Multimedia Audio / Video Communication Standards (MPEG)

- OVERVIEW OF MPEG
- STRUCTURE OF MPEG-1
- FEATURES OF OTHER MPEGS (MPEG 2/4/7/21)

Introduction

Nowadays, more and more ***audio-visual information*** is available from many sources around the world and many consumer electronics and telecommunication products incorporate ***complex technologies***

Therefore, the need for available ***standard*** is required.

MPEG provides a standard to satisfy a wide variety of applications and techniques.

About MPEG

What is MPEG?

- Definition
  - MPEG stands for Moving Pictures Experts Group.
  - MPEG is a working group of authorities that was formed by ISO and IEC to set ***standards for digital video and audio compression.***
- Basic principle
  - to transform a stream of discrete samples into a bitstream of tokens which takes ***less space***, but the quality seems to be the ***same to the eye or ear***.
- History
  - MPEG with 25 experts was established in Ottawa, 1988.
  - 350 experts from industries, universities and research institutions by late 2005.
  - 400 experts from 20 countries and >200 companies in 2016.

http://mpeg.chiariglione.org/about

About MPEG

History of MPEG

- 1988 : MPEG is established
- 1992 : MPEG-1 standard for Video CD and MP3
  - *Coding of moving pictures and associated audio for digital storage media at up to about 1.5 Mbit/s* (ISO/IEC 11172)
- 1994 : MPEG-2 standard for Digital Television and DVD
  - *Generic coding of moving pictures and associated audio information* (ISO/IEC 13818).
  - MPEG-3 was merged with MPEG-2, now is called MPEG-1 or MPEG-2 Audio Layer III.
- 1994 : MPEG-4 standard for multimedia applications.
  - *Coding of audio-visual objects. (ISO/IEC 14496).*
- 1996 : MPEG-7 standard for description and search of audio and visual content
  - *Multimedia content description interface. (ISO/IEC 15938).*
- 2000: MPEG-21 standard for Multimedia Framework
  - *Multimedia framework (MPEG-21). (ISO/IEC 21000).*

MPEG-3 is not MP3

About MPEG

MPEG-1	Coding of moving pictures and associated audio for digital storage media. Commonly limited to about 1.5 Mbit/s although specification is capable of much higher bit rates	ISO/IEC 11172	1993
MPEG-2	Generic coding of moving pictures and associated audio information	ISO/IEC 13818	1995
MPEG-4	Coding of audio-visual objects	ISO/IEC 14496	1999
MPEG-7	Multimedia content description interface	ISO/IEC 15938	2002
MPEG-21	Multimedia framework (MPEG-21)	ISO/IEC 21000	2001
MPEG-A	Multimedia application format (MPEG-A)	ISO/IEC 23000	2007
MPEG-B	MPEG systems technologies	ISO/IEC 23001	2006
MPEG-C	MPEG video technologies	ISO/IEC 23002	2006
MPEG-D	MPEG audio technologies	ISO/IEC 23003	2007
MPEG-E	Multimedia Middleware	ISO/IEC 23004	2007
MPEG-G	Genomic Information Representation	ISO/IEC 23092	2019
(none)	Supplemental media technologies	ISO/IEC 29116	2008
MPEG-V	Media context and control	ISO/IEC 23005[42]	2011
MPEG-M	MPEG extensible middleware (MXM)	ISO/IEC 23006[47]	2010
MPEG-U	Rich media user interfaces	ISO/IEC 23007[49]	2010
MPEG-H	High Efficiency Coding and Media Delivery in Heterogeneous Environments	ISO/IEC 23008[54]	2013
MPEG-DASH	Information technology – DASH	ISO/IEC 23009	2012
MPEG-I	Coded Representation of Immersive Media	ISO/IEC 23090	2020

About MPEG

Advantage

- MPEG compression dramatically decreases the amount of storage space.
  - For example, watching 2 hour movie with 640*480 pixel and 16-bit color depth

    ➔ 133 GB are required.

    MPEG can compress 100:1

    ➔ 1.33GB are required.

Disadvantage

- Computational complexity → higher CPU and more memory required.

About MPEG

How?

- Compression techniques
  - Losseless compression
  - Lossy compression
- MPEG compression exploits
  - Coding redundancy
  - Temporal redundancy
  - Spatial redundancy
  - Irrelevant information: Approximation Intensity

MPEG compression

Temporal Redundancy

- Two adjacent frames in a motion picture sequence are usually very nearly identical.
- The only difference is that some parts of the picture are shifted slightly between the frames.
- MPEG compression divides each new frame into the pieces and searching the previous frame to determine where each piece came from.

MPEG compression

Spatial Redundancy

- Within a single frame many parts, such as regions of sky or walls are almost entirely the same color.
- MPEG compression divides images into convenient pieces and reducing such parts to a single color.
  - If several pixel points in the same area are almost the same color, then send the color for the whole area once.

MPEG compression

Irrelevant information: Approximation Intensity

- The human eye sees less fine detail changes and color changes in images.
- MPEG compression eliminates non-essential color and approximates the intensity of fine detail.

MPEG-1

Designed to compress VHS-quality raw digital video and CD audio down to 1.5 Mbit/s without excessive quality loss.

Features

- Coding of moving pictures and associated audio for digital media
- Standard for efficient storage and retrieva video on compact disc.

Applications

- Video CD, VHS, VCR, MP3

1080p 720p VHS

Major differences from H.261

1. Frame types:

H.261 has I and P frames; MPEG-1 introduces bi-directional motion compensation (B-frames).

