Fundamentals of Multimedia

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4. Fundamental Concepts in Video

Content

1. Types of Video Signals

Component video;

Composite Video;

S-Video

1.1 Component video

- High-end video systems, such as for studio
  - Three separated video signals -- Red， Green and Blue image plane
  - Three wires connecting to Camera or other devices to TV or monitor
- Giving the best color reproduction
  - No "crosstalk" between the different channels
  - Requiring more bandwidth and good synchronization
- Besides RGB， YIQ, YUV and other model can be used
  - Luminance-chrominance transformation from RGB

1.2 Composite Video

- Chrominance and luminance signals mixed into a single carrier wave
  - Chrominance -- I and Q (or U and V)
  - Only one wire – some interference

Composite Video Cable and Connection

- Used by broadcast color TV，downward compatible with black-and-white TV
  - In NTSC TV，I and Q combined into chrominance signal，at the higher frequency end of the channel；

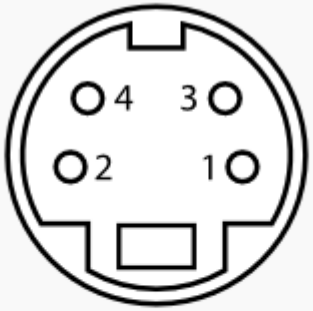
1.3 S-Video

- Separated video，or Super-video
- Two wires
  - One for luminance
  - Another for a composite chrominance
  - Less crosstalk
- Black-and-White: crucial for visual perception
  - Humans – better spatial resolution for grey-scale image
  - Color information – less accurate

1.3 S-Video

- S-Video Connector Example

A standard 4-pin S-Video cable connector, with each signal pin paired with its own ground pin.



Connector Pinout (looking at the socket).

Pin 1	GND	Ground (Y)
Pin 2	GND	Ground (C)
Pin 3	Y	Intensity (Luminance)
Pin 4	C	Color (Chrominance)

