Multimedia

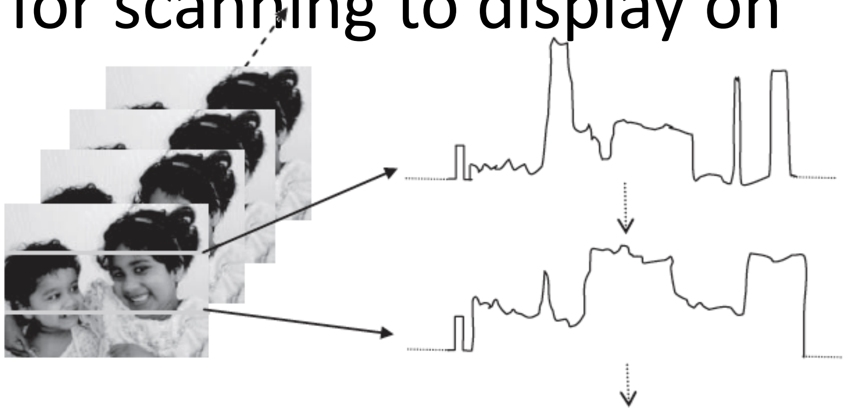
MEDIA REPRESENTATION
VIDEO, AUDIO & GRAPHICS

Representation of Digital Video

- Sequence of images shown in a quick succession
- Each image is called a frame
- Same properties as images: width, height, aspect ratio
- Additional: frame rate and scanning format.
  - Films used 24 fps while television use 30 fps or 25 fps (NTSC or PAL/SECAM)
  - Rate too slow → human perceives unevenness of motion called flicker

Analog video

- Digital TV → 3D (2D images changing over time)
- Analog TV → Converted into 1-D signal of scan lines
- Using electron guns in the television to draw image from left to right, top to bottom
- Color fades quickly, but frame rate ensures that guns fire again quickly using horizontal and vertical syncs
- Digital video → no need for scanning to display on digital devices.



Analog video & TV

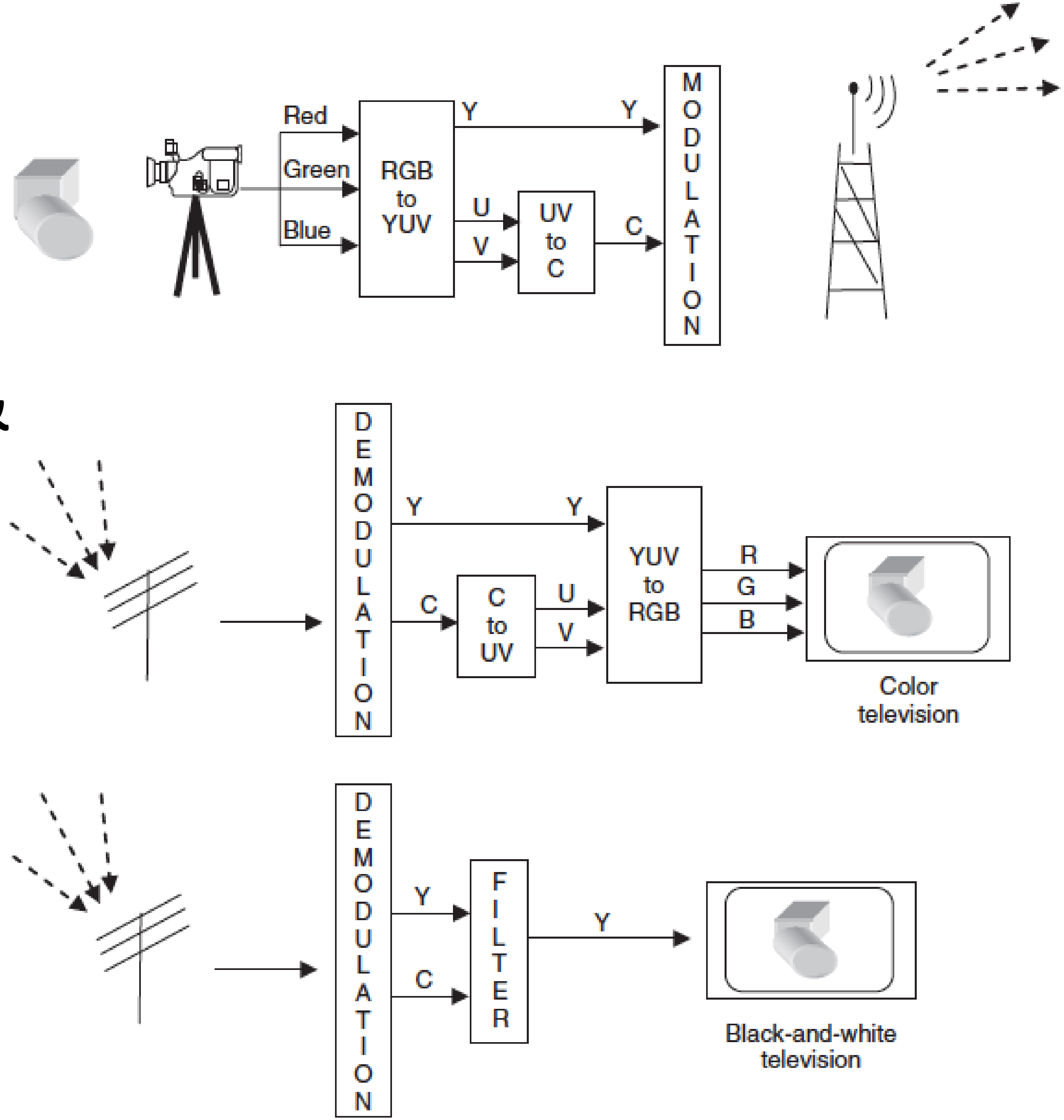
- Analog video: spatiotemporal information is ordered as a function of time = 1D signal.
- Scanned information is to be broadcasted to all users via broadcast station
- Broadcast of analog video → few requirements:
  - YUV color space conversion
  - Interlaced scanning

