Source Coding

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Time/Date/Instructor

- 1:30pm – 3:20pm, Monday;工程四館 ED301; 4:40pm – 5:30pm, Thursday; ED101 (Sept. 15, 2011 – Jan 12, 2012)
- Instructors: Hsueh-Ming Hang, 杭學鳴
- hmhang@mail.nctu.edu.tw
- Classnotes: http://cwww.ee.nctu.edu.tw/

Grading

- 5 or so Homework Assigns: 35 % (including 2 computer assignments in C, 25%)
- Examine: 30% (2 hours, open book)
- Final Project: 35% (One computer assignment + paper study (given list);

  2 person as a group; oral and written reports)

Text Book and Recommended Readings

- Textbook: **K. Sayood, *Intro. to Data Compression***, 3rd Ed., Morgan Kaufman, 2006.
- Recommended Readings:

(1) J.-R. Ohm, *Multimedia Communication Technology*, Springer, 2004.

(2) Y. Q. Shi and H. Sun, *Image and Video Compression for Multimedia Engineering*, 2nd ed, CRC Press, 2008

(3) D. Salomon, *Data Compression: The Complete Reference*, Springer, 2007

(4)戴顯權,資料壓縮,旗標出版社, 2009年

Topics to be covered

(1) Fundamental theory on (data) compression

(2) (Lossless) Data compression

(3) Speech compression

(4) Audio compression

(5) (Still) Image compression

(6) Video compression

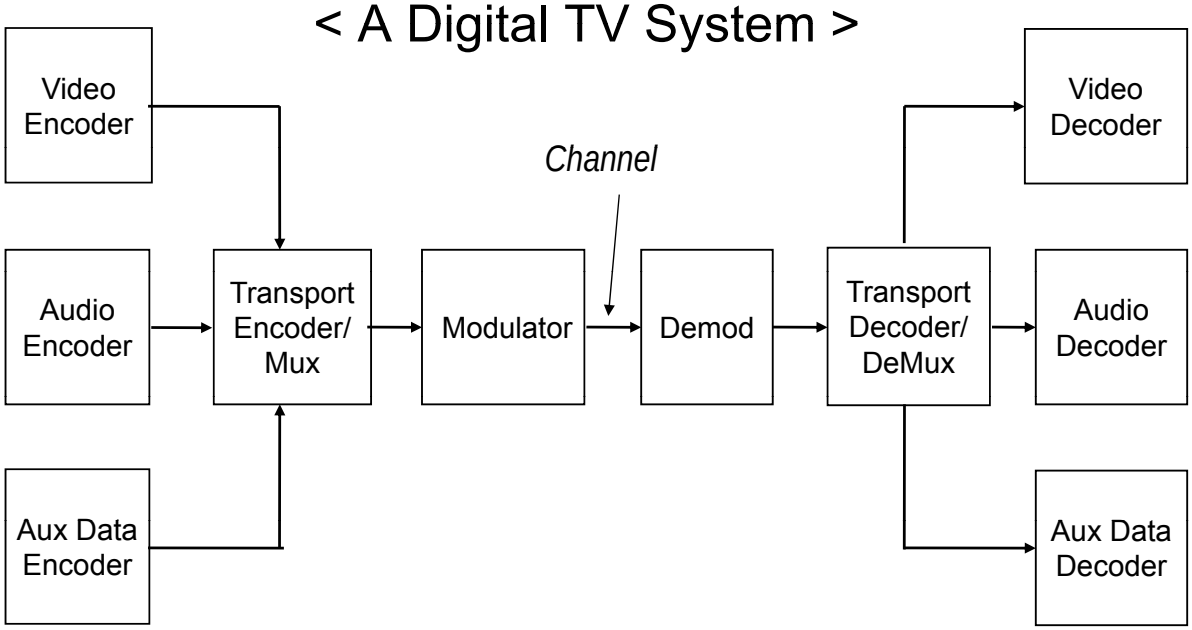
- There is no single book that covers all the above subjects in adequate depth.

Chap. 1 Introduction

Digital Media in Daily Life

An Example of Comm. Systems

< A Digital TV System >



Why Compression?