2. Analog Video

Related Concepts

NTSC Video, PAL Video, SECAM Video,

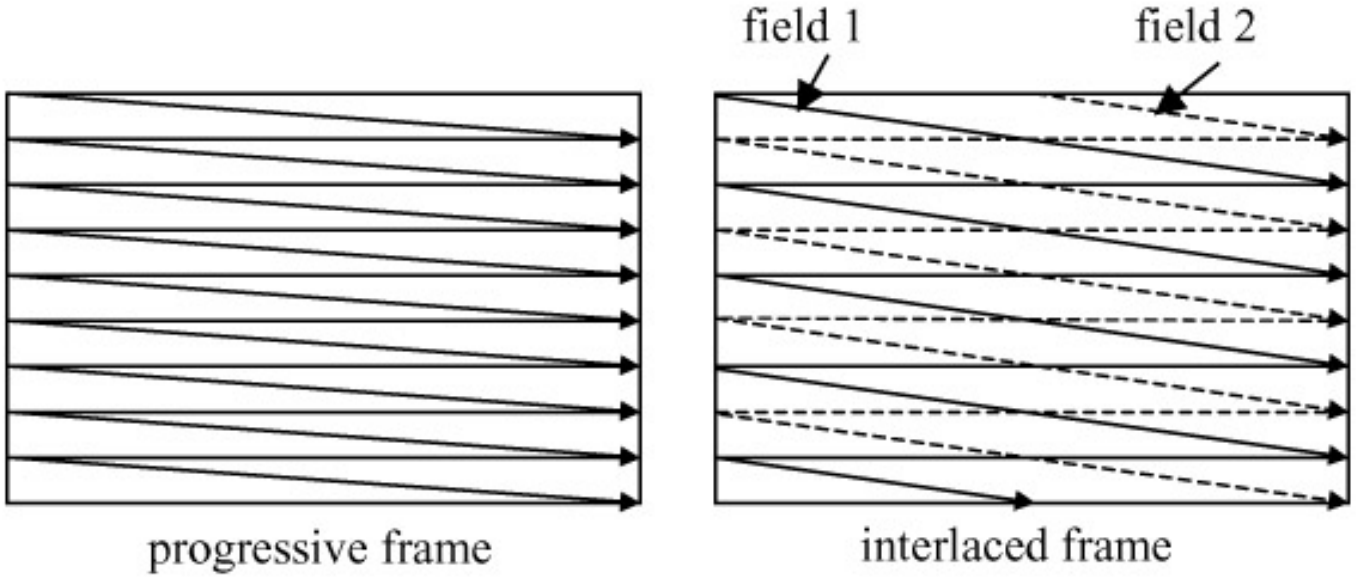
Comparison NTSC, PAL and SECAM

2.1 Related Concepts

- Analog signal : f(t) -- time-varying images
- Progressive scanning
  - Scanning a complete frame row-wise for each interval
  - High-resolution monitor – an interval of 1/72 second
- Interlaced scanning
  - Odd-numbered lines first, then even-numbered lines
  - “odd” and “even” fields make up a frame
  - Reducing perceived flicker
  - High-speed action – image blurred
  - De-interlace
- Vertical retrace and horizontal retrace

2.1 Related Concepts

- Two-dimensional scene transformed into one-dimensional signal
- Scan lines – Object resolutions and bandwidth