2. Source format:

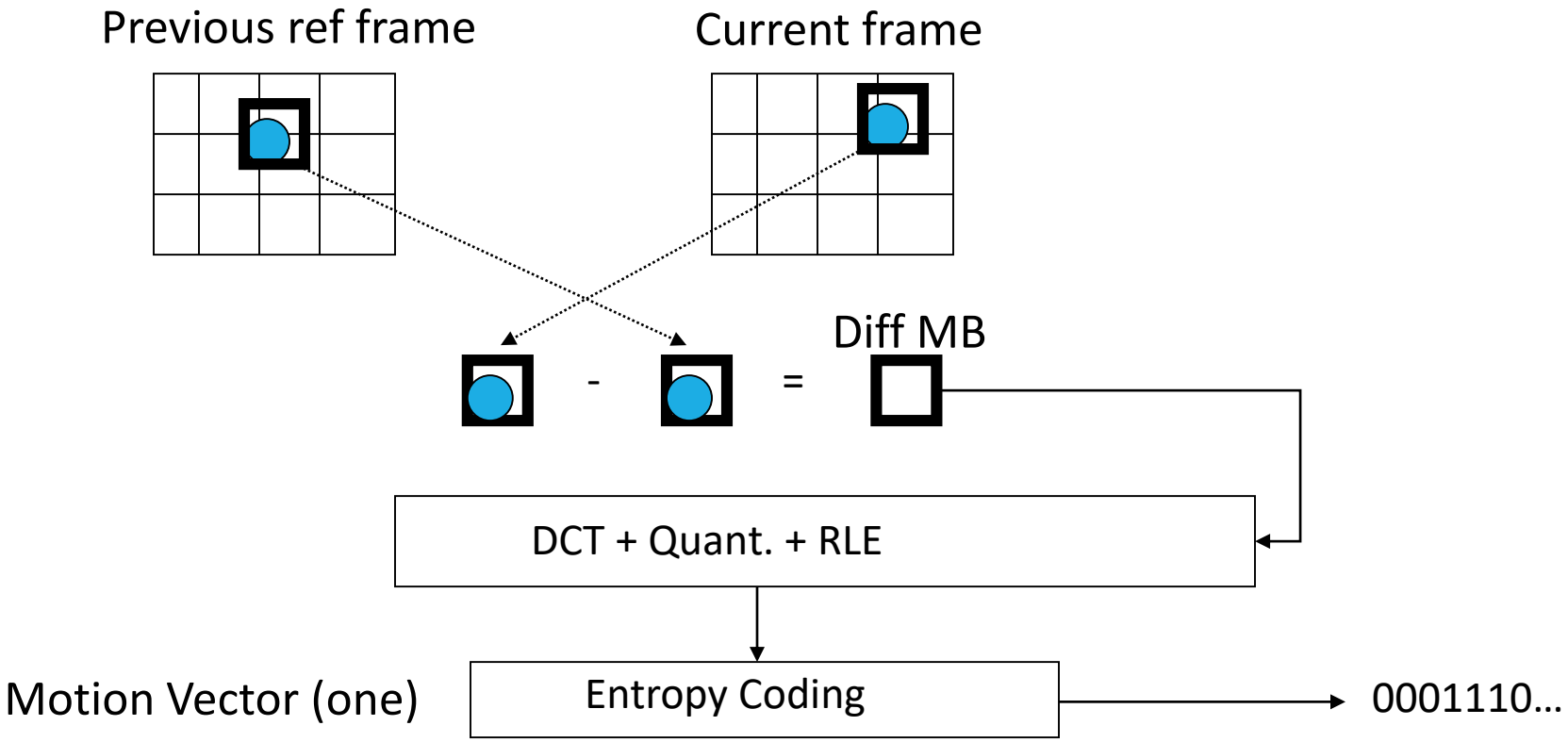
H.261 supports CIF and QCIF source formats only; MPEG-1 supports SIF and other formats as long as certain constrained parameter set is satisfied.

3. Slices:

GOBs in H.261; MPEG-1 picture can be divided into one or more slices which are more flexible than GOBs.

