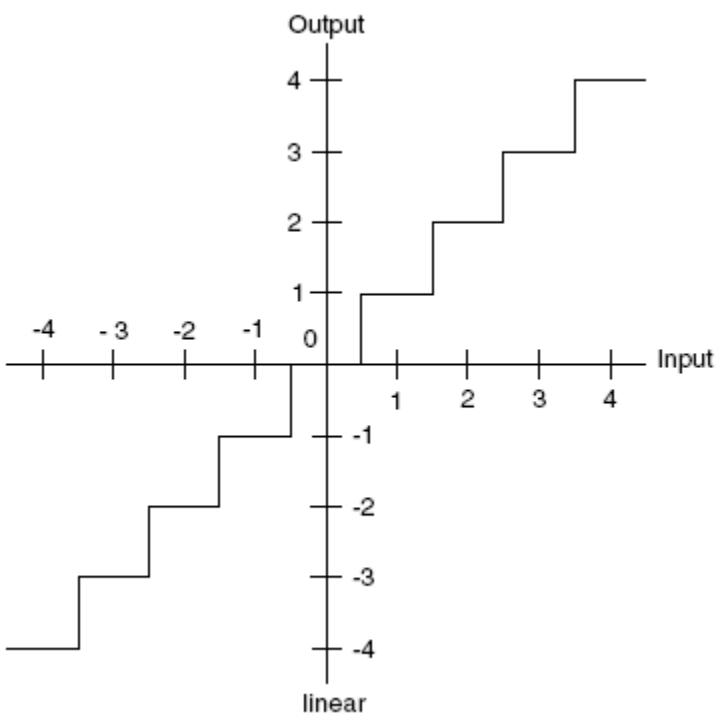
126	159	178	181
98	151	181	181
80	137	176	156
75	114	88	68

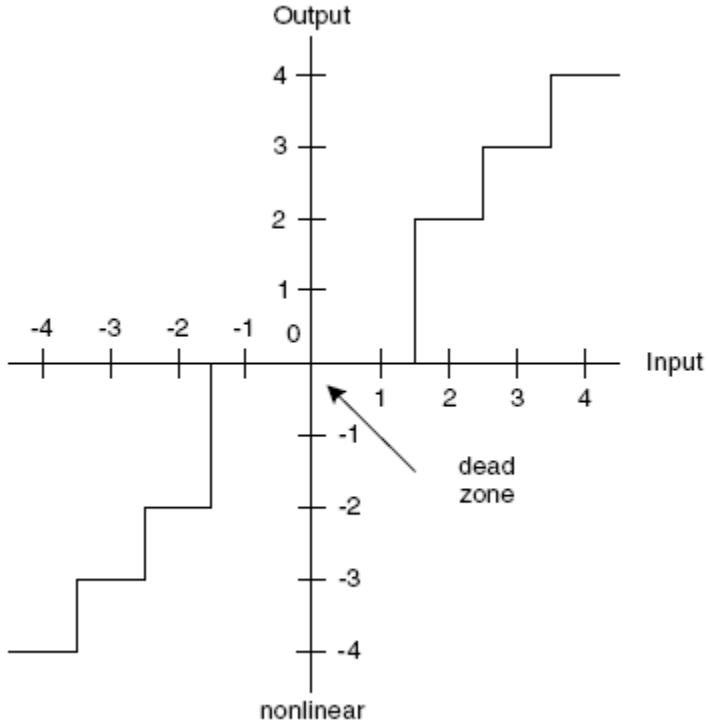
537.2	-76.0	-54.8	-7.8
-106.1	35.0	-12.7	-6.1
-42.7	46.5	10.3	-9.8
-20.2	12.9	3.9	-8.5