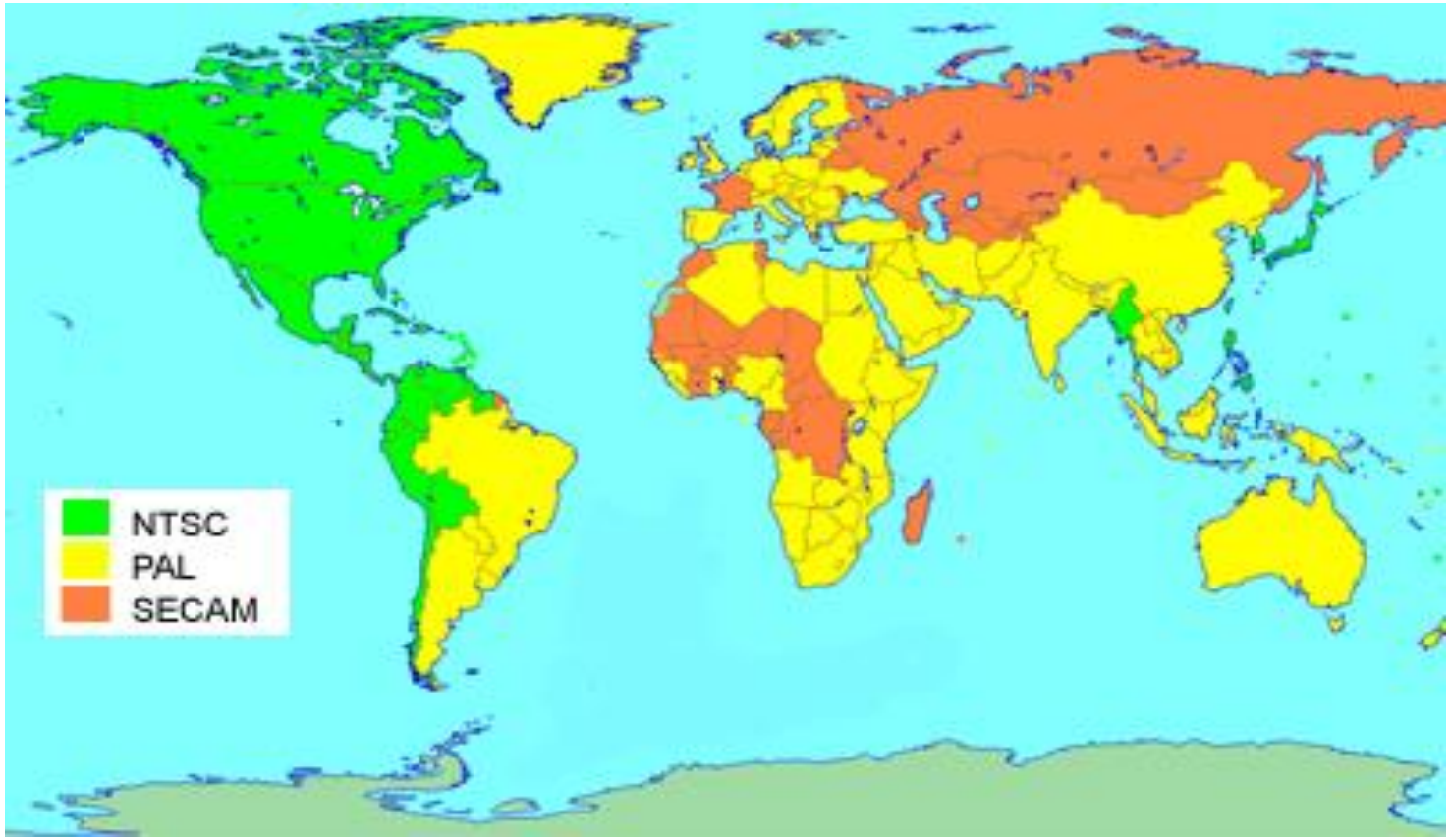
2.1 Related Concepts

- **Television Standards for analog TV**
  - **NTSC Video（正交平衡调幅）**
    - **USA, Canada, Japan and Korea，1953 by USA**
  - **PAL Video（逐行倒相正交平衡调幅）**
    - **Germany, England and China, 1962 by Germany**
  - **SECAM Video（顺序传送彩色与存储）**
    - **France, Russia，1966 by France**

- **Downward compatible with black-and-white TV system**
  - **Parameters Consistence: scan method, scan row-frequency, field frequency, frame frequency, image carrier-frequency, audio carrier-frequency**
  - **Signal transmission Consistence: Luminance signal, two chrominance signals**