-- Massive data

- **Speech**: 8 bits (per sample) x 8K (samples/sec) = 64Kbits/s
- **CD audio:**

16 bits x 44.1K (samples/sec) x 2 (channels) = 1.411Mbits/sec
(44.1K = 60 (fields) x 245 (lines) x 3 (samples) (J. Watkinson, *The Art of Digital Audio*, p.28, Focal Press, 1989))

- **Digital TV:** (4:2:2, NTSC in CCIR 601)

Still picture: 720 (pels) x 483 (lines) x 2.0 bytes = 5.564 Mbits
Motion picture: 5.564 Mbits x 29.97 (frames/sec) = 167Mbits/sec

- **Digital HDTV:** (ATSC)

1920 (pels) x 1080 (lines) x 1.5 bytes x 30 (frames/sec)=746Mbits

Examples of Data

-- Classified based upon compression techniques

- **General digital data:** various types of computer files
- **Text**
- **Speech:** human conversation
- **Audio:** music
- **Bi-level images:** fax, dithered (two-tone) images
- **Still gray-level pictures:** graphics, natural images
- **Motion pictures:** video conferencing, television.

-- Data characteristics can be used to reduce bit rate.

How Compression Possible?

Characteristics of data:

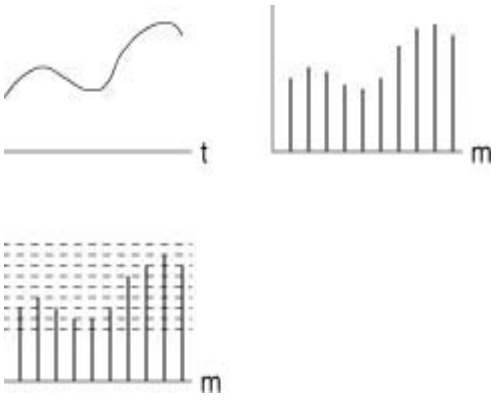
- Stationary statistical model
  -- Shannon information theory
- Non-stationary properties such as local correlation

Characteristics of human perception:

- Finite resolution of hearing and vision
- Auditory masking effect
- Color representation
- Visual masking effect

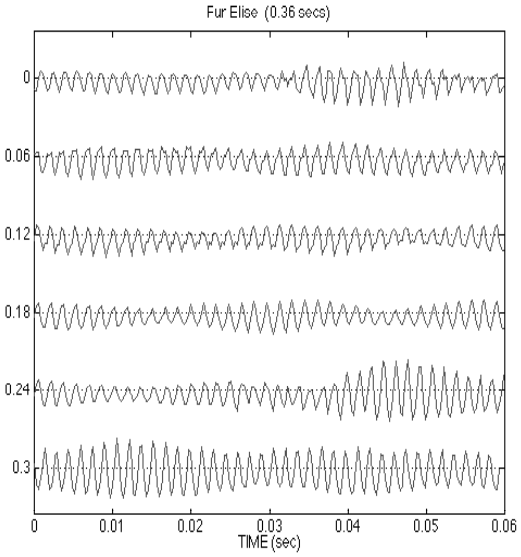
Signals (Waveforms)

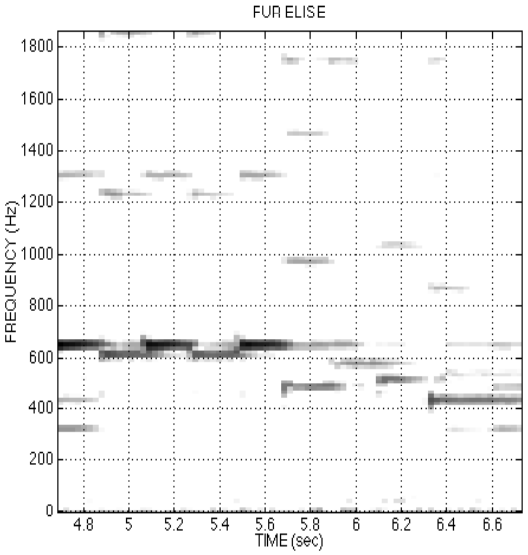
	Time/ Space	Amp.
Analog Signals x(t)	Conti.	Conti.
Discrete-time (discrete-space) (sampled-data) signal x(m)	Discrete	Conti.
Digital signals x(m)	Discrete	Discrete



Audio Samples

- Piano (fur Elise) samples and spectrogram (McClellan et al., *DSP First*, Prentice-Hall, 1998)





Data Compression Techniques

Information lossless: Redundancy reduction ─ The original data can be completely recovered.

- Direct: Huffman codes, arithmetic coding, Ziv-Lempel coding, … (narrow-sense *data compression*)
- Predictive: Run length coding, …

Information lossy: Information (entropy) reduction -- The reproduced data are *approximations* of the original data. This may not be meaningful for a computer file.

