5.2 Digital Video

- The advantages of digital representation for video are many. For example:

  (a) Video can be stored on digital devices or in memory, ready to be processed (noise removal, cut and paste, etc.), and integrated to various multimedia applications;

  (b) Direct access is possible, which makes nonlinear video editing achievable as a simple, rather than a complex, task;

  (c) Repeated recording does not degrade image quality;

  (d) Ease of encryption and better tolerance to channel noise.

5.2.1 Chroma Subsampling

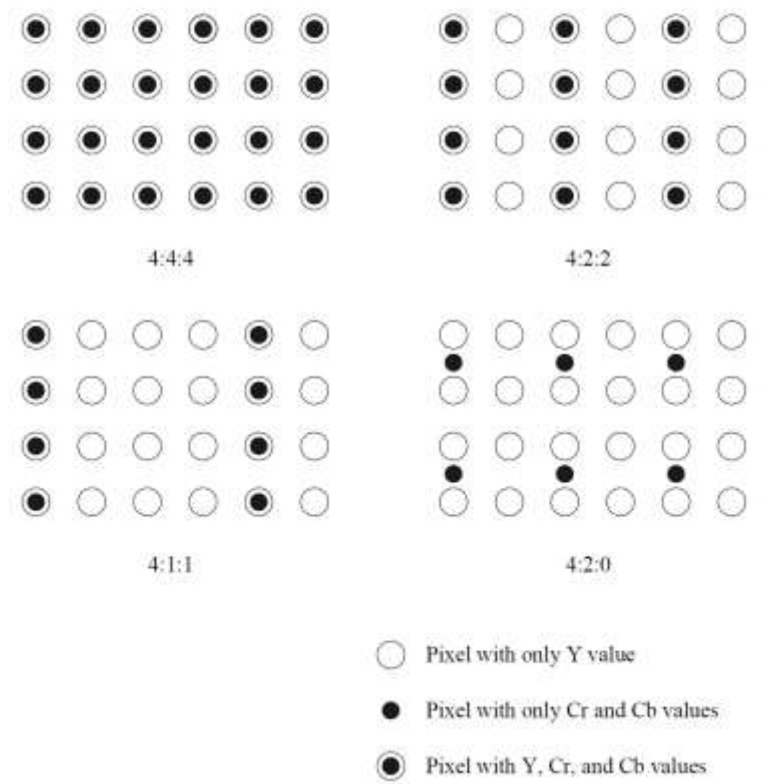
- Since humans see color with much less spatial resolution than they see black and white, it makes sense to “decimate” the chrominance signal.
- Interesting (but not necessarily informative!) names have arisen to label the different schemes used.
- To begin with, numbers are given stating how many pixel values, per four original pixels, are actually sent (kept).

5.2.1 Chroma Subsampling

- The chroma subsampling scheme "4:4:4" indicates that no chroma subsampling is used: each pixel's Y, Cb and Cr values are transmitted, 4 for each of Y, Cb, Cr.

- The scheme "4:2:2" indicates horizontal subsampling of the Cb, Cr signals by a factor of 2.
  – That is, of four pixels horizontally labelled as 0 to 3, all four Ys are sent, and every two Cb's and two Cr's are sent, as (Cb0, Y0)(Cr0, Y1)(Cb2, Y2)(Cr2, Y3), and so on (or averaging is used).
- The scheme "4:1:1" subsamples *horizontally* by a factor of 4.

- The scheme "4:2:0" subsamples in both the *horizontal* and *vertical* dimensions by a factor of 2.
  – Theoretically, an average chroma pixel is positioned between the rows and columns as shown Fig.5.6.
  – is commonly used in JPEG and MPEG (see later chapters in Part 2).



5.2.2 CCIR and ITU-R Standards for Digital Video

- **CCIR** is the Consultative Committee for International Radio, and one of the most important standards it has produced is CCIR-601, for component digital video.
  - This standard has since become standard ITU-R-601, an international standard for professional video applications
    - adopted by certain digital video formats including the popular DV video.

- Table 5.3 shows some of the digital video specifications, all with an aspect ratio of 4:3. The CCIR 601 standard uses an interlaced scan, so each field has only half as much vertical resolution (e.g., 240 lines in NTSC).

- CIF stands for Common Intermediate Format specified by the CCITT.

  (a) The idea of CIF is to specify a format for lower bitrate.

  (b) CIF is about the same as VHS quality. It uses a progressive (non-interlaced) scan.