2.1 Related Concepts

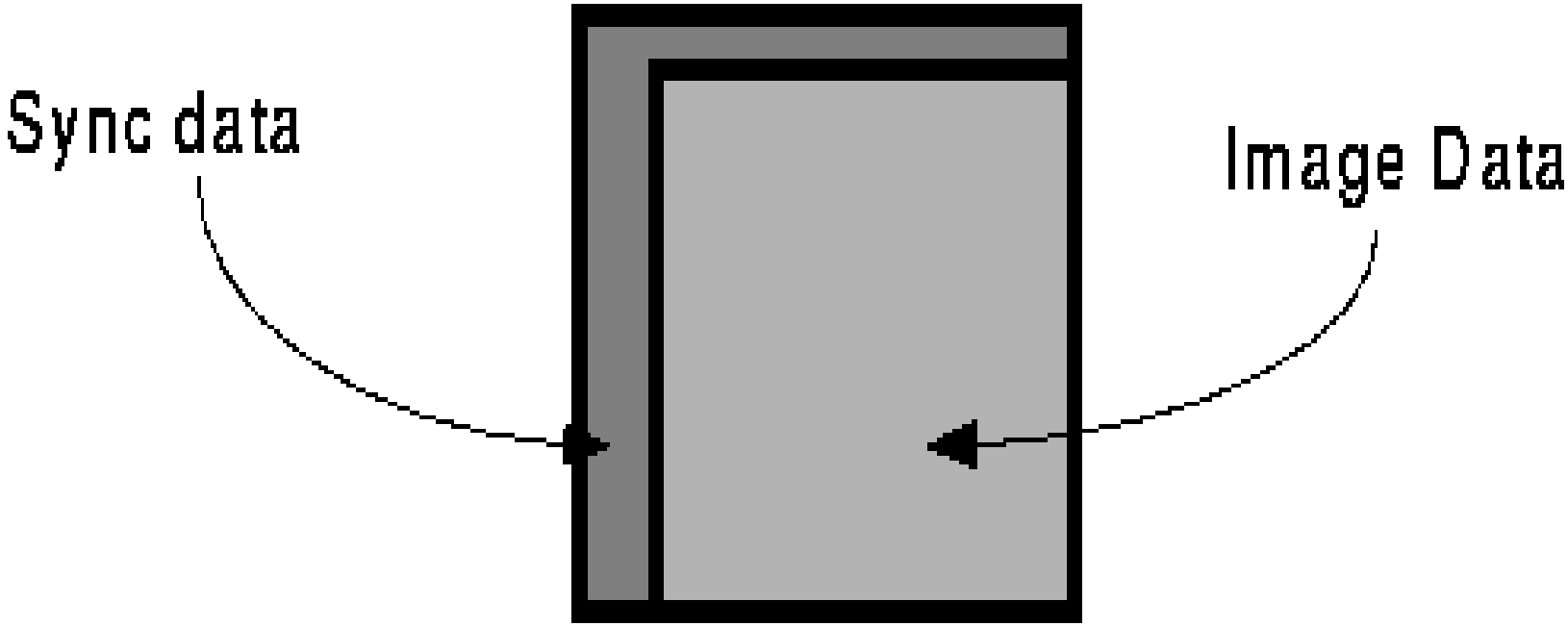
- Standards distribution



2.2 NTSC Video

- NTSC (National Television Standards Committee)
  - 4:3 length and width ratio;
  - 525 line per frame;
  - 30 frames per second (30 fps)。
- Detailed parameter
  - 29.97 fps; or 33.37ms per frame;
  - Interlace scan, 262.5lines/fields
  - Horizontal scan frequency, 525×29.97=15,734 lines;
  - Time per line: 1/15,734=63.6*u*sec（10.9+52.7）
  - Vertical Retrace, reserved 20 lines per fields; 485 lines
  - Horizontal scan, 1/6 of raster reserved
  - Horizontal resolution – sample number per line

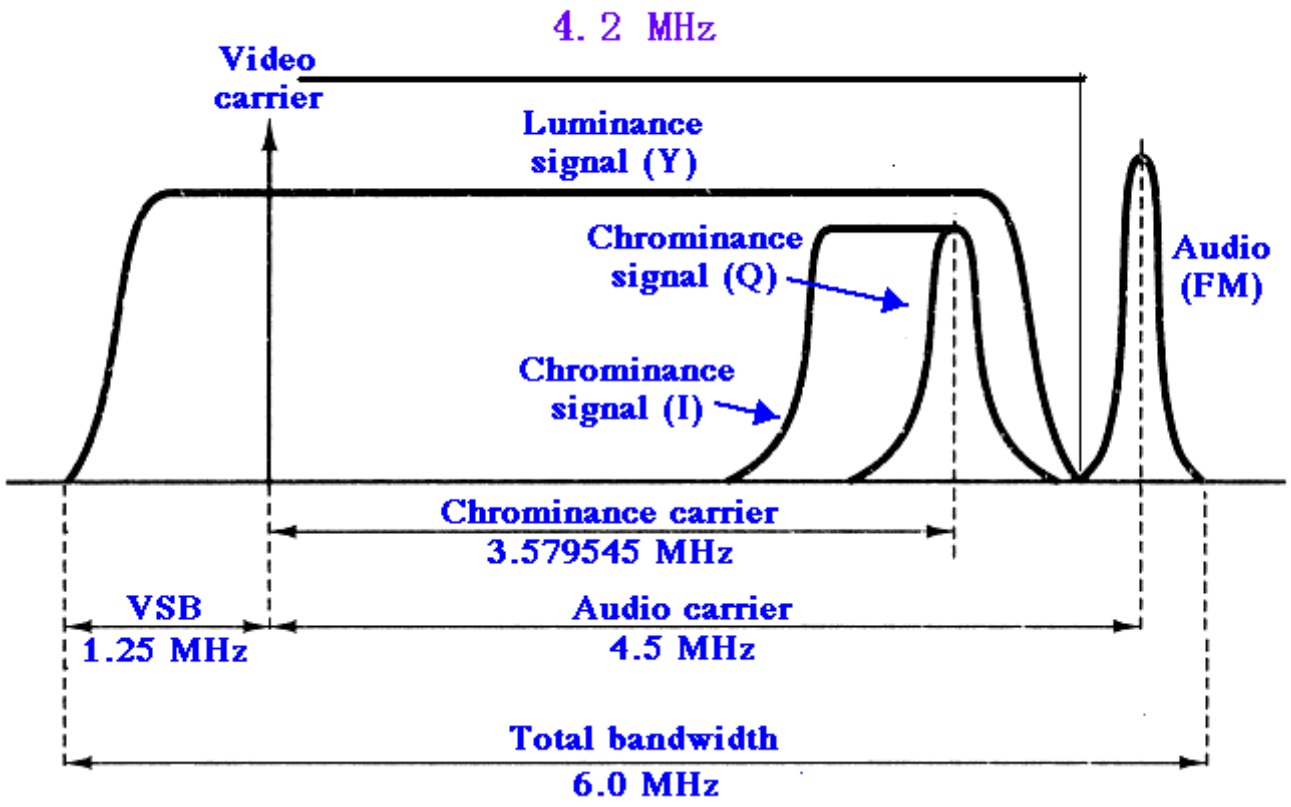
2.2 NTSC Video



2.2 NTSC Video

- **YIQ Color Model**
  - Quadrature Modulation to mix I and Q into one signal
  - C=I cos（$F_{sc}t$）＋Q sin($F_{sc}t$) called color sub-carrier
  - Magnitude：$\sqrt{I^2+Q^2}$
  - Phase： $\tan^{-1}(Q/I)$
  - Frequency F_{sc}＝3.58MHZ
  - Composite＝Y＋C=Y+ I cos（$F_{sc}t$）＋Q sin($F_{sc}t$)
- **Related Parameter**
  - 4.2Mhz for Y；
  - 1.6Mhz for I；
  - 0.6Mhz for Q

