Video Compression

- Chapter 8C

Evolution of Video Mediums

- Film
  - Invented in late 18th century, still widely used today

- VHS
  - Released in 1976, rapidly disappearing

Evolution of Video Mediums

- DVD
  - Released in 1996, dominant for over a decade
- Hard Disk
  - Around for many years, only recently widely used for storing video (helped by explosion of Internet)

Video Encoding/Compression

- Need to **convert** analog video to digital format
- New digital video cameras have on-board hardware to **capture** directly to digital format
- Once video is in digital format, it makes sense to **compress** it
- Similar to image compression, we want to store video data as efficiently as possible
- Again, we want to both maximize **quality** and minimize **storage space** and processing resources

Definitions

- **Bitrate**
  - Information stored/transmitted per unit time
  - Usually measured in Mbps (Megabits per second)
  - Ranges from > 1 Mbps to < 40 Mbps
- **Resolution**
  - Number of pixels per frame
  - Ranges from 160x120 to 1920x1080
- **FPS (frames per second)**
  - Usually 24, 25, 30, or 60
  - Don’t need more because of limitations of the human eye

Scan Types

- Interlaced scan
  - Odd and even lines displayed on alternate frames
- Progressive scan
  - Display all lines on each frame

Leonardo Chiariglione

- Moving Picture Experts Group
- Established in 1988
- Committee of experts that develops video encoding standards

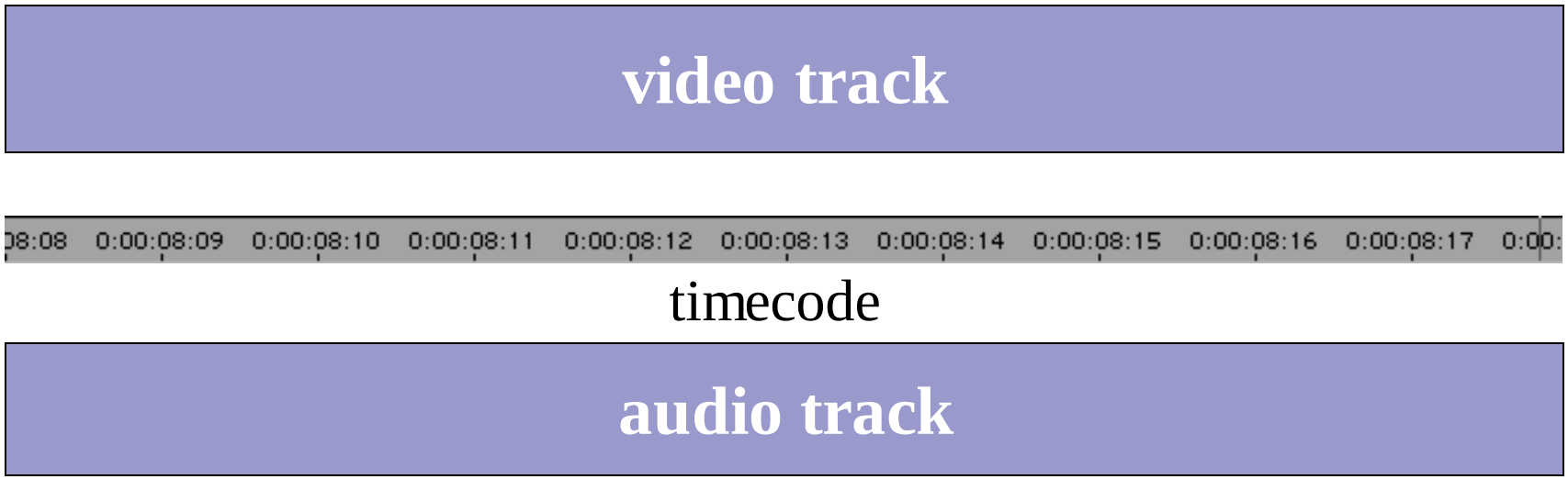
Evolution of MPEG Video Standards

- MPEG-1
  - Initial audio/video compression standard
  - Used by VCD's
  - MP3 = MPEG-1 audio layer 3
  - Target of 1.5 Mb/s bitrate at 352x240 resolution
- MPEG-2
  - Current de facto standard, widely used in DVD and Digital TV

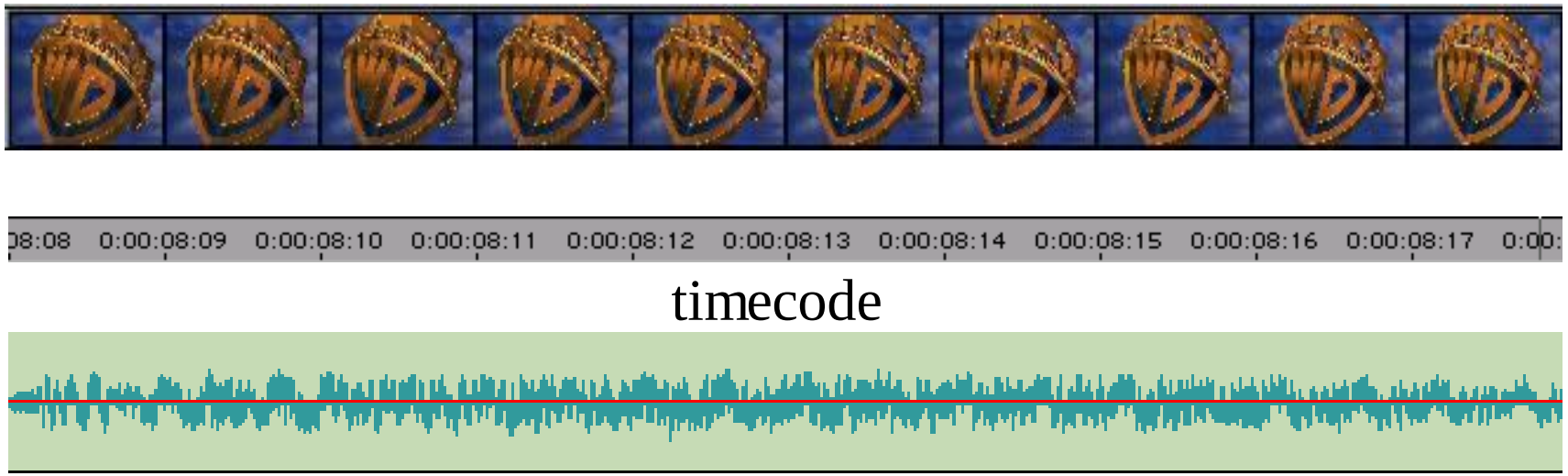
Evolution of MPEG Video Standards

- MPEG-3
  - Originally developed for HDTV, but abandoned when MPEG-2 was determined to be sufficient
- MPEG-4
  - Includes support for AV “objects”, 3D content, low bitrate encoding

What is a Movie?

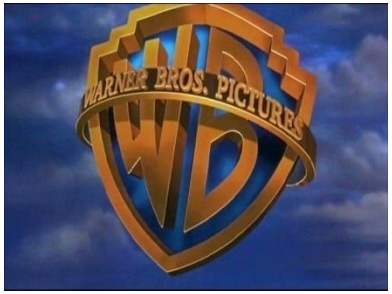


What is a Movie?