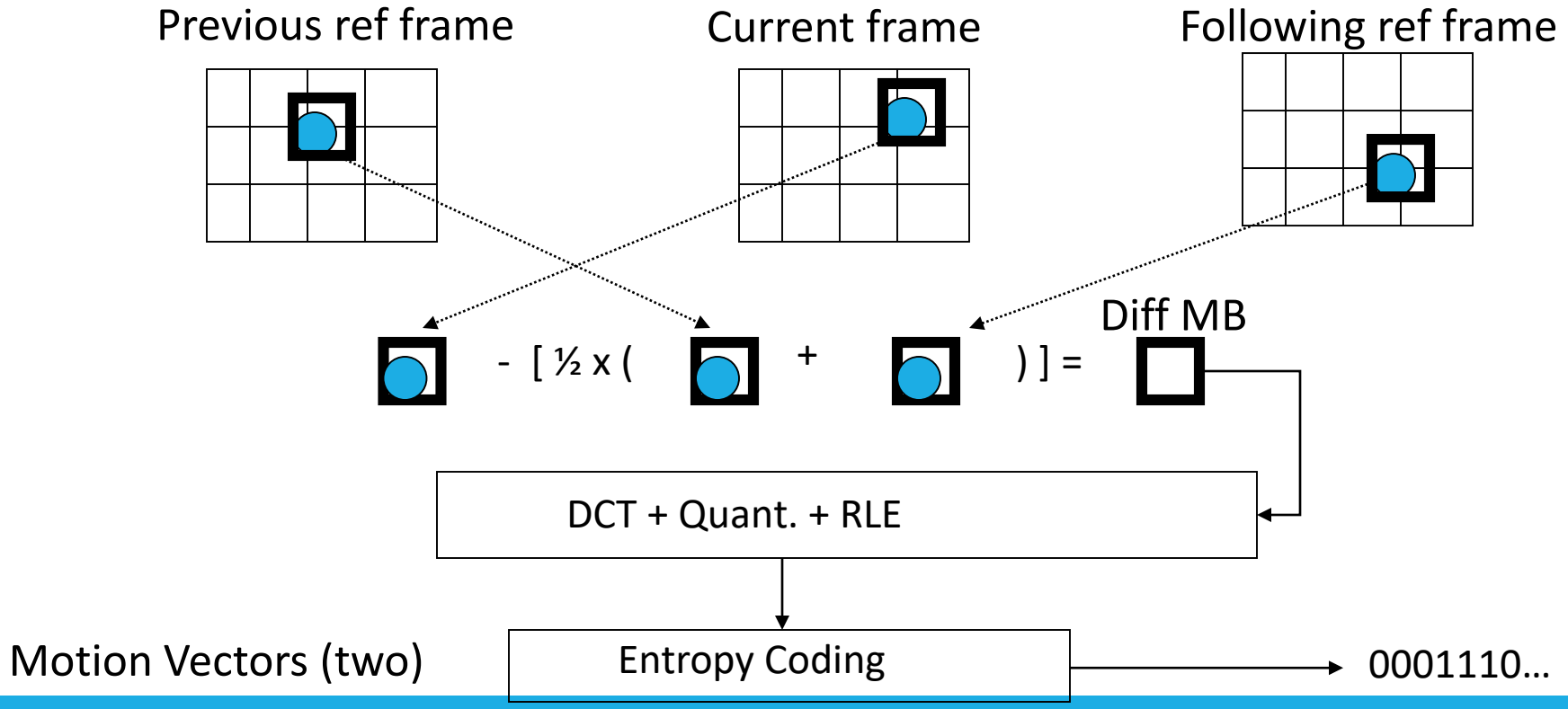
P-Frame

P-frames require information of the previous I or P-frame.



B-Frame

B-frames (bi-directionally predictive-coded frames) require information of the previous and following I and/or P-frame.



MPEG-1

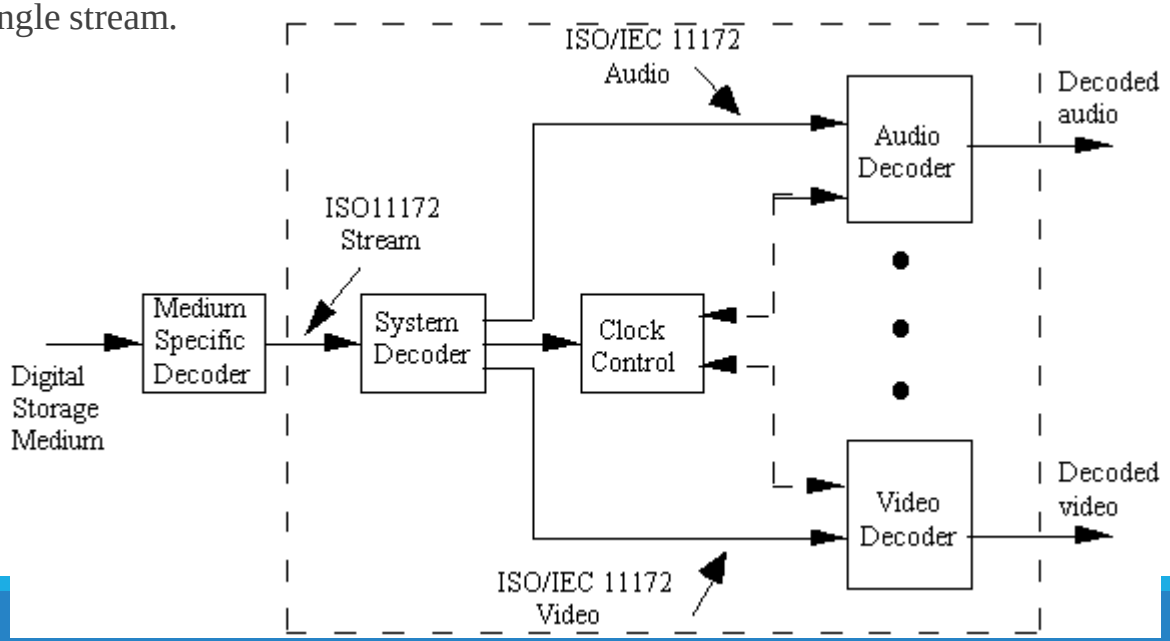
MPEG-1 standards consists of 5 parts

- Part 1 System:
  - storage and synchronization of video, audio and other data together
- Part 2 Video:
  - compressed video content
- Part 3 Audio:
  - compressed audio content
- Part 4 Conformance Testing:
  - testing the correctness of implementations of the standards
- Part 5 Software Simulation:
  - example software showing how to encode and decode according to the standard.