2.2 NTSC Video



2.2 NTSC Video

- **The spectrum shows:**
  - **The picture carrier at 1.25MHz, total bandwidth 6MHz**
  - **The color subcarrier Fsc≈3.58MHz, high-end of the channel, the center frequency 1.25+3.58=4.83MHz**
  - **Audio carrier 4.5MHz, center frequency 1.25+4.5=5.75MHz**

- **NTSC: slow frame rate , reduce the interference between color and audio**
  - **Frame frequency: 30*1000/1001≈29.97fps**
  - **Fsc=29.97*525*227.5≈3.579545MHz**

2.2 NTSC Video

- **Steps for decoding the composite signal:**
  - **First, extract Y using low-pass filters**
    - $Y + I\cos(F_{sc}t) + Q\sin(F_{sc}t)$
  - **After separation from Y, demodulate C to extract I and Q**
  - **1. C multiply 2 cos(Fsc t)**
    - $C \cdot 2\cos(Fsc\ t) = I + I \cdot \cos(2Fsc\ t) + Q \cdot 2\sin(2Fsc\ t)$
  - **2. Apply low-pass to extract I**
  - **Similarly, Q can be extracted by multiply 2 $\sin(F_{sc}\ t)$**

2.3 PAL Video

- **PAL: Phase Alteration Line**
  - **625 scan lines, 25 frames/second, 4:3 aspect ratio**
- **Color Model -- YUV， Y –Luminance, U and V – Two Chrominance**

$$Y = 0.299R + 0.587G + 0.114B$$
$$U = -0.147R - 0.289G + 0.436B$$
$$V = 0.615R - 0.515G - 0.100B$$

- **In PAL standard: Y with bandwidth 5.5 MHz， U and V with bandwidth 1.8 MHz respectively**
- **HDTV（High Definition Television）: Y and U, V have the same bandwidth**

2.4 Comparison of NTSC, PAL and SECAM

TV System	Frame Rate (fps)	Number of Scan lines	Total channel width (MHz)	Bandwidth allocation (MHz)		
				Y	I or U	Q or V
NTSC	29.97	525	6.0	4.2	1.6	0.6
PAL	25	625	8.0	5.5	1.8	1.8
SECAM	25	625	8.0	6.0	2.0	2.0

3. Digital Video

Advantage of digital representation,

Chroma Subsampling,

Digital video CCIR standard, CIF standard

High Definition TV, Video image quality

3.1 Advantages of digital representation

- Storing video on digital devices or in memory
- Ready to be processed and integrated into various multimedia applications

- Direct access – nonlinear video editing
- Repeated recording without degradation of image quality
- Ease of encryption and better tolerance to channel noise