Encoding & Decoding

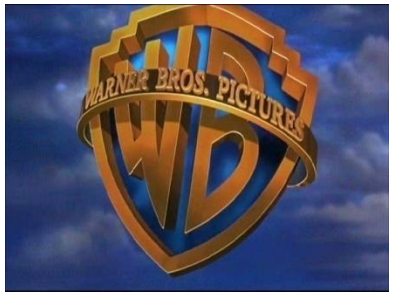
Encoder



100111010011

Decoder

100111010011

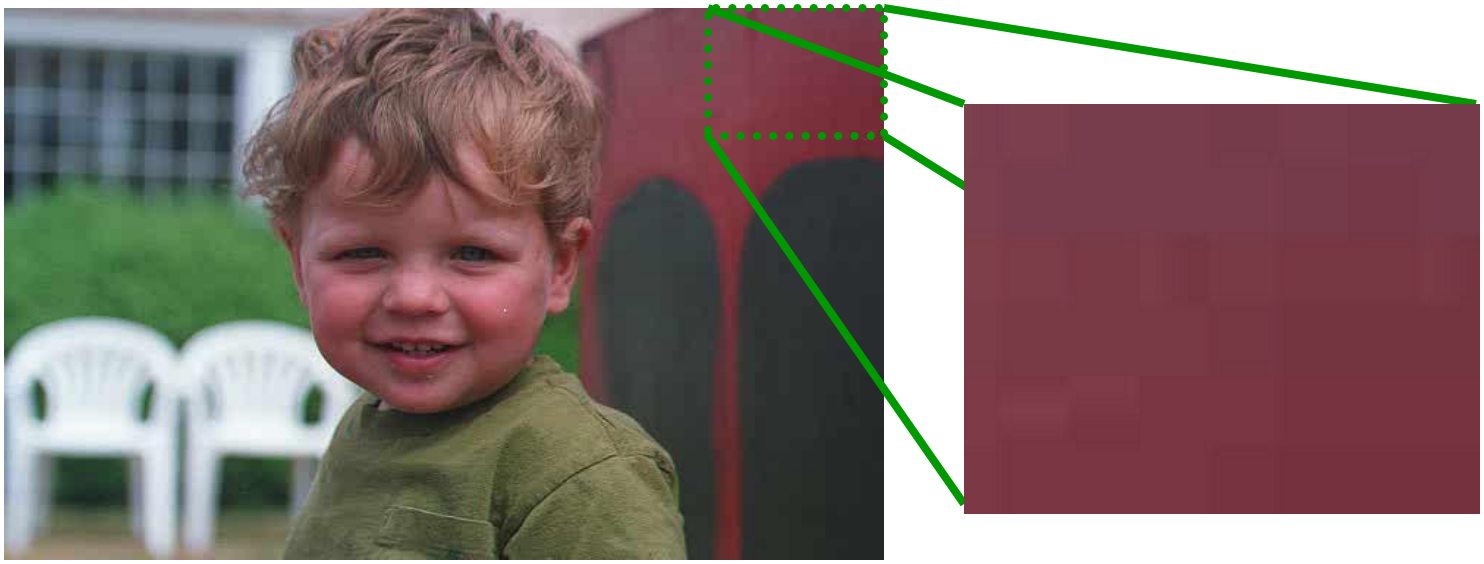


MPEG Compression

- Takes advantage of
  - Spatial Redundancy
  - Temporal Redundancy

Spatial Redundancy

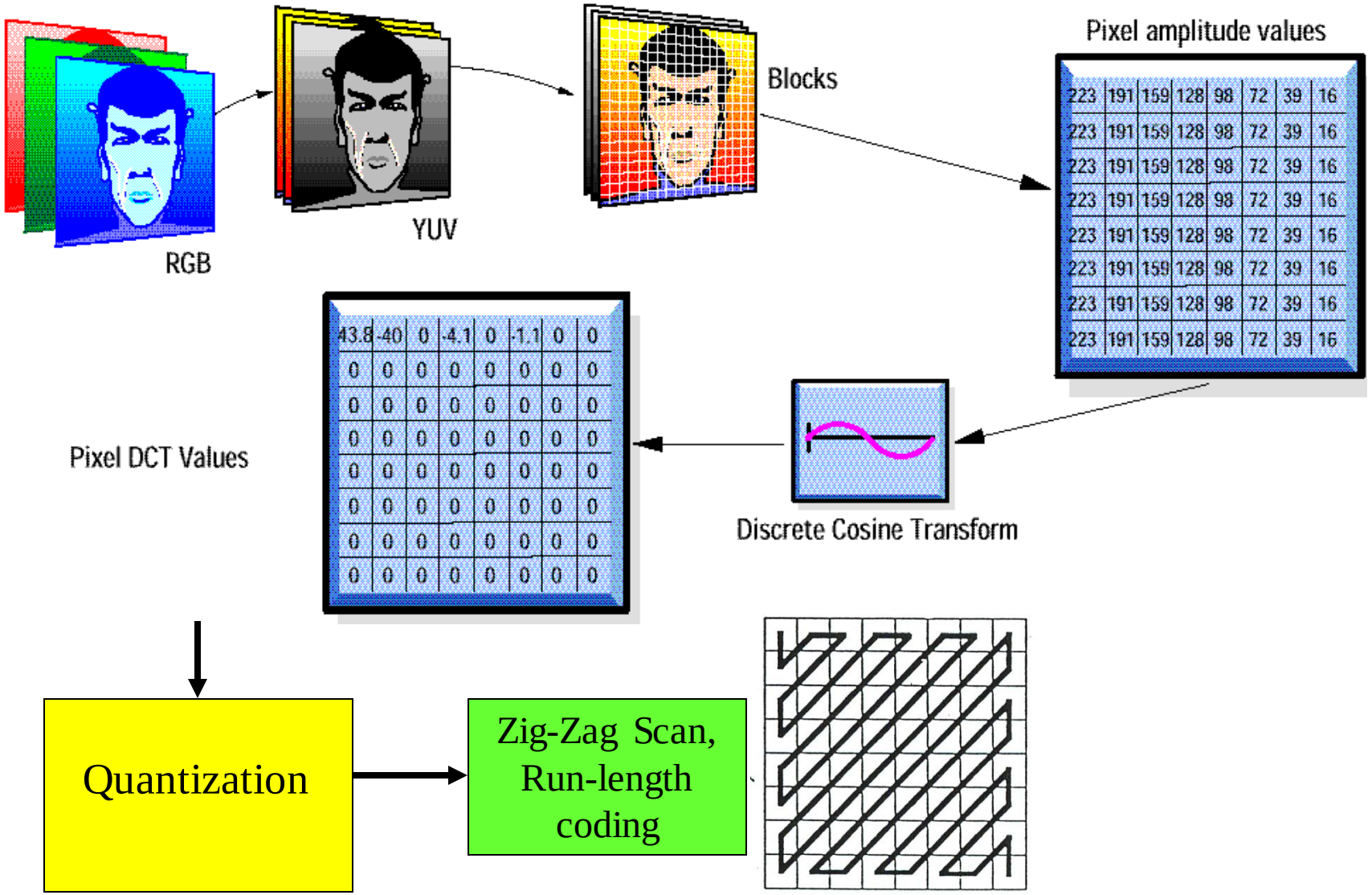
- Take advantage of similarity among most neighboring pixels



Spatial Redundancy Reduction

- RGB to YUV
  - Less information required for YUV (humans less sensitive to chrominance)
- Macro Blocks & Blocks
  - Macro block (16x16) – Block 8x8
- Discrete Cosine Transformation (DCT)
  - Based on Fourier analysis where represent signal as sum of sine's and cosine's
  - Concentrates on higher-frequency values
  - Represent pixels in blocks with fewer numbers
- Quantization
  - Coefficients are divided by quantization values (given by the JPEG group) and then rounded to the next integer value
- Run-Length Encoding
  - Compress

Spatial Redundancy Reduction



Temporal Redundancy

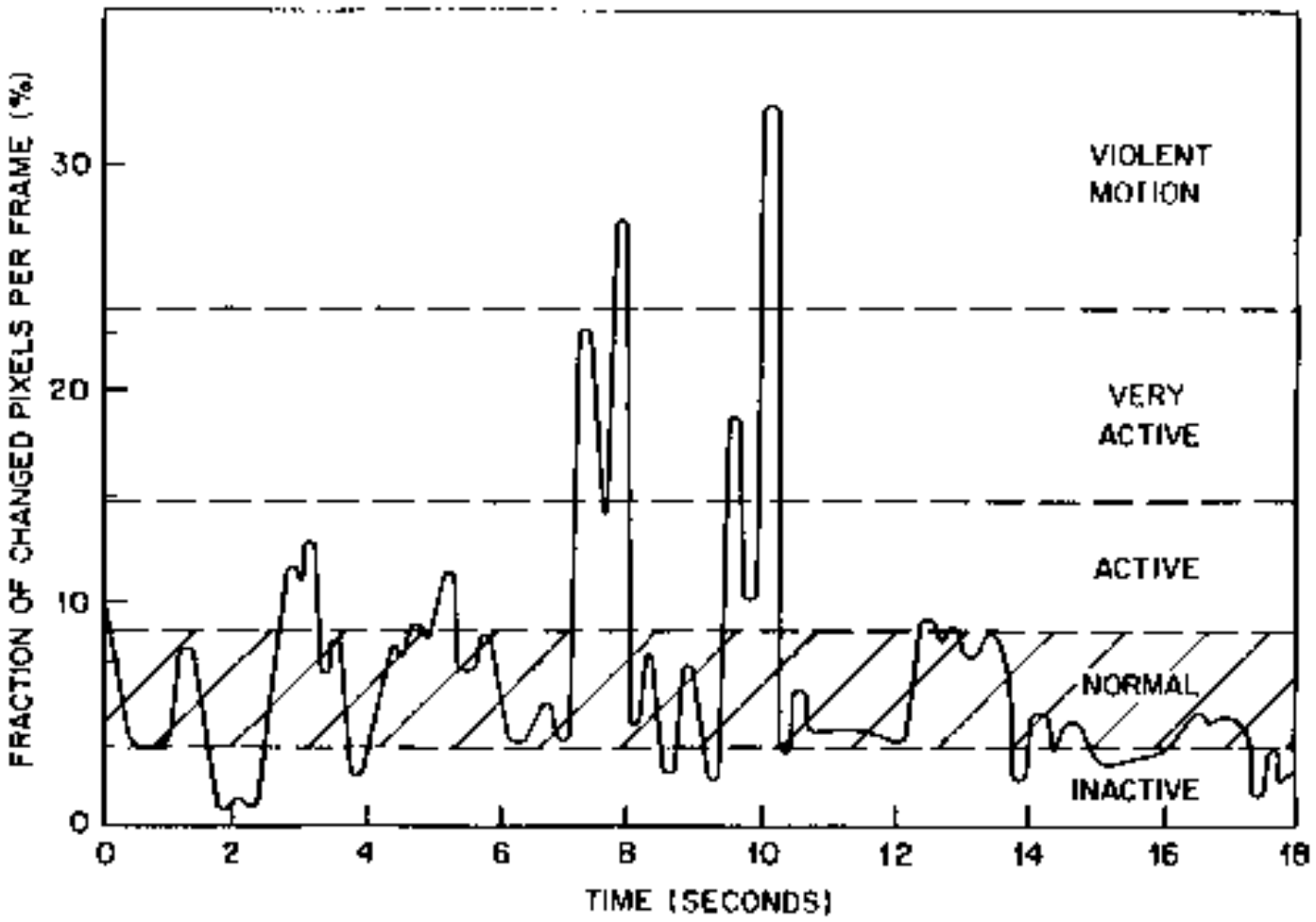
- Take advantage of similarity between successive frames