  (c) QCIF stands for “Quarter-CIF”. All the CIF/QCIF resolutions are evenly divisible by 8, and all except 88 are divisible by 16; this provides convenience for block-based video coding in H.261 and H.263, discussed later in Chapter 10.

a) Note, CIF is a compromise of NTSC and PAL in that it adopts the 'NTSC frame rate and half of the number of active lines as in PAL.

Table 5.3: ITU-R digital video specifications

	CCIR 601 525/60 NTSC	CCIR 601 625/50 PAL/SECAM	CIF	QCIF
Luminance resolution	720 x 480	720 x 576	352 x 288	176 x 144
Chrominance resolution	360 x 480	360 x 576	176 x 144	88 x 72
Colour Subsampling	4:2:2	4:2:2	4:2:0	4:2:0
Fields/sec	60	50	30	30
Interlaced	Yes	Yes	No	No

5.2.3 High Definition TV (HDTV)

- The main thrust of **HDTV** (High Definition TV) is not to increase the "definition" in each unit area, but rather to increase the visual field especially in its width.

  a) The first generation of HDTV was based on an analog technology developed by Sony and NHK in Japan in the late 1970s.

  b) It has 1,125 scan lines, interlaced (60 fields per second), and 16:9 aspect ratio.

  c) Since uncompressed HDTV will easily demand more than 20 MHz bandwidth, which will not fit in the current 6 MHz or 8 MHz channels, various compression techniques are being investigated.

  d) It is also anticipated that high quality HDTV signals will be transmitted using more than one channel even after compression.

- A brief history of HDTV evolution:

  - In 1987, the FCC decided that HDTV standards must be compatible with the existing NTSC standard and be confined to the existing VHF (Very High Frequency) and UHF (Ultra High Frequency) bands.

  - In 1990, the FCC announced a very different initiative, i.e., its preference for a full-resolution HDTV, and it was decided that HDTV would be simultaneously broadcast with the existing NTSC TV and eventually replace it.

  - Witnessing a boom of proposals for digital HDTV, the FCC made a key decision to go all-digital in 1993. A “grand alliance” was formed that included four main proposals, by General Instruments, MIT, Zenith, and AT&T, and by Thomson, Philips, Sarnoff and others.

  - This eventually led to the formation of the ATSC (Advanced Television Systems Committee) — responsible for the standard for TV broadcasting of HDTV.

  - In 1995 the U.S. FCC Advisory Committee on Advanced Television Service recommended that the ATSC Digital Television Standard be adopted.

- The standard supports video scanning formats shown in Table 5.4. In the table, “I” mean interlaced scan and “P” means progressive (non-interlaced) scan.

Table 5.4: Advanced Digital TV formats supported by ATSC

# of Active Pixels per line	# of Active Lines	Aspect Ratio	Frame Rate
1,920	1,080	16:9	60P 60I 30P 24P
1,280	720	16:9	60P 30P 24P
704	480	16:9 or 4:3	60P 60I 30P 24P
640	480	4:3	60P 60I 30P 24P

- For video, MPEG-2 is chosen as the compression standard. For audio, AC-3 is the standard. It supports the so-called 5.1 channel Dolby surround sound, i.e., five surround channels plus a subwoofer channel.

- The salient difference between conventional TV and HDTV:

  a) HDTV has a much wider aspect ratio of 16:9 instead of 4:3.

  b) HDTV moves toward progressive (non-interlaced) scan. The rationale is that interlacing introduces serrated edges to moving objects and flickers along horizontal edges.

5.2.4 Ultra High Definition TV (UHDTV)

- UHDTV is a new generation of HDTV. The standards initiated in 2012 support 4K UHDTV: 2160P (3,840×2,160, progressive scan) and 8K UHDTV: 4320P (7,680×4,320, progressive scan).
- The aspect ratio is 16:9. The bit-depth is 10 or 12 bits per sample, and the chroma subsampling can be 4:2:0, 4:2:2, or 4:4:4.
- The supported frame rate has been gradually increased to 120 fps.
- The UHDTV will provide superior picture quality, comparable to IMAX movies, but it will require a much higher bandwidth and bitrate.

- 16K UHDTV has been demonstrated in 2018, targeting applications such as Virtual Reality with true immersion. Its resolution is 15,360 × 8,640 for a total of 132.7 megapixels.

Table 5.5: A Summary of UHDTV

Type of UHDTV	Resolution	Bit Depth	Aspect Ratio	Frame Rate
4K UHD (2160P)	3840 x 2160	10 or 12 bits	16:9	Up to 120P
8K UHD (4320P)	7680 x 4320	10 or 12 bits	16:9	Up to 120P
16K UHD (8640P)	15360 x 8640	10 or 12 bits	16:9	Up to 240P