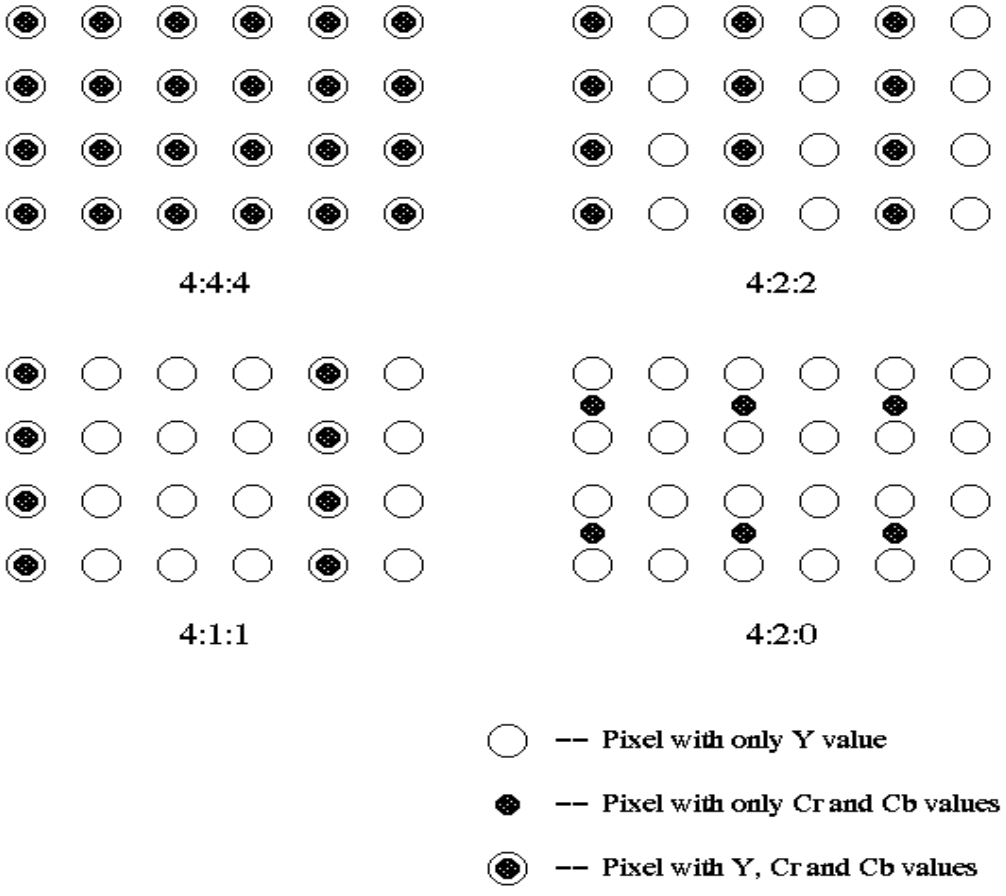
3.2 Chroma subsampling

- Human vision : see color with less resolution than Black and White – different Schemes

- Per four original pixels, how many pixel values really sent?
  - 4:4:4 indicates no subsampling
  - 4:2:2 indicates horizontal subsampling of Cb and Cr with factor 2
  - 4:1:1 indicates horizontal subsampling of Cb and Cr with factor 4
  - 4:2:0 indicates horizontal and vertical subsampling of Cb and Cr with factor 2 respectively

- 4:2:0 scheme generally used in JPEG and MPEG

3.2 Chroma subsampling



3.3 Digital video CCIR standard

- CCIR (Consultative Committee for International Radio)
- CCIR-601 : one important standard for component digital video, further become ITU-R-601 standard
- For NTSC standard:
  - 525 lines; 858 pixels（where, 720 is visible）;
  - 4:2:2 scheme;
  - One pixel -- two bytes
- CCIR 601（NTSC）date rate:
  - 525×858×30×2bytes×8bits/byte≈216Mbps

3.3 Digital video CCIR standard

Digital video Specification

	CCIR 601 525/60 NTSC	CCIR 601 625/50 PAL/SECAM	CIF	QCIF
Luminance Resolution	720×480	720×576	352×288	176×144
Chrominance Resolution	360×480	360×576	176×144	88×72
Color Subsample	4:2:2	4:2:2	4:2:0	4:2:0
Fields/sec	60	50	30	30
Supporting interlacing	Y	Y	N	N

3.4 CIF standard

- CIF -- Common Intermediate Format
  - Specified by CCITT; Superseded by ITU-T
- The idea of CIF: a format for lower bitrate, with the same quality as VHS
- QCIF -- Quartar-CIF， more lower bitrate
- The resolution of CIF/QCIF can be divided by 8 or 16
  - Convenient for block-based video coding in H.261、H.263