MPEG-1

Part 1 System

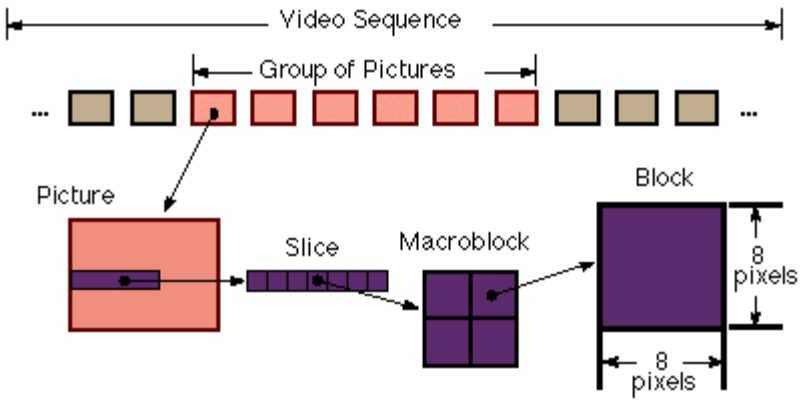
- Specifies the logical layout and methods used to store the encoded audio, video and other data into a standard bit stream. (**Multiplexing**)
- Maintains **synchronization** between the different contents.
- The structure was named an *MPEG program stream* (PS).
  - Combines one or more data streams from the video and audio with timing information to form a single stream.



MPEG-1

Part 2 Video

- provides efficient encoding of pictures with VHS quality.
  - the structure of pictures in the standard.



MPEG-1

Part 2 Video

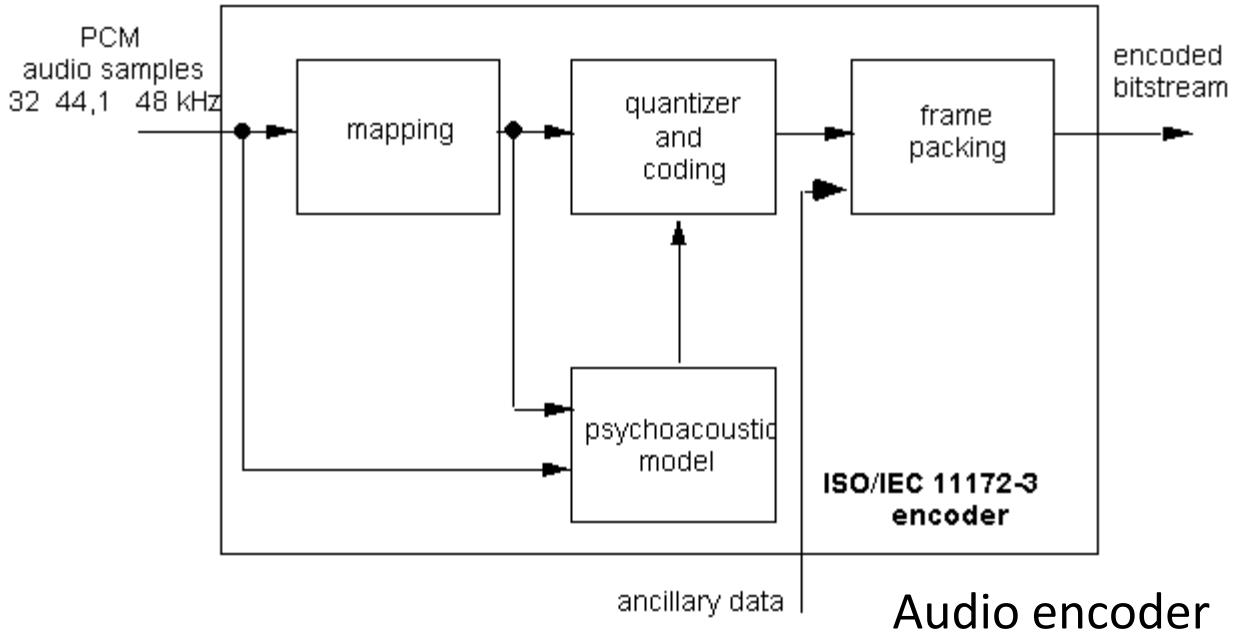
- A number of requirements apply in the context of storage and replay of stored data, which mainly are related to random access:

  - The video sequence must be replayable forward and backward;
  - Fast forward/reverse modes have to be supported;
  - Editing (e.g. extracting or replacement of frames) must be possible

MPEG-1

Part 3 Audio

- Utilizes psychoacoustics to significantly reduce the data rate required by an audio stream.
- provides encoding of stereo audio at 192 kbit/s.



Audio encoder

MPEG-1

Part 3 Audio has 3 layers:

- Layer 1/MP1
  - Layer I uses a smaller 384 sample frame size for very low delay and finer resolution.
  - Eg. Digital Compact Cassette.
- Layer II/MP2
  - Lossy
  - provides 192 kbit/s for stereo sound.
  - Application: HDV camcorders
- Layer III/MP3
  - Lossy
  - Provides 64 kbit/s for mono audio and 128kbit/s for stereo sound.

The layers are semi backwards compatible.

MPEG-1 Part 3 Layer comparison

High layer compression is more efficient at lower bitrates than lower layers.

		Layer 1	Layer 2	Layer 3
Bit Rate	mono	128kbps	96kbps	64kbps
	stereo	256kbps	192kbps	128kbps
Quality		low	medium	high
Comp Rto		1:4	1:6~1:8	1:10~1:12

MPEG-1

Part 4 Conformance Testing

- specifies how tests can be designed to verify whether bit streams and decoders meet the requirements as specified in parts 1, 2 and 3 of the MPEG-1 standard.
- These tests can be used by manufacturers and their customers.