- Block coding: vector quantization, transform coding, …
- Sequential: DPCM, tree coding, …
- Multi-resolution (non-block): sub-band, wavelet, ...

Compression Techniques

- **Waveform coding:** Reproduce waveform,

  e.g., DPCM, transform, sub-band, …

  -- Universal but lower efficiency.
- **Content-based coding:** Reproduce *contents*,

  e.g., (speech) vocoder, (image) contour-texture coding, (video) model-based coding.
- **International standards:** JPEG, MPEG, H.261/3, …

Elements in Waveform Coding

- **Decorrelation:** Reduce spatial and temporal redundancy. *Techniques:* prediction, transform, …
- **Selecting representatives:** Reduce the number of possible signals.

  Techniques: quantization, …
- **Entropy coding:** Equalize the probability distribution of the output symbols.

  Techniques: Huffman codes, Ziv-Lempel coding, ...

Multimedia Coding Standards

- Complete, practical coding algorithms

  -- A balance between (compression) performance and (implementation) complexity (and a compromise among various interest parties)
- Critical for telecommunication products and consumer audio/video media products

Image/Video Standards

- **ISO/IEC JTC1 SC29** – ISO and IEC Joint Technical Committee (on Information Technology) Subcommittee 29 (Coding of audio, picture, multimedia and hypermedia)

  – Working Group (WG) 1:

  JBIG (Joint Bi-level Image Group) **–** 1-bit to 4/5-bit still pictures

  JPEG (Joint Photographic Experts Group) **–** 8-bit or more still pictures
- **ISO/IEC JTC1 SC29**

  – WG 11: MPEG (Moving Picture Experts Group) **–** Motion pictures

  – WG 12: MHEG (Multimedia-Hypermedia Experts Group) **–** Multi/Hyper-media exchange format

Standards Organizations

- **CCITT** – Comité Consultaitif International Télégraphique et Téléphonique (International Telegraph and Telephone Consultative Committee)
- **ITU** – International Telecommunication Union
- **ISO** – International Standardization Organization
- **IEC** – International Electrotechnical Commission

Speech Coding Standards

Standards	Typical rates (Year)	Quality: MOS (1-5)
PCM	64 kbits/s (1972)	4.4 (PSTN)
G.721 ADPCM	32 kbits/s (1984)	4.1 (PSTN)
GSM	13 kbits/s (1991)	3.6 (Cellular)
G.728 (low delay)	16 kbits/s (1992)	4.0
IS-96A (CDMA)	0.8-8.55 kbits/s (1993)	~3.4 (Cellular)
G.729	8 kbits/s (1995)	~4.2
G.723.1	5.3, 6.3 kbits/s (1995)	~4.0
Half-rate GSM	5.6 kbits/s (1995)	~3.4 (Cellular)
AMR	5.15-12.2 kbits/s (1999)	~3.9 (3GPP)

MOS: Mean Opinion Score -- 5=excellent, 4=good, 3=fair, 2=poor, 1=bad

MPEG Audio Standards

MPEG-1 Layer 1: 1992	(good: 256k /2ch)	1-2 chs
MPEG-1 Layer 2: 1992	(good: 192k /2ch)	1-2 chs
MPEG-1 Layer 3: 1993 (MP3)	(good: 128k /2ch)	1-2 chs
MPEG-2 Layers 1,2,3: 1994		1-5.1 chs
MPEG-2 AAC: 1997; Advanced Audio Coding (AAC)	(good: 96k /2ch)	1-96 chs
MPEG-4 (v1) AAC: 1999	(new tools)	1-96 chs

MPEG-4 Amd 1: (2003) Bandwidth extension (SBR -- Spectral Band Replication)	HE-AAC, AAC+ (good: 48k)
MPEG-4 Amd 2: (2004) Parametric Audio extension → MPEG surround (MPEG-D 2006)	(good: 24k)
MPEG-D: Unified Speech and Audio Coding (2011?)	MPEG surround + AMR (speech)