950

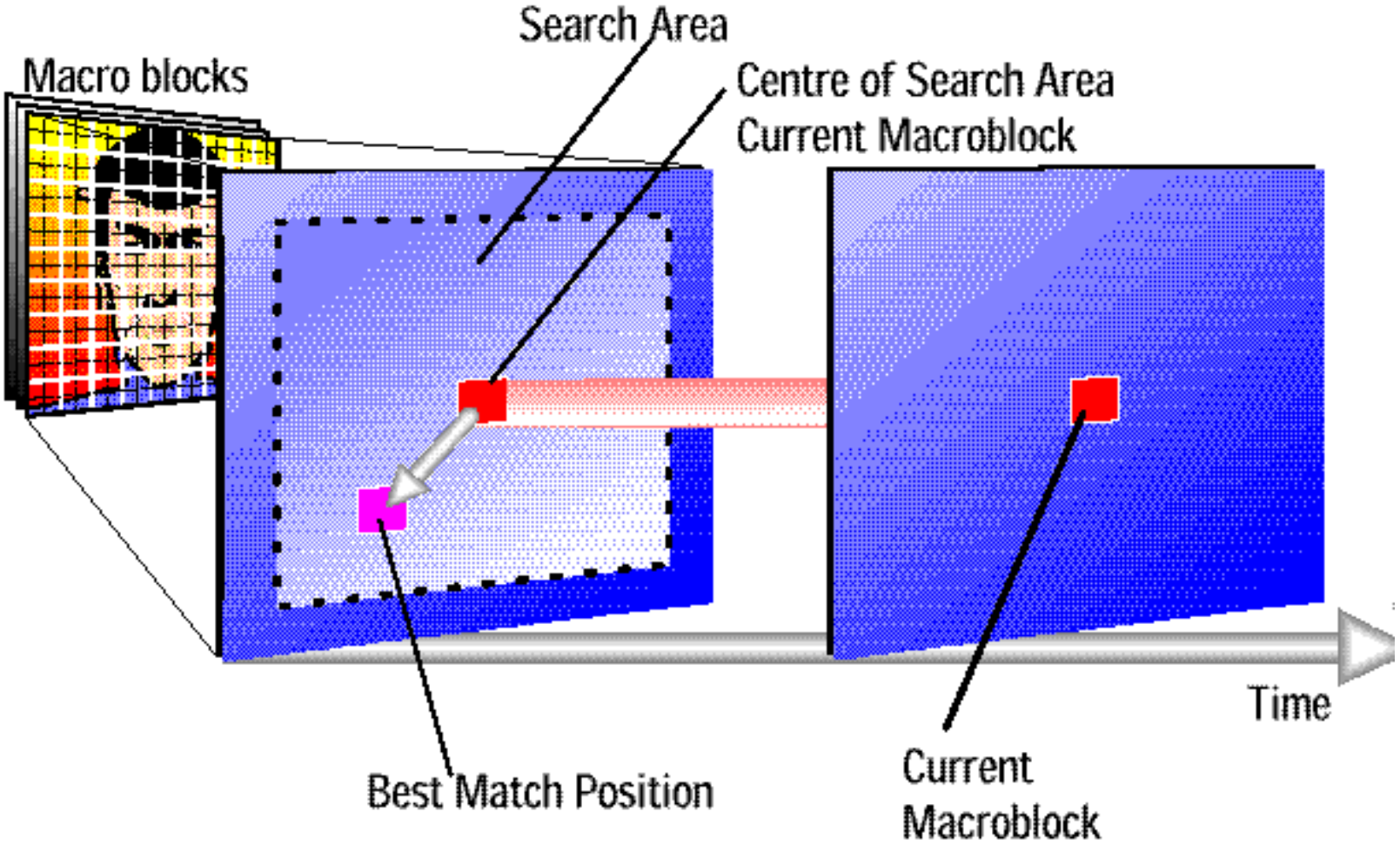
951

952

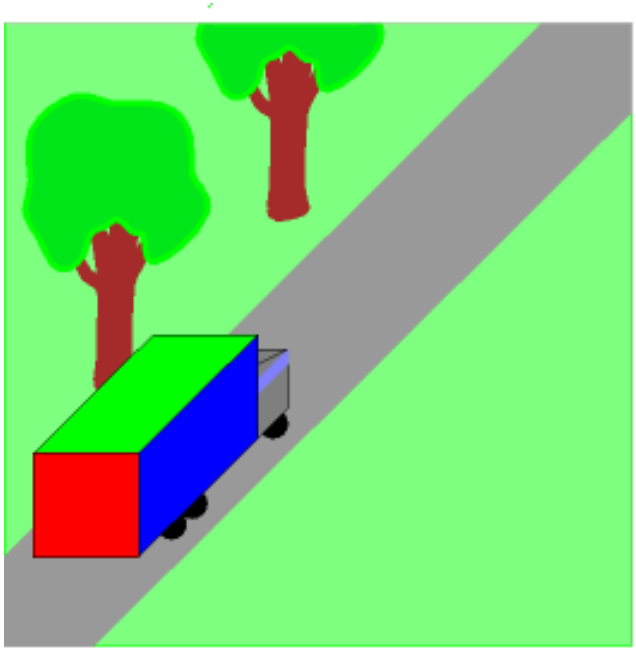
Temporal Activity



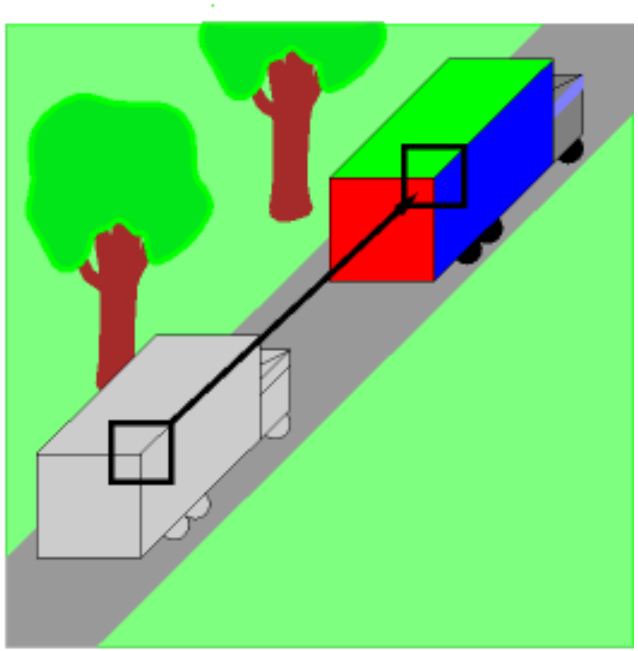
Temporal Redundancy Reduction



Temporal Redundancy Reduction

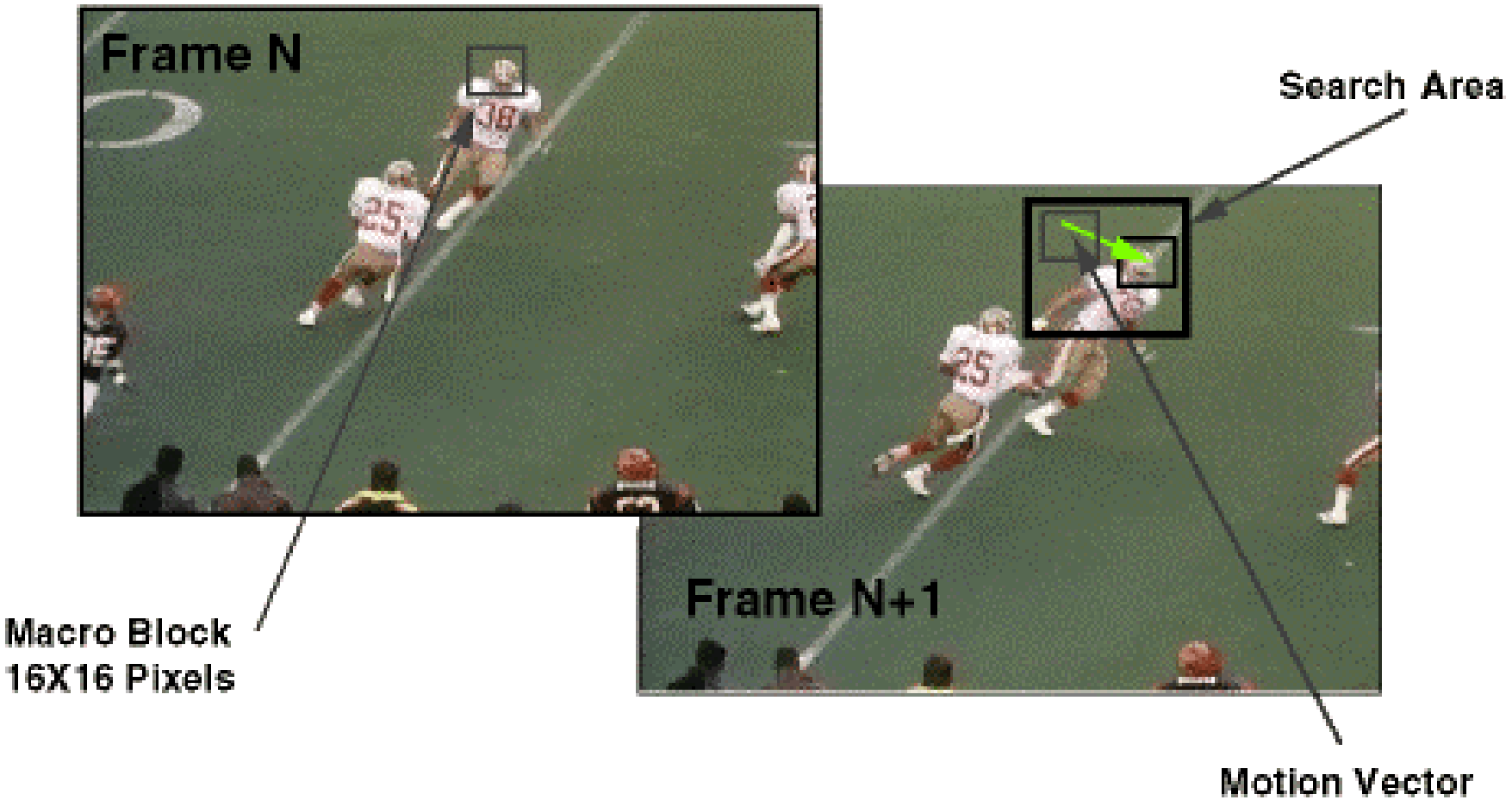


Picture 1



Picture 2

Temporal Redundancy Reduction

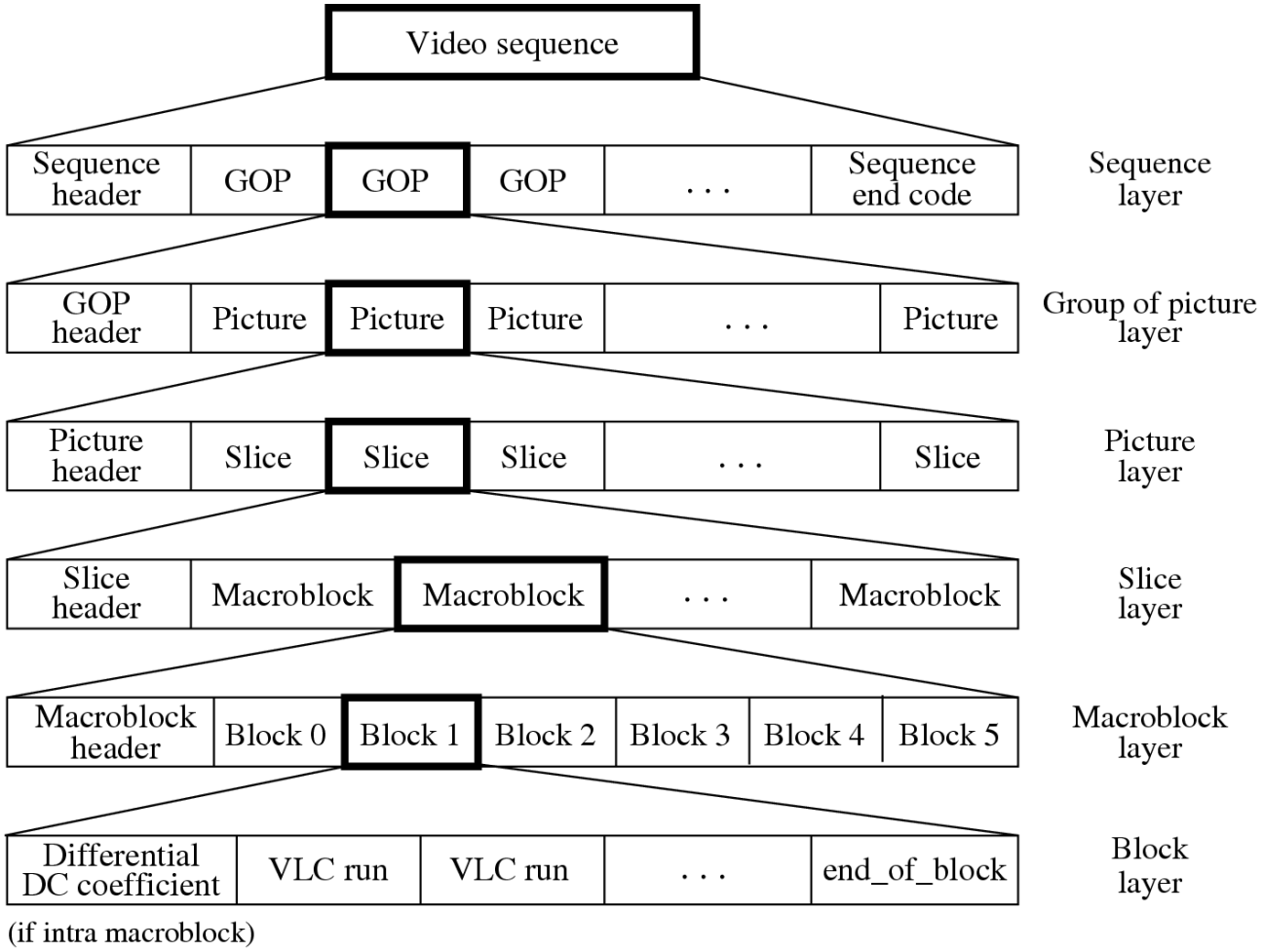


Temporal Redundancy

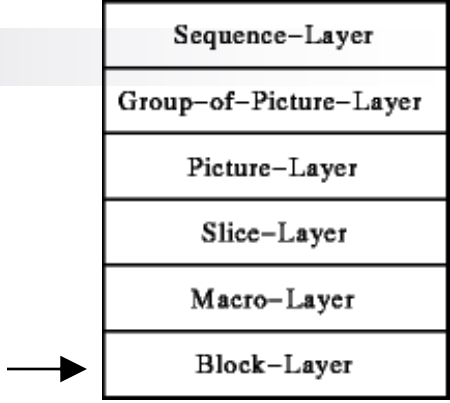
Many scene changes vs. few scene changes

High Motion

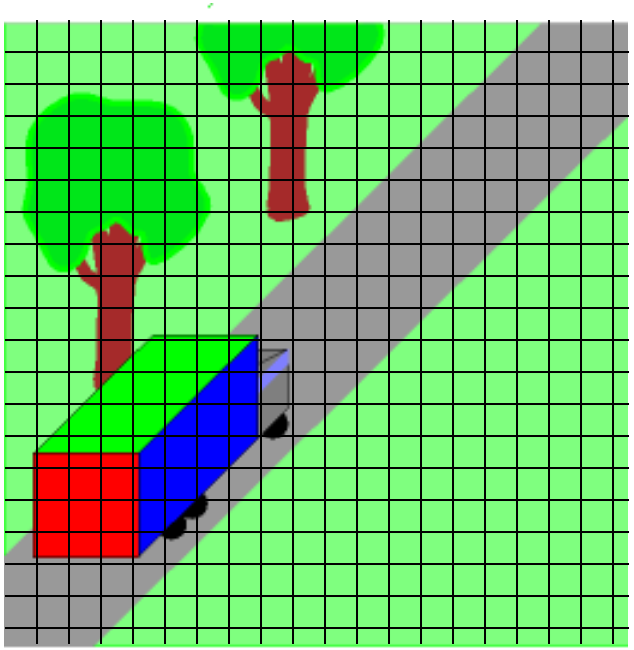
Layers of MPEG1 Video bitstream



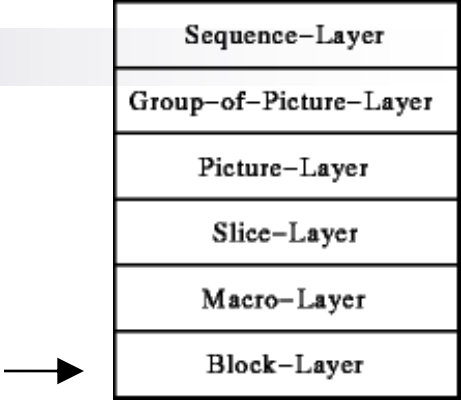
The Block Layer



- Picture is divided in 8x8 blocks
- The blocks are processed independent from each other
  - DCT
  - Quantization



DCT & Quantization



- Matrix of DCT-coefficients
- Coefficients are divided by quantization

values and then rounded to the next

integer value

DCT & Quantization

Sequence–Layer
Group–of–Picture–Layer
Picture–Layer
Slice–Layer
Macro–Layer
Block–Layer

-415	-29	-62	25	55	-20	-1	3
7	-21	-62	9	11	-7	-6	6
-46	8	77	-25	-30	10	7	-5
-50	13	35	-15	-9	6	0	3
11	-8	-13	-2	-1	1	-4	1
-10	1	3	-3	-1	0	2	-1
-4	-1	2	-1	2	-3	1	-2
-1	-1	-1	-2	-1	-1	0	-1