MPEG-1

Part 5 Software Simulation

- gives a full software implementation of the first three parts of the MPEG-1 standard.
- Reference code for encoding and decoding of audio and video, multiplexing and de-multiplexing.

MPEG-2

Features

- Generic coding of moving pictures and associated Audio.
- Standard for Digital Television and DVD
- Improves the audio-visual quality of MPEG-1.
  - Video Quality
    - MPEG-1 : Video CD
    - MPEG-2 : DVD
  - Audio Quality
    - MPEG-1 : stereo-two channels
    - MPEG-2 : multichannel (AAC 5.1 channels)

Applications

- digital TV / DVD / HDTV

MPEG-4

Features

- Coding of audio-visual objects.
- Standard for multimedia applications.
- Enable higher level of interaction with media contents.
  - improve the video compression efficiency
  - work in a wide range of bitrate 64kbps – 4Mbps
  - provide robustness to information errors and loss, resolution scalability, and object scalability.

Major Difference: MPEG-4 and MPEG-1/2

MPEG-4 relates to *the application level.*

- MPEG- 4 defines content that needs to be delivered over a network as a framework of media objects and scene descriptions.

MPEG-1 and MPEG-2 relate only to *audio-video streams*.

- MPEG-1 and MPEG-2 are standards that focus on the compression and decompression of audio and video streams.

MPEG-4 parts

Part 1, Systems – synchronizing and multiplexing audio and video

Part 2, Visual – coding visual data

Part 3, Audio – coding audio data, enhancements to Advanced Audio Coding and new techniques

Part 4, Conformance testing

Part 5, Reference software

Part 6, DMIF (Delivery Multimedia Integration Framework)