DCT Coefficients

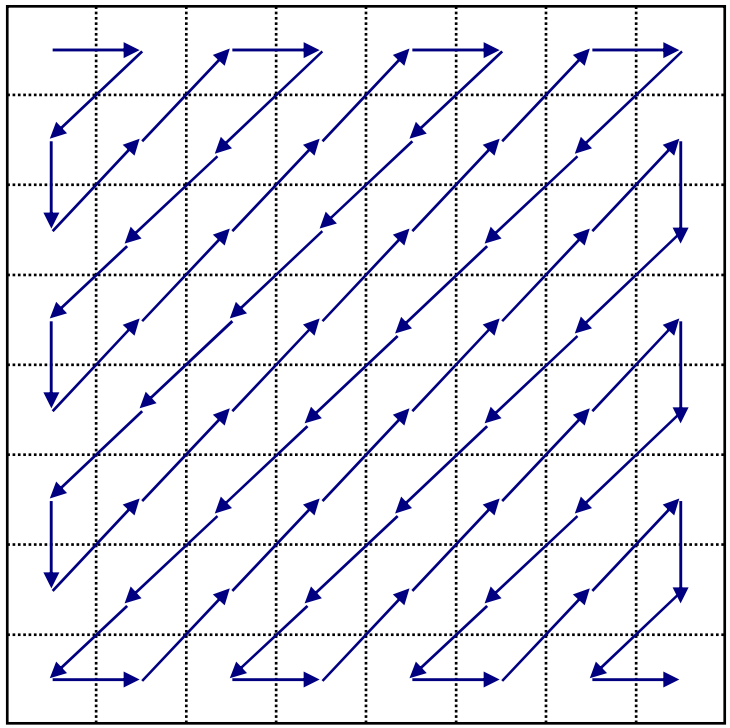
Quantization

- Usually made up of two parts: a forward quantizer FQ in the encoder and an ‘inverse quantizer’ in the decoder

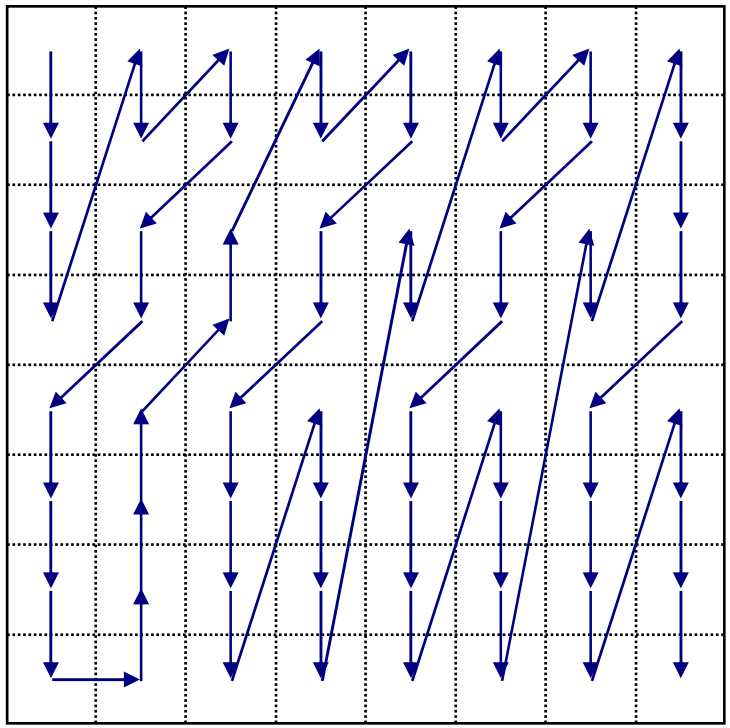




Scanning



Frame Block



Field Block

Entropy Coder

- **Converts as series of symbols representing elements of the video sequence into a compressed bitstream**
  - Predictive Coding
  - Variable-length Coding
    - Huffman Coding
  - Arithmetic Coding

Example

Frame F_n

Reconstructed reference Frame F_{n-1}

Residual F_n - F_{n-1}

16 x 16 Motion Vector

Example

MPEG-2

MPEG-4

Example

MPEG-4

H.264

Applications

Application	Requirements	MPEG-4 Profiles*	H.264 Profiles
Broadcast television	Coding efficiency, reliability (over a 'controlled' distribution channel), interlace, low-complexity decoder	ASP	Main
Streaming video	Coding efficiency, reliability (over an 'uncontrolled' packet-based network), scalability	ARTS or FGS	Extended
Video storage and playback (e.g. DVD)	Coding efficiency, interlace, low-complexity decoder	ASP	Main
Videoconferencing	Coding efficiency, reliability, low latency, low-complexity encoder and decoder	SP	Baseline
Mobile video	Coding efficiency, reliability, low latency, low-complexity encoder and decoder, low power consumption	SP	Baseline
Studio distribution	Lossless or near-lossless, interlace, efficient transcoding	Studio	Main

Thank You
For Your Attendance