DC co-efficient

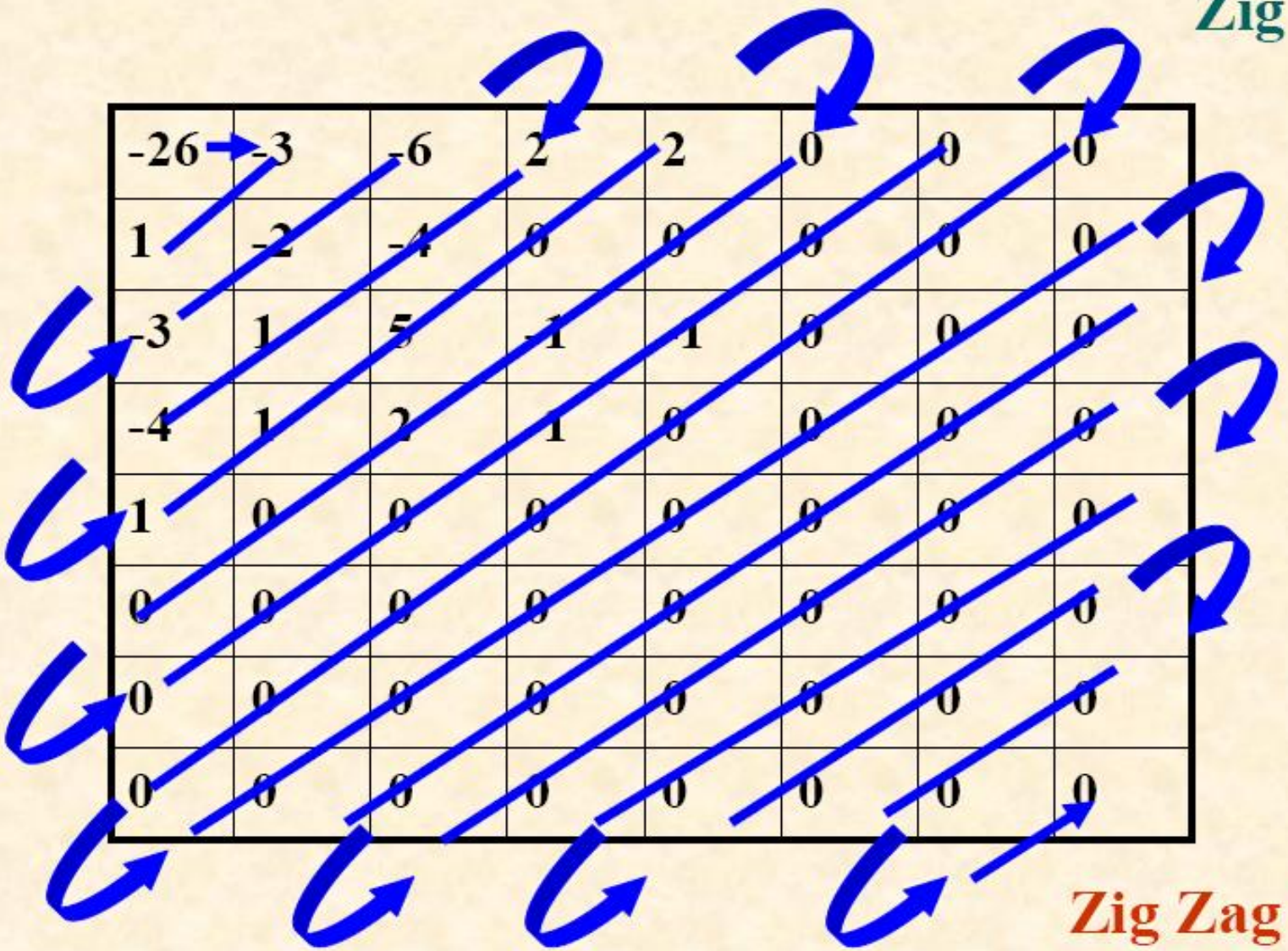
Quantization table

Divided by

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

Quantized co-efficients

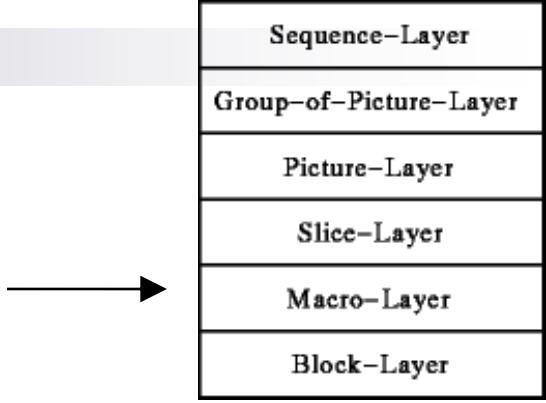
Zig zag scan

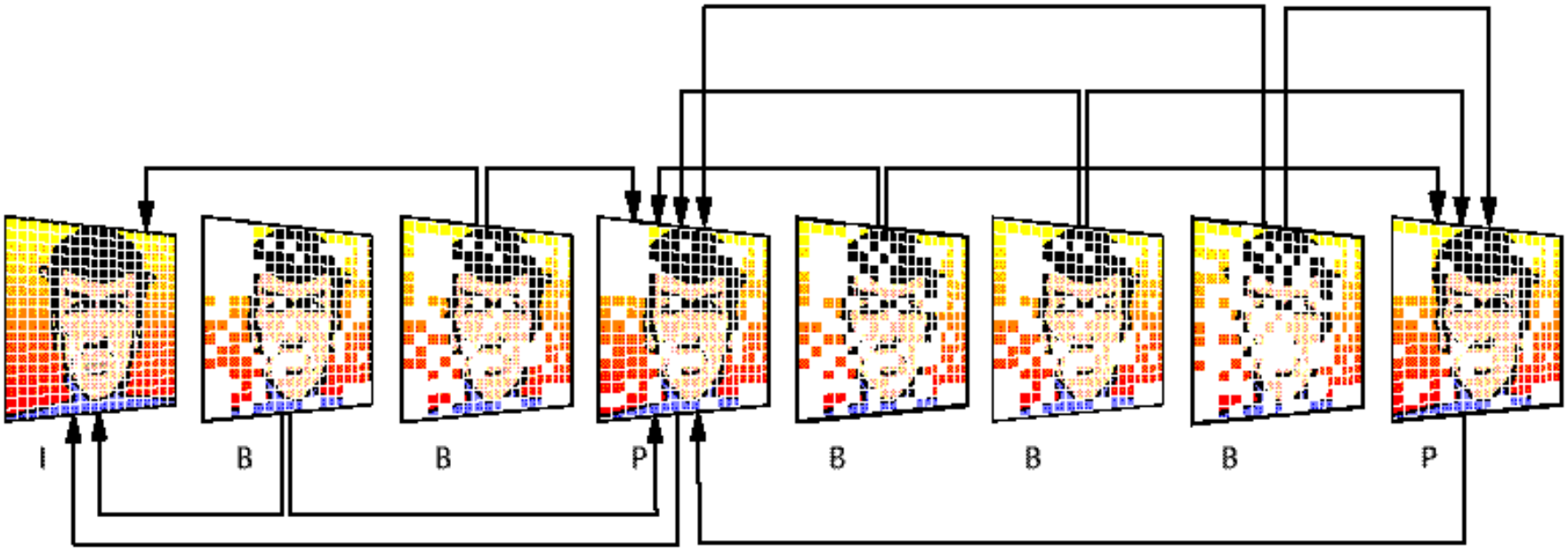


Zig Zag Scan o/p

-26 -3 1 -3 -2 -6 2 -4 1 -4 1 1 5 0 2 0 0 -1 2 0 0 0 0 0 1 1 EOB

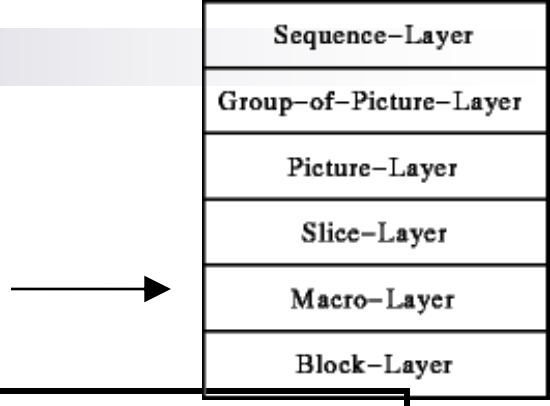
The Macro Block Layer

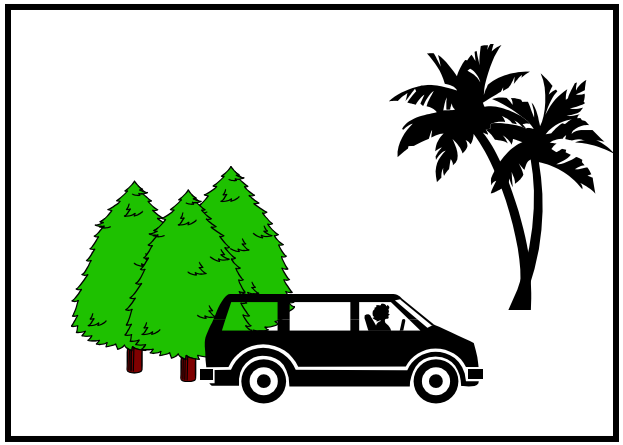




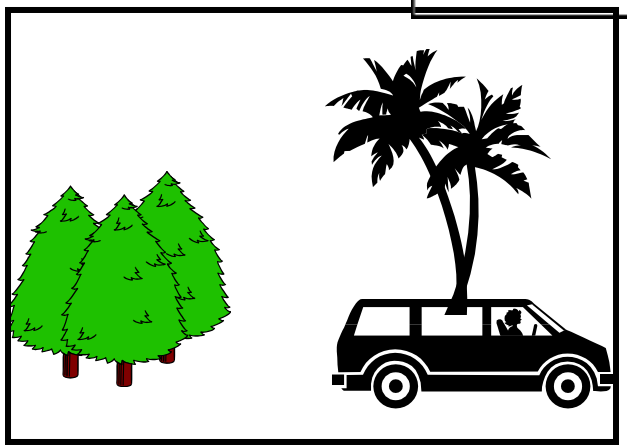
- *I* frames are independently encoded
- *P* frames are based on previous frames
- *B* frames are based on previous and following frames

The Macro Block Layer

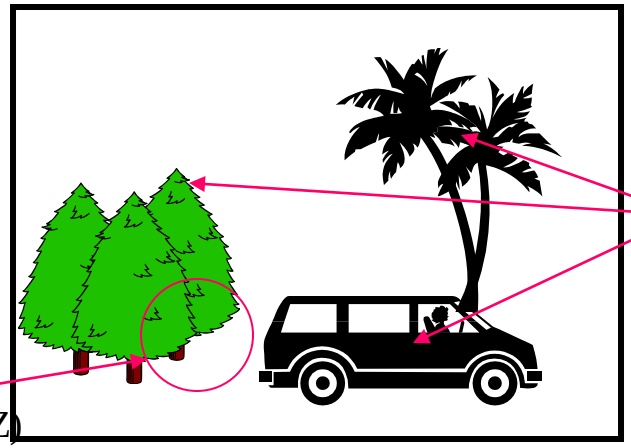




X



Z

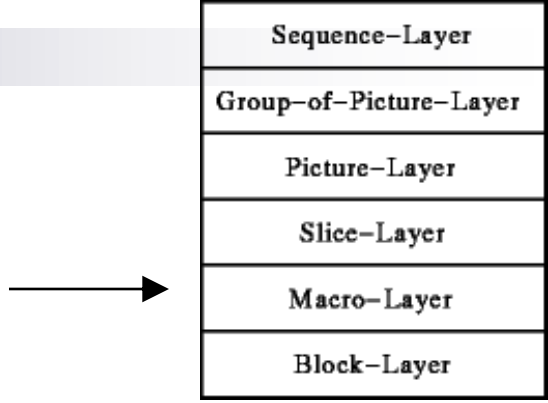


Available from earlier frame (X)