Part 7, optimized reference software for coding audio-video objects

Part 8, carry MPEG-4 content on IP networks

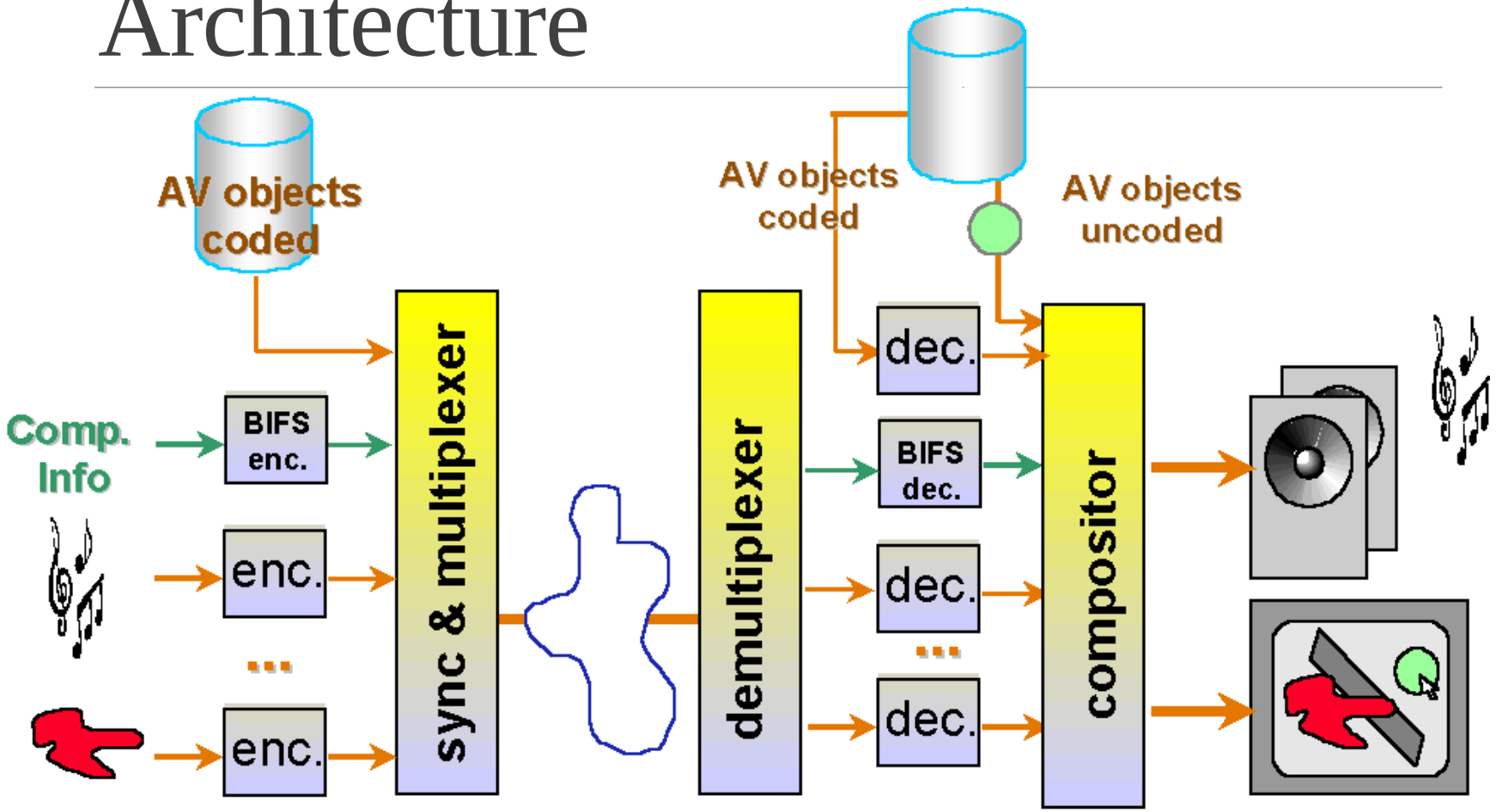
MPEG-4 parts

- Part 9, reference hardware implementation
- **Part 10, Advanced Video Coding (AVC)**
- Part 11, Scene description and application engine; BIFS (Binary Format for Scene) and XMT (Extensible MPEG-4 Textual format)
- Part 12, ISO base media file format
- Part 13, IPMP extensions
- Part 14, MP4 file format, version 2
- Part 15, AVC (advanced Video Coding) file format
- Part 16, Animation Framework eXtension (AFX)
- Part 17, timed text subtitle format
- Part 18, font compression and streaming
- Part 19, synthesized texture stream

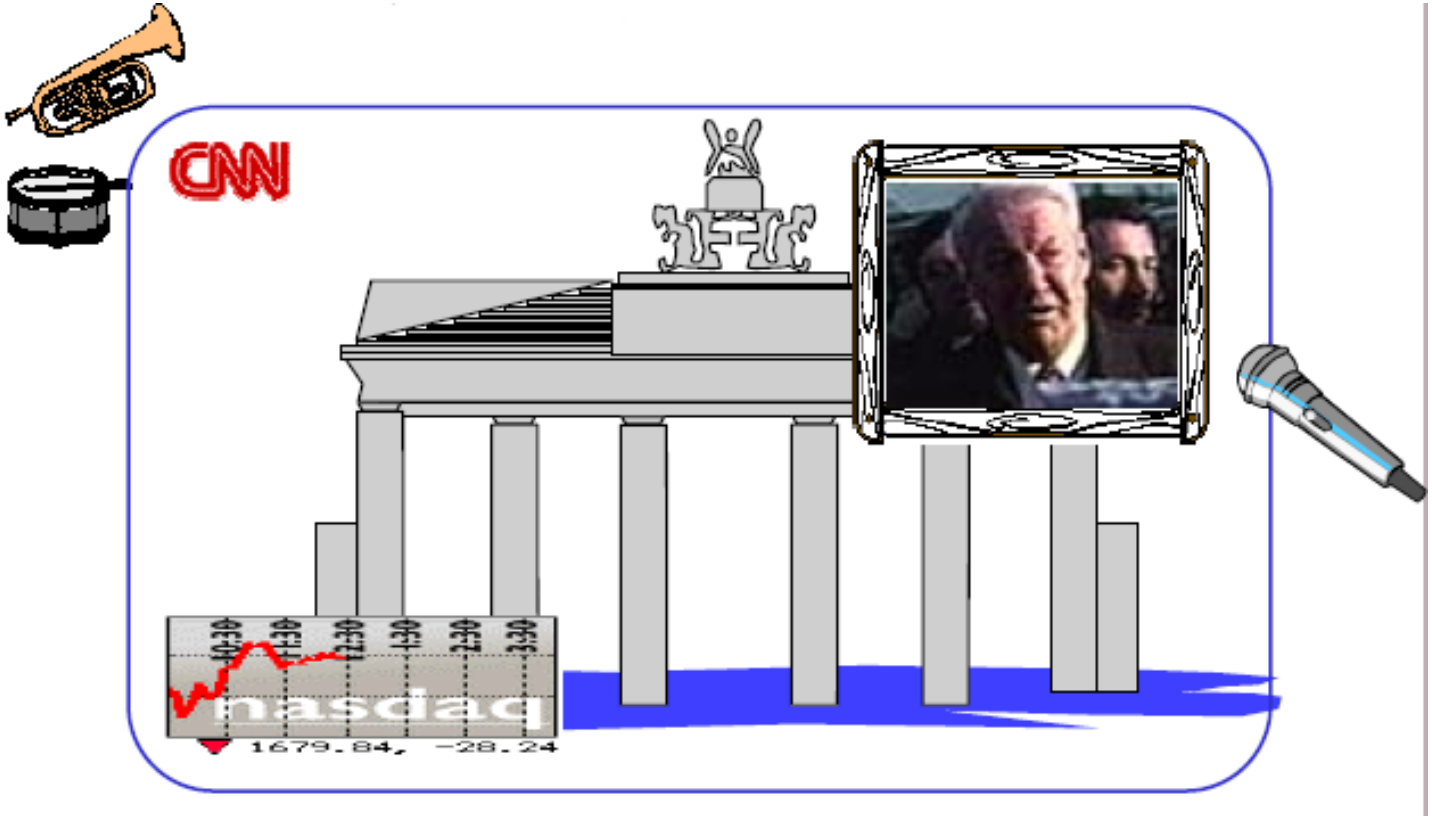
MPEG-4 parts

- Part 20, Lightweight Application Scene Representation (LASeR) and Simple Aggregation Format (SAF)
- Part 21, MPEG-J Graphics Framework eXtension (GFX)
- Part 22, Open Font Format
- Part 23, Symbolic Music Representation
- Part 24, audio and systems interaction
- Part 25, 3D Graphics Compression Model
- Part 26, audio conformance
- Part 27, 3D graphics conformance