Video Coding Standards

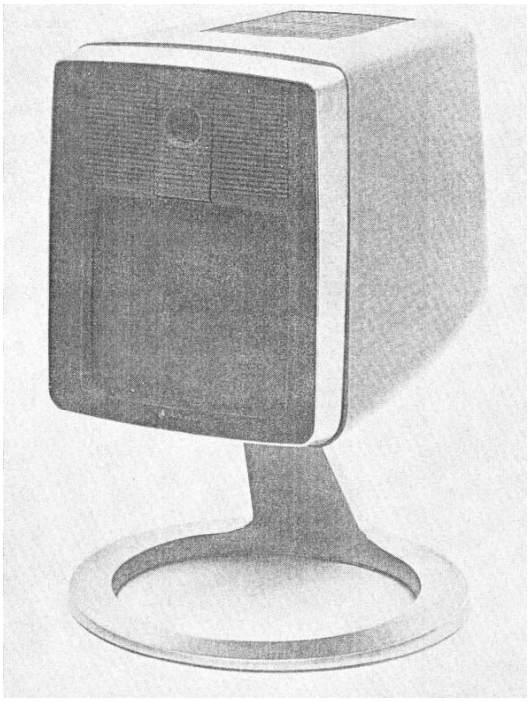
Standards	Typical rates	Applications
ITU-T (CCITT) H.261	128 384k bits/s	Videophone over ISDN
ISO MPEG-1 (11172-2)	1.2 Mbits/s	Video CD
ISO MPEG-2 (13818-2)	4–10 Mbits	Digital TV/HDTV
(ITU-T H.262)	20 Mbits/s	Over air/networks
ITU-T H.263	< 64k bits/s	Videophone
ISO MPEG-4 (14496-2)	Low/high-rates	Object-oriented
ISO MPEG-7 (15938)	Database	Content description
ITU-T H.263 v2	< 64k bits/s	PSTN/wireless Videophone
ITU-T H.264 (JVT,AVC)	< 40k bits/s	Net/wireless Videophone
ITU-T H.264 ext (SVC)	Multi-layer	Net/wireless streaming

ISDN: Integrated Services Digital Network

AT&T Picturephone@

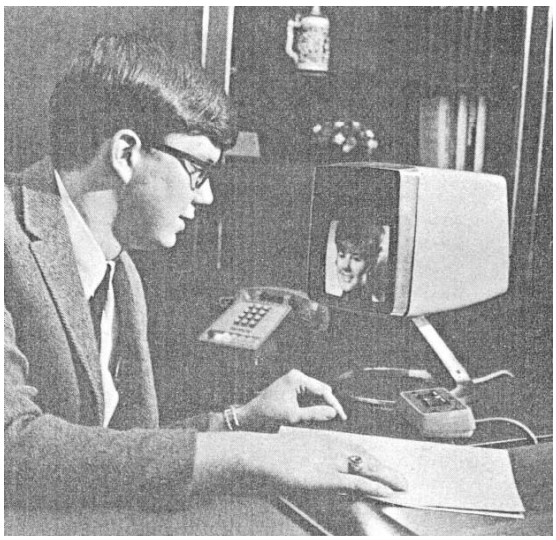
- *1984, Visual Communications Dept. of AT&T Bell Labs,*

  At a corner of a lab. shelf …



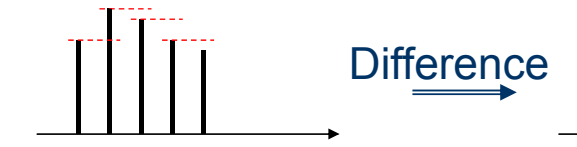
AT&T Picturephone (2)

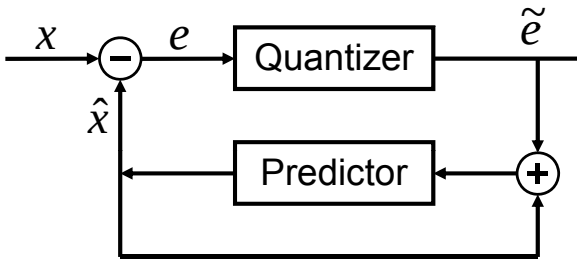
- "Mod II" was developed and field-tested by AT&T Bell Labs around 1966-1969. Commercial service July 1, 1970. (*BSTJ,* Feb. 71)
- Digital: 275 pels x 250 lines; 6.312 Mb/s (T2 line)