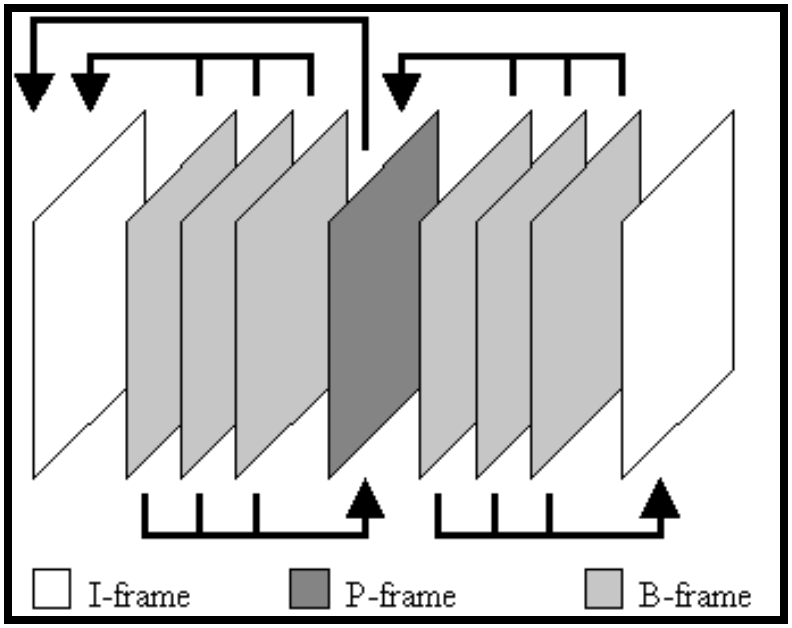
Available from later frame (Z)

Y

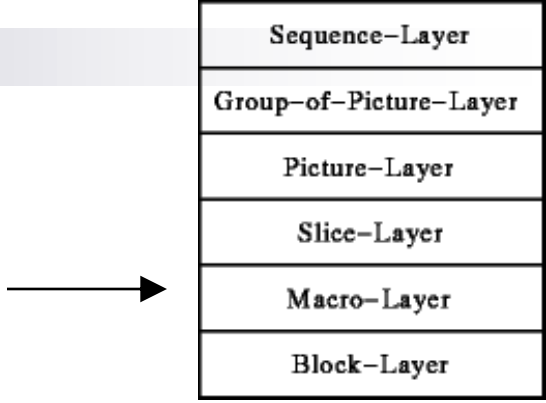
The Macro Block Layer



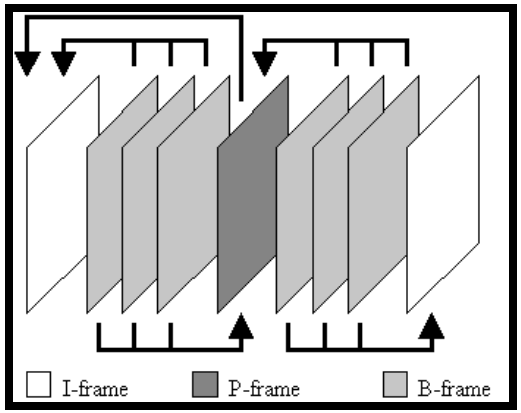
- I – Frame, P – Frame or B – Frame?



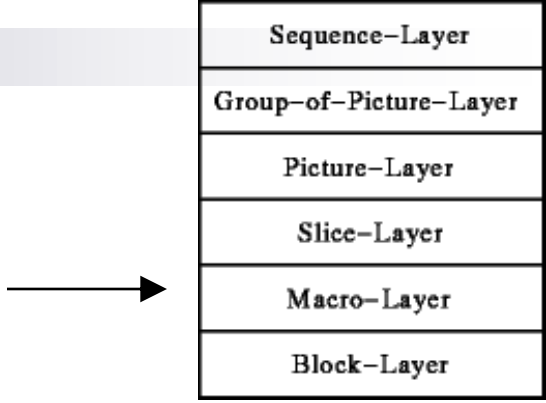
The Macro Block Layer



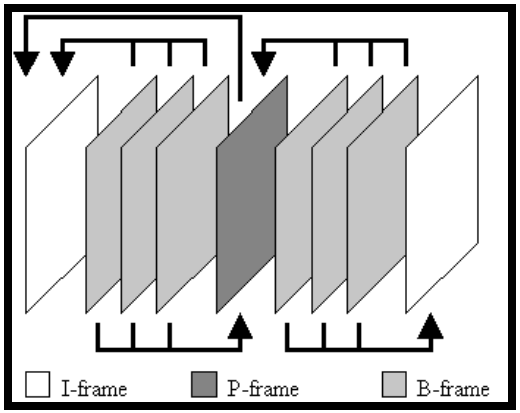
- I – Frames:
  - Intra coded image
  - Highest amount of data
  - Coding is very similar to a JPEG picture
  - Can be processed independent from other frames



The Macro Block Layer



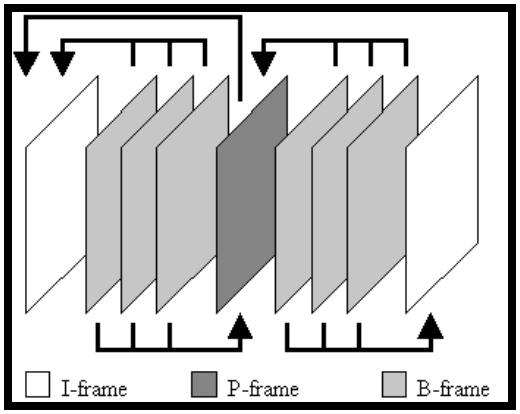
- P – Frames:
  - Predicted image
  - Medium amount of data
  - Difference to some previous frame is stored



Sequence–Layer
Group–of–Picture–Layer
Picture–Layer
Slice–Layer
Macro–Layer
Block–Layer

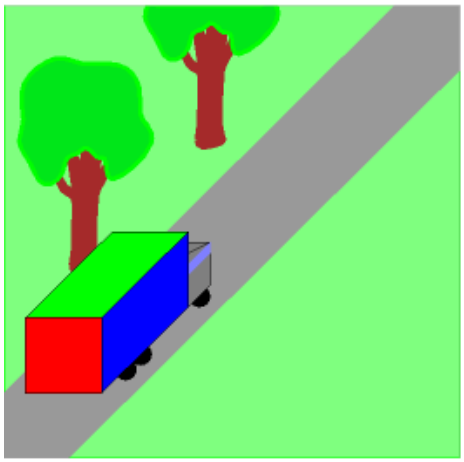
The Macro Block Layer

- B – Frames:
  - Bi-directionally interpolated image
  - Lowest amount of data
  - Most frequent type of frame
  - Depend on the previous or following frames

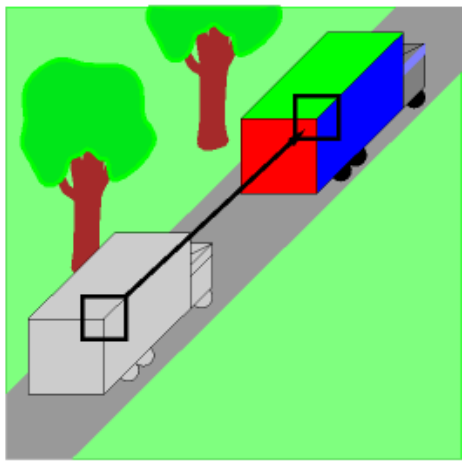


The Macro Block Layer

Sequence–Layer
Group–of–Picture–Layer
Picture–Layer
Slice–Layer
Macro–Layer
Block–Layer