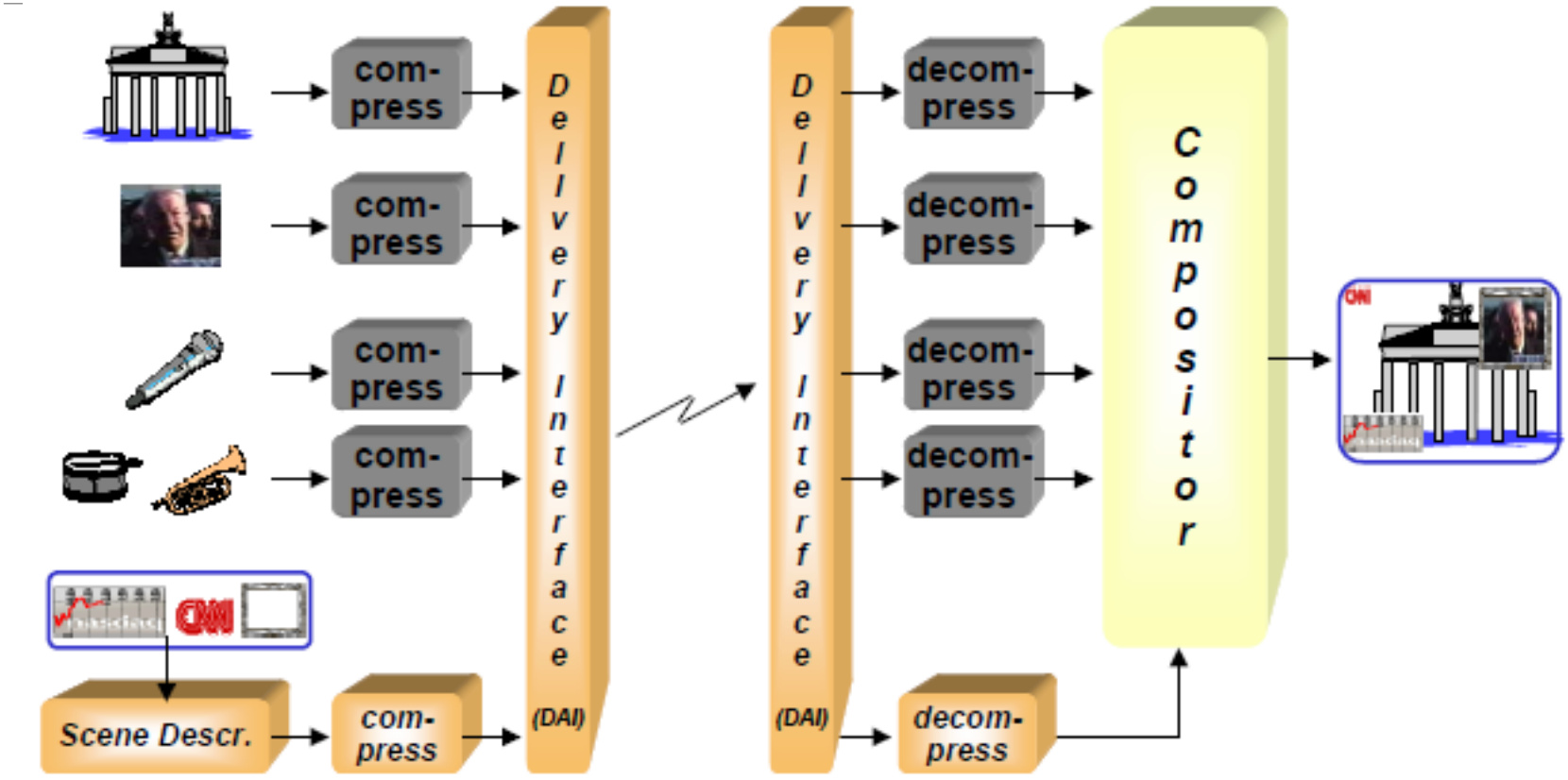
MPEG 4 object-based Architecture



An example MPEG-4 scene



MPEG 4 object-based Architecture



MPEG-4

Applications

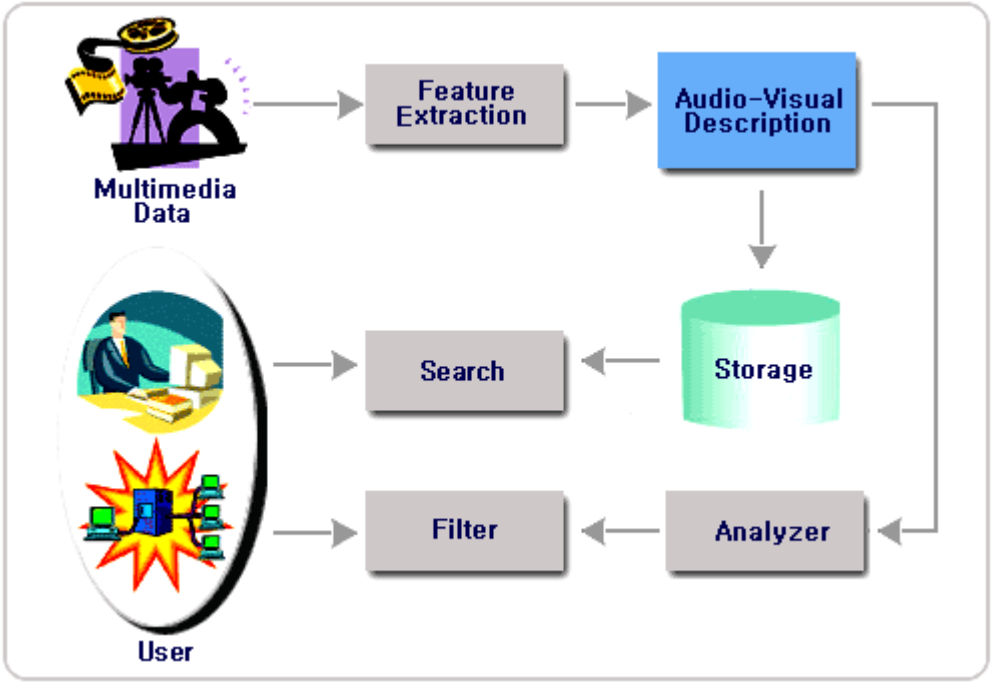
- Internet multimedia
- Wireless multimedia
- Interactive video game
- Interactive storage media
- Broadcasting applications