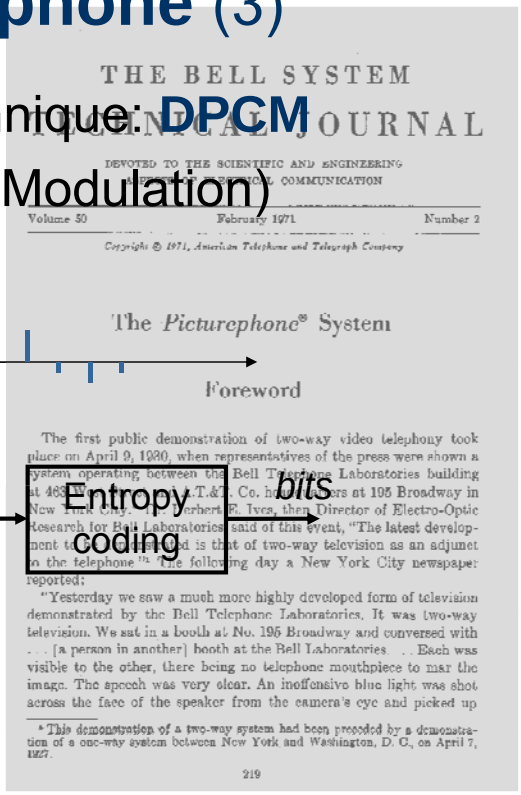


AT&T Picturephone (3)

- Image Compression Technique: **DPCM** (Differential Pulse Coded Modulation)







THE BELL SYSTEM TECHNICAL JOURNAL

DEVOTED TO THE SCIENTIFIC AND ENGINEERING ASPECTS OF ELECTRICAL COMMUNICATION

Volume 50 February 1971 Number 2

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The *Picturephone*® System

Foreword

The first public demonstration of two-way video telephony took place on April 9, 1930, when representatives of the press were shown a system operating between the Bell Telephone Laboratories building at 463 West Street and A.T.&T. Co. headquarters at 195 Broadway in New York City. Herbert E. Ives, then Director of Electro-Optic Research for Bell Laboratories, said of this event, "The latest development to be demonstrated is that of two-way television as an adjunct to the telephone." The following day a New York City newspaper reported:

"Yesterday we saw a much more highly developed form of television demonstrated by the Bell Telephone Laboratories. It was two-way television. We sat in a booth at No. 195 Broadway and conversed with . . . [a person in another] booth at the Bell Laboratories . . . Each was visible to the other, there being no telephone mouthpiece to mar the image. The speech was very clear. An inoffensive blue light was shot across the face of the speaker from the camera's eye and picked up

[a] This demonstration of a two-way system had been preceded by a demonstration of a one-way system between New York and Washington, D. C., on April 7, 1927.

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NCTU MPEG Activity

- Tihao Chiang (蔣迪豪), C.J. Tsai (蔡淳仁), Wen Peng (彭文孝) and H.-M. Hang (杭學鳴)
- Tihao Chiang : Co-editor, MPEG-4 Part 7 **Optimised Reference Software** (Done)
- C.J. Tsai : Co-editor, MPEG-21 Part 12 **Multimedia Test Bed for Resource Delivery** (Done)
- 100+ contributions (input and output documents) in the past 8 years. [Dr. Y.-S. Tung (童怡新), NTU; Prof. Chris Lee (李國君), NCKU]
- ***Example:* Call for Proposal on Scalable Video Coding** (Feb. 2004) – 2 out of 14 proposals
- **HEVC proposal**: 2010.2 – one out of 27

MPEG Committee

- Convener: Leonardo Chiariglione
- Standards:
  -- MPEG-1: done
  -- MPEG-2: done
  -- MPEG-4: done?!
  -- MPEG-7: done?!
  -- MPEG-21: done?
  -- MPEG A,B,C,D,E: on-going

MPEG-2:*1996 Emmy for Technical Excellence*
AVC: 2008 *ATAS Primetime Emmy Engineering Award*
2009 *Paired NATAS Tech & Eng Emmy Award*

ISO/IEC 11172 MPEG-1

MPEG - 1 1992 Coding of moving pictures and associated audio for digital storage media at up to about 1,5 Mbit/s

Part 1 – MPEG-1 Systems
Part 2 – MPEG-1 Video for CD
Part 3 – MPEG-1 Audio (Layers I, II, and III)
Part 4 – Conformance
Part 5 – Software

ISO/IEC 13818 MPEG-2

MPEG - 2 1994 Generic coding of moving pictures and associated audio information

1996 Emmy for technical excellence

Part 1 Systems
Part 2 Video
Part 3 Audio
Part 4 Conformance
Part 5 Technical Report
Part 6 DSM CC - Digital Storage Media Cmd and Cntl
Part 7 AAC - Advanced Audio Coding
Part 9 RTI - Real Time Interface
Part 10 Conformance Extensions
Part 11 IPMP on MPEG-2 Systems