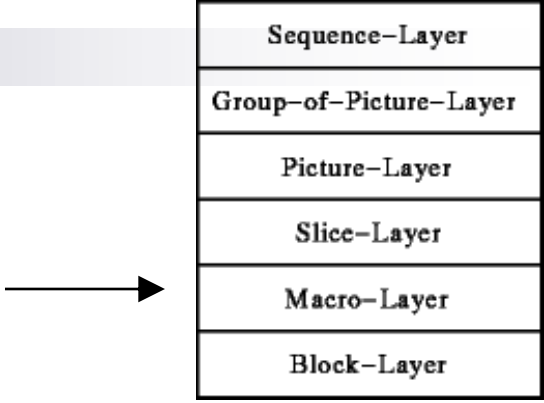


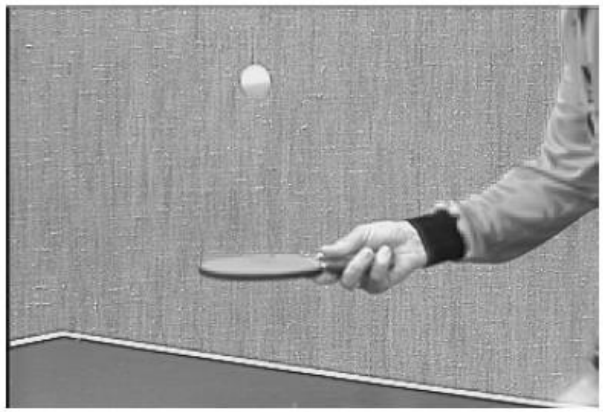
I - Frame

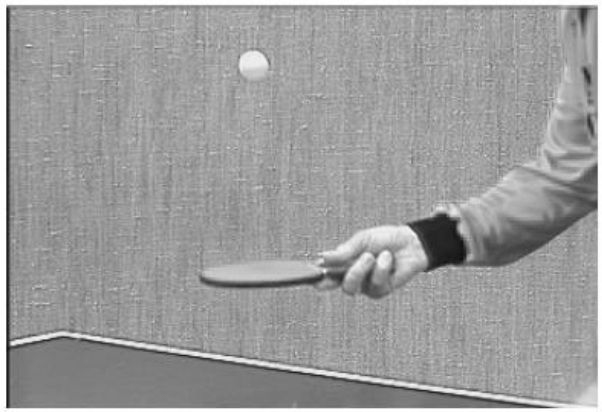


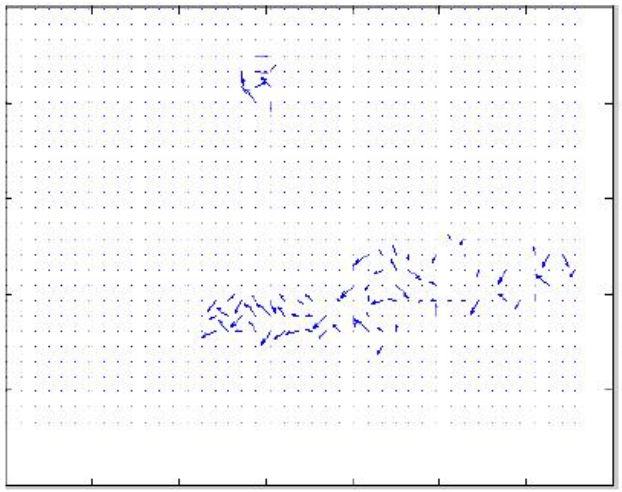
P - Frame

The Macro Block Layer



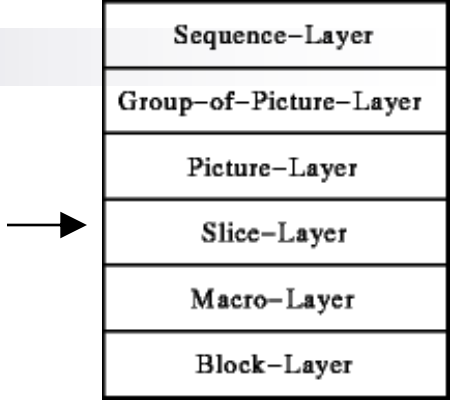




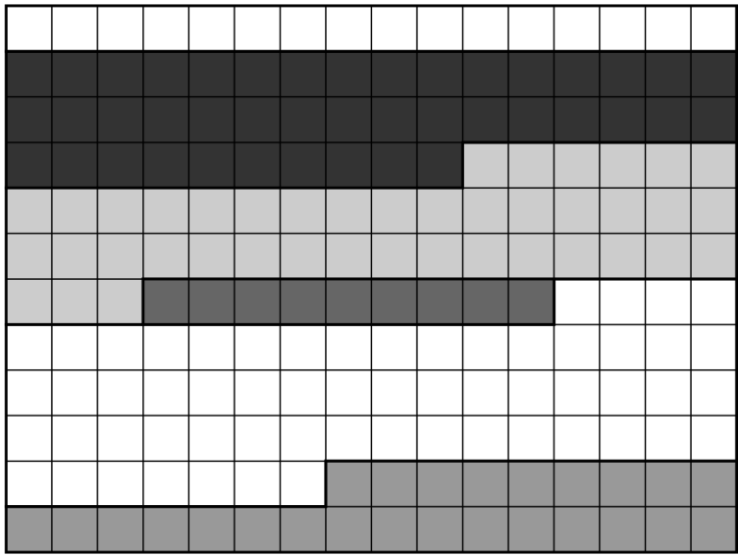


Motion vector

The Slice Layer

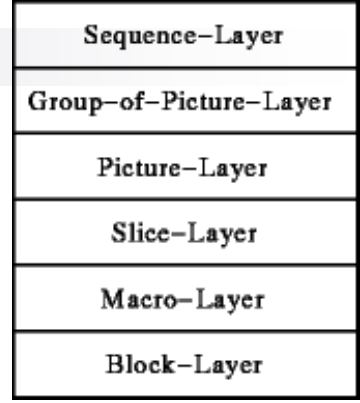


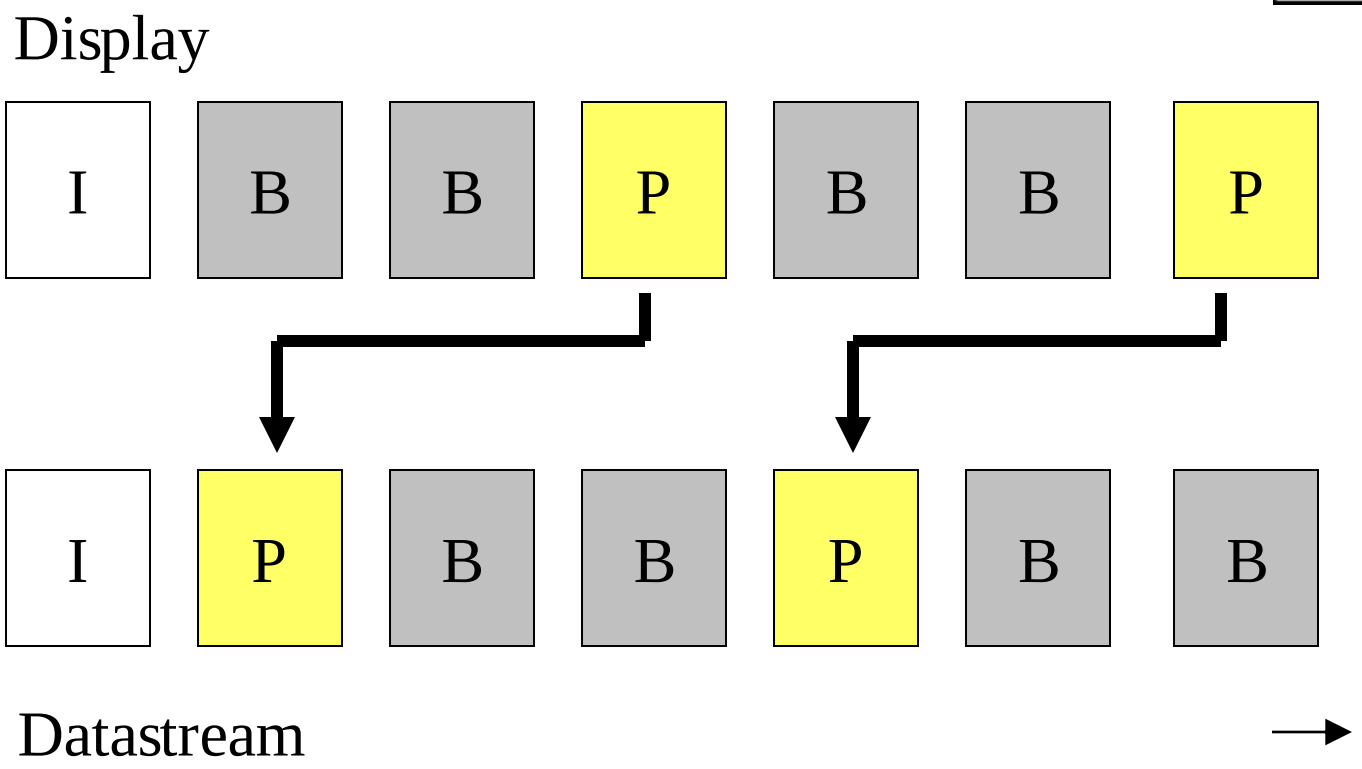
- Slices are a group of succesive macro-blocks