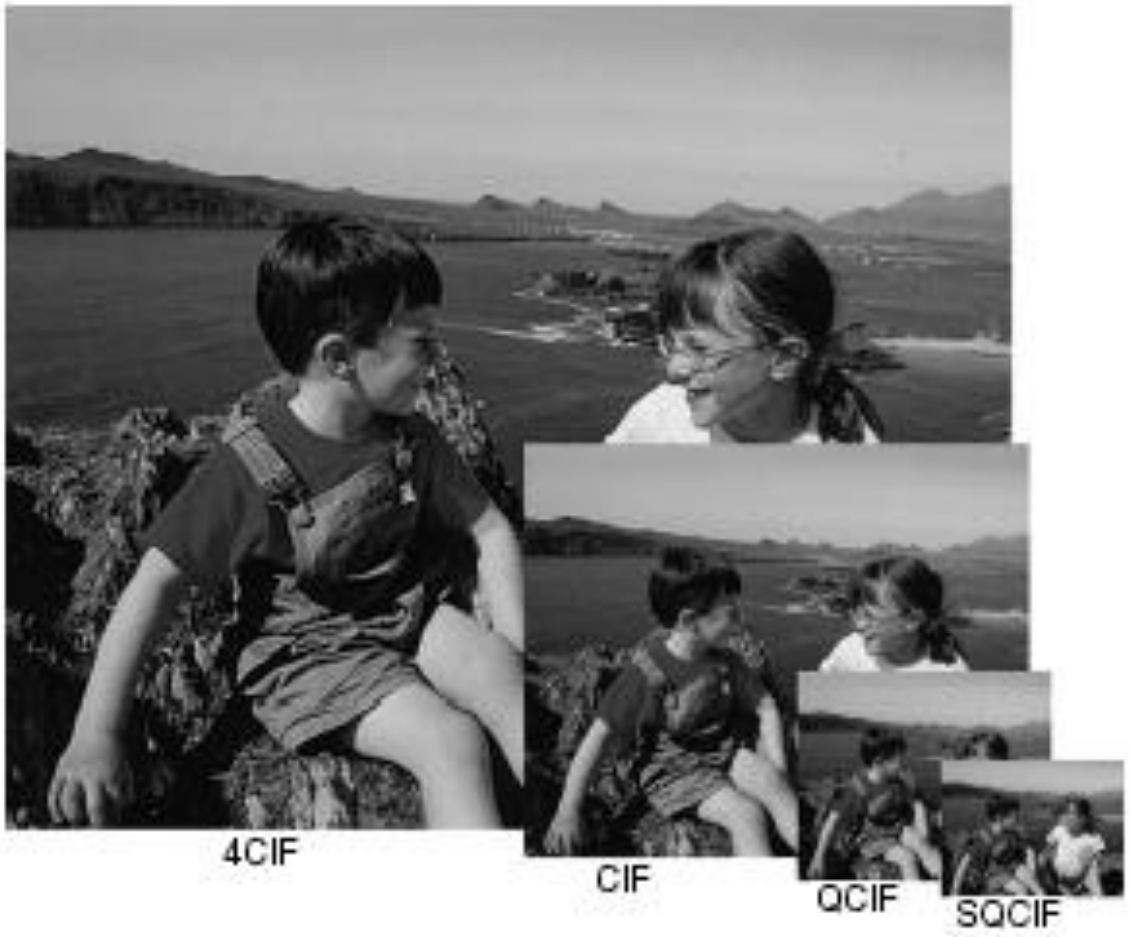
3.4 CIF standard

	CIF		QCIF		SQCIF	
	lines/frame	Pixel/line	lines/frame	pixel/line	lines/frame	pixel/line
Luminance(Y)	288	360(352)	144	180(176)	96	128
Chrominance(Cb)	144	180(176)	72	90(88)	48	64
Chrominance(Cr)	144	180(176)	72	90(88)	48	64

3.4 CIF Standard

- 4CIF、CIF、QCIF and SQCIF

CIF : 4:2:0 scheme



3.5 High Definition TV

- The first generation HDTV based on analog signal， in the late 1970s by Sony and NHK
  - 1,125lines； 60fields/second（Interlaced）
  - 16:9 aspect ratio；
  - DBS（Direct Broadcast Satellite）； 24 Mhz
- 1995， ATSC (Advanced Television System Committee) Digital TV standard recommended by FCC(Federal Communication Commission) ACATS (Advisory Committee on Advanced Television Service)
- MPEG2 Chosen as the compression standard
  - Main Level to High Level of the Main Profile
  - AC-3 for Audio ； 5.1 channel Dolby surround sound

3.5 High Definition TV

- **HDTV: Example**

3.5 High Definition TV

Active pixel per line	lines	Aspect ratio	Frame rate
1920	1080	16:9	60I 30P 24P
1280	720	16:9	60P 30P 24P
704	480	16:9 and 4:3	60I 60P 30P 24P
640	480	4:3	60I 60P 30P 24P

Digital format support by ATSC

The End

Thanks