ISO/IEC 14496 MPEG-4

MPEG - 4 1998 Coding of audio-visual objects

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 Software
Part 8 MPEG 4 on IP
Part 9 Reference Hardware
Part 10 Advanced Video Coding (AVC) (JVT, H.264)
Part 11 Scene Description and Application Engine
Part 12 ISO Base Media File Format
Part 13 IPMP Extensions
Part 14 MP4 File Format
Part 15 AVC File Format
Part 16 Multimedia Animation Framework eXtension (AFX)
Part 17 Streaming Text Format
Part 18 Font Compression and Streaming
Part 19 Synthesized Streams
Part 20 Lightweight Application Scene Representation
Part 21 MPEG-J Extension for rendering
Parts 22 --25

ISO/IEC 15938 MPEG-7

MPEG - 7 2001 Multimedia content description interface

Part 1 Systems
Part 2 DDL - Description definition language
Part 3 Visual
Part 4 Audio
Part 5 Multimedia description schemes
Part 6 Reference software
Part 7 Conformance testing
Part 8 Extraction and use of description
Part 9 MPEG-7 Profiles
Part 10 Schema Definition
Part 11 Profile Schemas Part 12 Query format

ISO/IEC 21000 MPEG-21

Part 1 Vision, Technologies and Strategy
Part 2 Digital Item Declaration (DID)
Part 3 Digital Item Identification (DII)
Part 4 Intellectual Property Management and Protection (IPMP)
Part 5 Rights Expression Language (REL)
Part 6 Rights Data Dictionary (RDD)
Part 7 Digital Item Adaptation (DIA)
Part 8 Reference Software
Part 9 File Format
Part 10 Digital Item Processing
Part 11 Persistent Association
Part 12 Multimedia Test Bed Resource Delivery
Part 14 Conformance Testing
Part 16 Binary Format
Part 17 Fragment Identification for MPEG Media Types
Part 18 Digital Item Streaming Part 19 Media Value Chain Ontology

MPEG-A,B,C,…

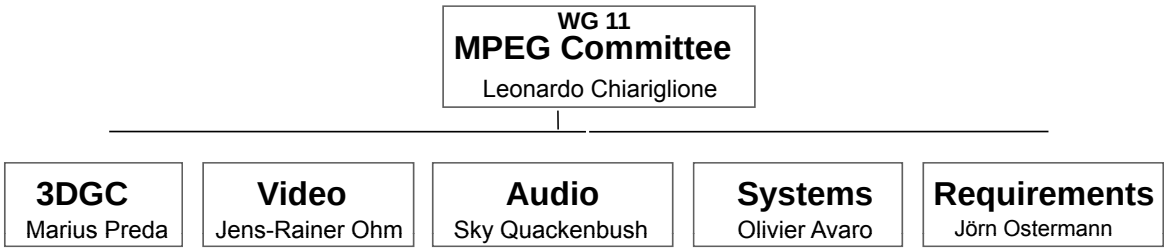
- **MPEG-A** (ISO/IEC 23000) Multimedia Application Formats
- **MPEG-B** (ISO/IEC 23001) MPEG Systems Technologies
- **MPEG-C** (ISO/IEC 23002) MPEG Video Technologies
- **MPEG-D** (ISO/IEC 23003) MPEG Audio Technologies
- **MPEG-E** (ISO/IEC 23004) Multimedia Middleware (M3W)
- **MPEG-H** High Efficiency Video Coding (HEVC)
- **MPEG-M** (ISO/IEC 23006) MPEG Extensible Middleware (MXM)
- **MPEG-U** (ISO/IEC 23007) Rich-Media User Interface
- **MPEG-V** (ISO/IEC 23005) Media Context and Control

MPEG Chair Dr. Chiariglione at NCTU (2003.12)

- http://www.chiariglione.org

MPEG Meetings

- 4 meetings a year; 5+ days per meeting
- ~200 participants
- Over 200 companies
- Meetings are divided into groups



The MPEG Process

1. **Exploration**
   Search for new technology
2. **Requirements**
   Establish work scope
   Call for Proposals
3. **Competitive phase**
   Do Homework
   Response to CfP
   Initial technology selection
4. **Collaborative phase**
   Core Experiments
   Working Drafts
5. **Standardization**
   Ballots
   National Body Comments
6. **Amendment**
   Adding new technology
7. **Corrigenda**
   Corrective actions
8. **New subdivisions**
   Add new non-compatible technology

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