MPEG-7

Features

- Multimedia Content Description Interface
- Standard for audio-visual information representation.
- allow operation such as search, access, filter, retrieve, and manage audio-visual information
- Not a standard which deals with encoding like MPEG 1,2 and 4.
- It uses XML to store metadata to timecode in order to tag particular events. E.g. synchronize lyrics to a song.

MPEG-7


Multimedia Data
Feature Extraction
Audio-Visual Description
Storage
Search
Filter
Analyzer
User

MPEG-7

Applications

- Indexing and retrieval
  - Digital library (image catalog) or multimedia information
- Selection and filtering
  - Broadcast media selection, personalized TV services, multimedia catalog (tourist info, geo-info system.)
- Professional purpose
  - Remote shopping, biomedical applications, semi-automatic multimedia editing, education, security surveillance and vision-based control.

MPEG-21

Features

- Multimedia Framework standard
- enables use of multimedia resources across a wide range of networks and devices used by different communities
- defines the description of content and processes for accessing, searching, storing and ***protecting the copyrights of content***-DRM***(Digital Rights Management)***

MPEG-21

Key technologies

1. Digital Item Declaration
2. Digital Item Identification and Description
3. Content Handling and Usage
4. Intellectual Property Management and Protection
5. Terminals and Networks
6. Content Representation
7. Event Reporting

Summary of MPEG standards

MPEG Standard	Targeted Usage
MPEG-1 MPEG-2 MPEG-4	Coding of audio/visual content
MPEG-7	Providing metadata that describes multimedia content
MPEG-21	Providing a framework for the all-electronic creation, production, delivery and trade of content.

Key compression features

Features	H.261	MPEG-1	MPEG-2	H.263	MPEG-4	H.264	WMV9/ VC-1	AVS
Picture coding type	I, P	I, P, B	I, P, B	I, P, B	I, P, B	I, P, B	I, P, B	I, P, B
Entropy Coding	VLC	VLC	VLC	VLC, SAC	VLC	UVLC, CAVLC, CABAC	Multiple table VLC	Adaptive VLC
MV resolution	Int. Pel	½ pel	½ pel	½ pel	¼ pel	¼ pel	¼ pel	¼ pel
Transform	8x8 DCT	8x8 DCT	8x8 DCT	8x8 DCT	8x8 DCT	4x4 & 8x8 Integer	8x8, 8x4, 4x8, 4x4 Integer DCT	8x8 integer
Vector Block size	16x16	16x16	16x16, 16x8	16x16, 8x8	16x16, 8x8	16x16, 16x8, 8x16, 8x8, 8x4, 4x8, 4x4	16x16, 8x8	16x16, 16x8, 8x16, 8x8,8x4, 4x8, 4x4
Spatial Intra Prediction	No	No	No	No	No	Yes	No	Yes
Formats supported	Prog.	Prog	Prog/Intr	Prog.	Prog/Intr	Prog/Intr	Prog/Intr	Prog/Intr
Prediction Modes	Frame	Frame	Field & Frame	Frame	Field & Frame	Field & Frame	Field & Frame	Field & Frame
De-blocking filter	In-loop	None	Post	Annex J in-loop	Post	In-loop	In-loop	In-loop

https://www.eetimes.com/video-codecs-tutorial-trade-offs-with-h-264-vc-1-and-other-advanced-codecs/

Summary of common video codecs

Codec groups	Container examples	Stage of use (shaded = common or preferred use)		
		Capture	Edit	Distribution
WMV (WMV-9, VC-1)	wmv, avi	• slideshows • screencasts	need to convert	• web clips • file sharing
DV, DVCAM, DVCPRO, Digital8	avi, mov, mxf	• legacy and pro • SD and HD • digitized VHS	easy	• archive VHS, DV • broadcast work • large file sizes
MPEG-2 (DVD, HDV)	m2t (Blu-ray), mts, mpg, vob (DVD), mxf	• legacy and pro • SD and HD • digitized VHS	native or convert	• high-quality • DVD • broadcast
Motion-JPEG (MJPEG)	avi, mov	• photo cameras • option on new • SD and HD	easy	• archive format for short clips (large file sizes)
M-JPEG2000	mj2, mov	• digital cinema • HD and beyond	easy	• archive SD, HD • efficient file sizes
MPEG-4 (DivX, H.264, AVCHD)	avi, mp4, m4v, mov, mkv, m2ts	• low- and high-end video • SD and HD	need to convert	• long web clips (efficient format) • modern devices
Cineform		• edit codec • convert source	HD work ¨lossless¨	• intermediate • very large files
Flash	flv, swf	• slideshows • screencasts	need to convert	• web clips for viewing on standard computers

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Q&A