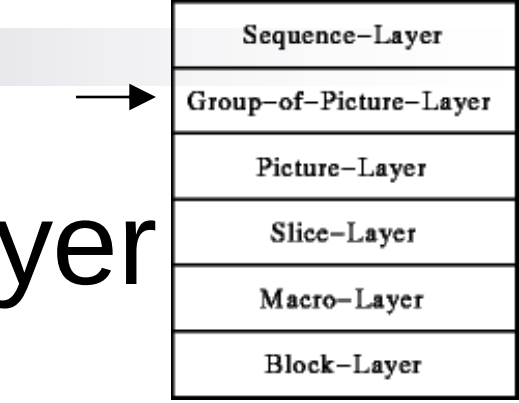


Slices in an MPEG-1 Picture

The Picture Layer

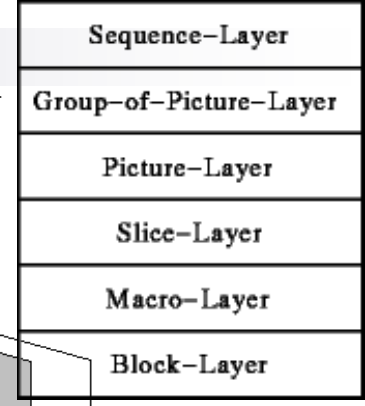


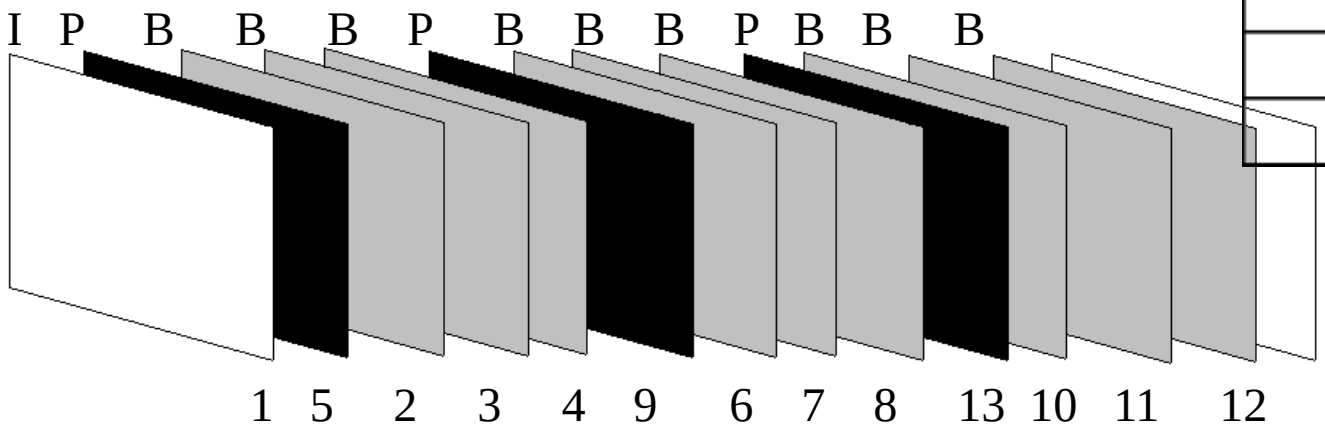




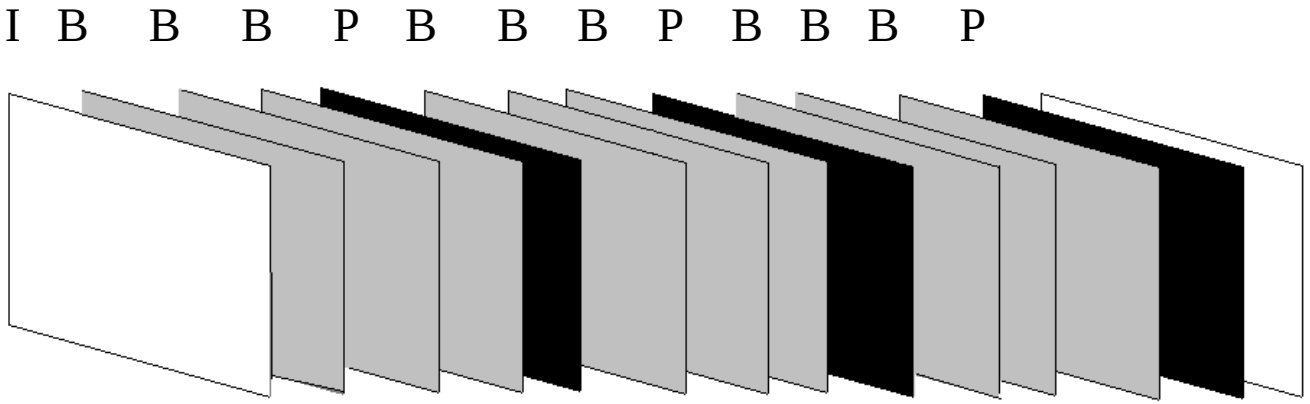
The Group of Pictures Layer

- Starts with an I-frame
- Ends with frame right before next I-frame

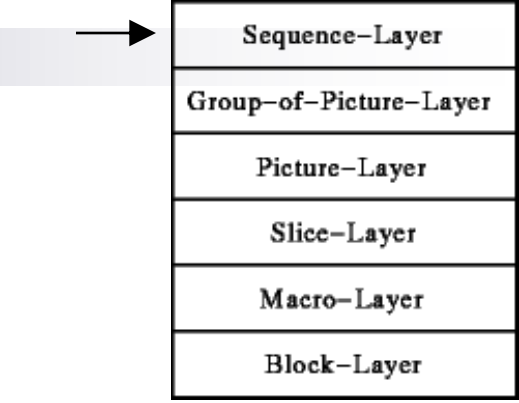




A typical group of pictures in coding order



A typical group of pictures in display order



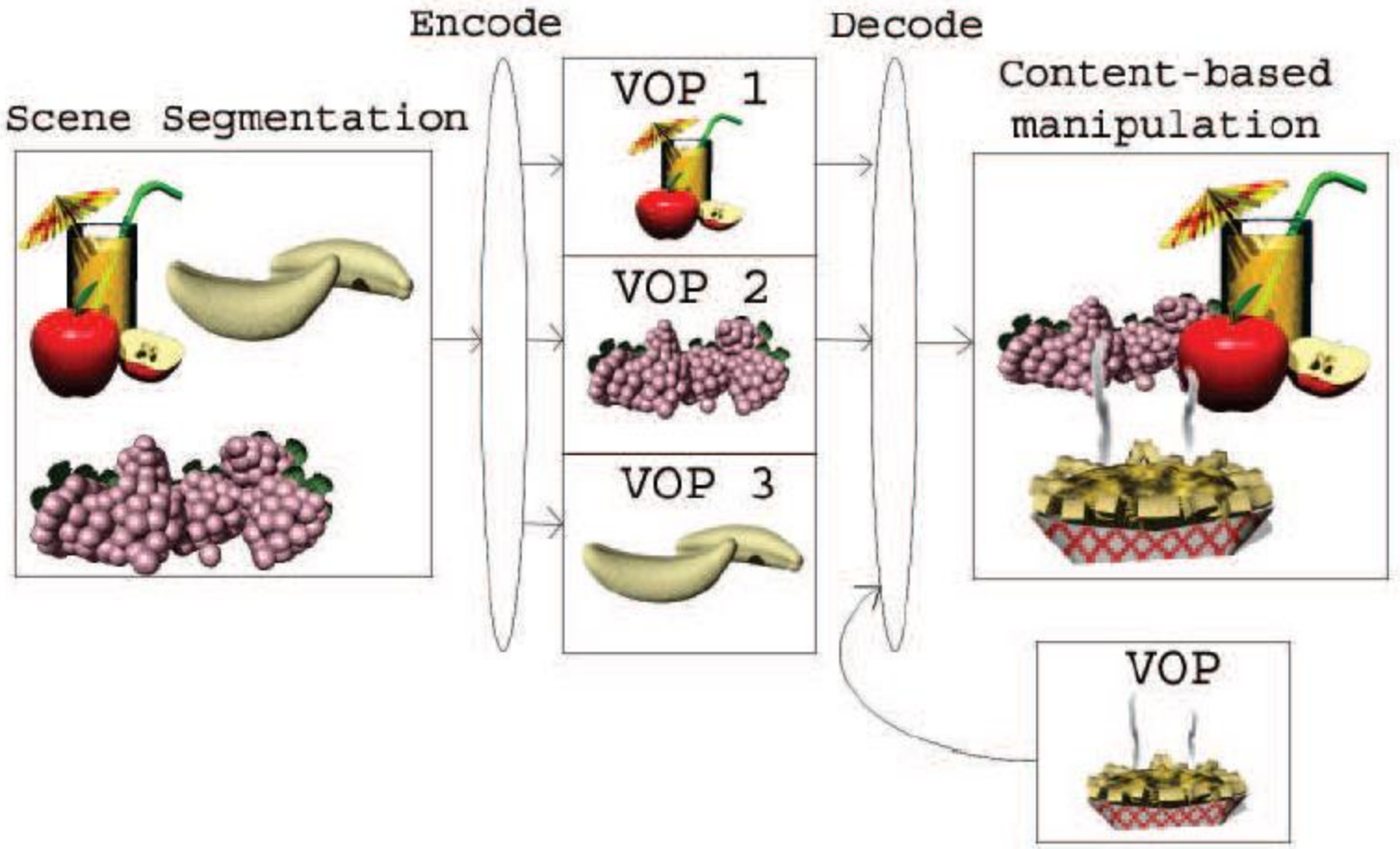
The Sequence Layer

- Union of GOPs
- Movie width
- Movie height
- Framerate (fps)
- Bit-rate

Overview of MPEG-4

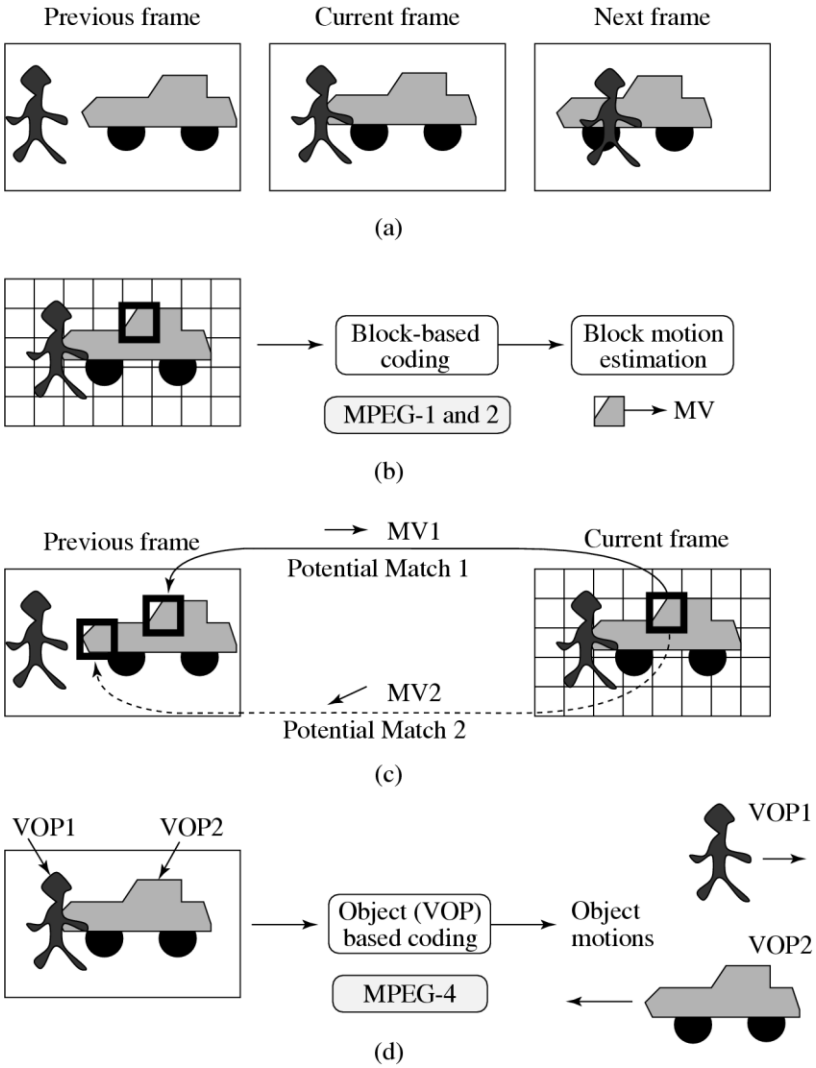
- Besides compression, pays great attention to issues about user interactivities
- **Object-based coding**
- The bit-rate for MPEG-4 video covers a large range between 5 kbps to 10 Mbps.

Overview of MPEG-4



Composition and Manipulation of MPEG-4 Videos.

VOP=Video Object Plane



Comparison between Block-based Coding and Object-based Coding

References

- A Handbook of Image and Video Processing - A.Bovik & J.Gibson
- MPEG: A Video Compression Standard for Multimedia Applications - Václav Hlaváč CTU Prague
- MPEG – Presentation by Sebastian Graf and Thomas Winterscheid
- MPEG Video Coding - Li & Drew
- Video Compression MPEG - Roger Cheng