Analog video & TV

Conversion to YUV:

- RGB should be converted into YUV for transmission purposes
- Aim is to decouple the intensity information (Y or luminance) from the color information (UV or chrominance)
- Intention was to reduce the transmission bandwidth
- Based on the fact that humans are more tolerant to color distortions than to intensity distortions.
  - reducing the color resolution does not affect our perception

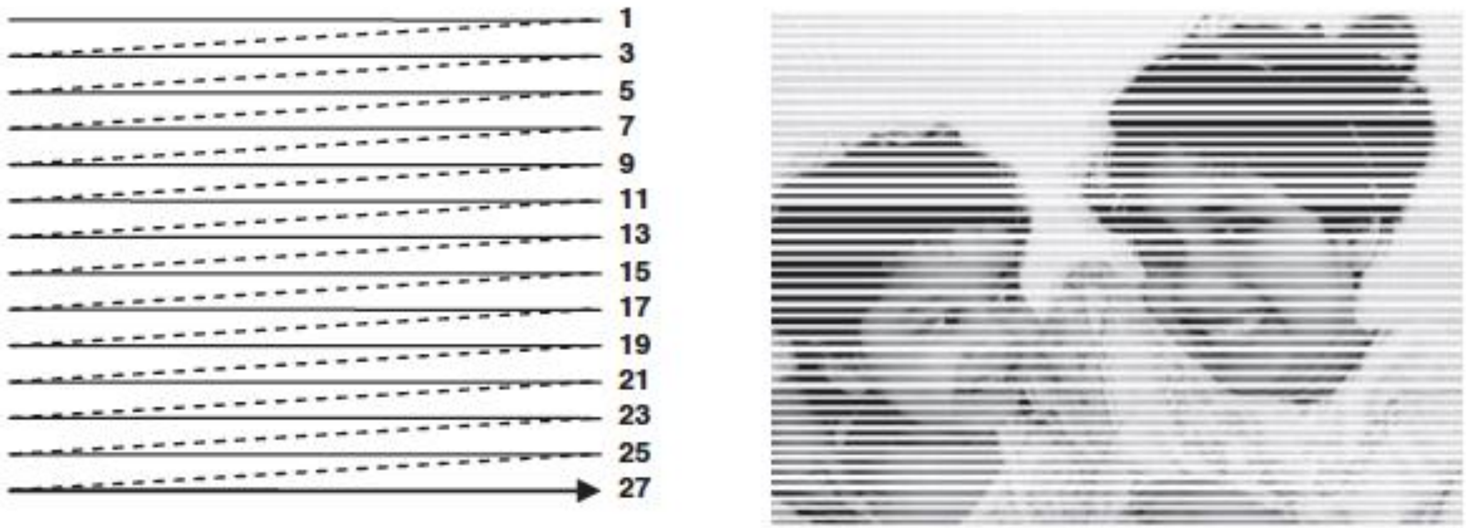
Analog video & TV



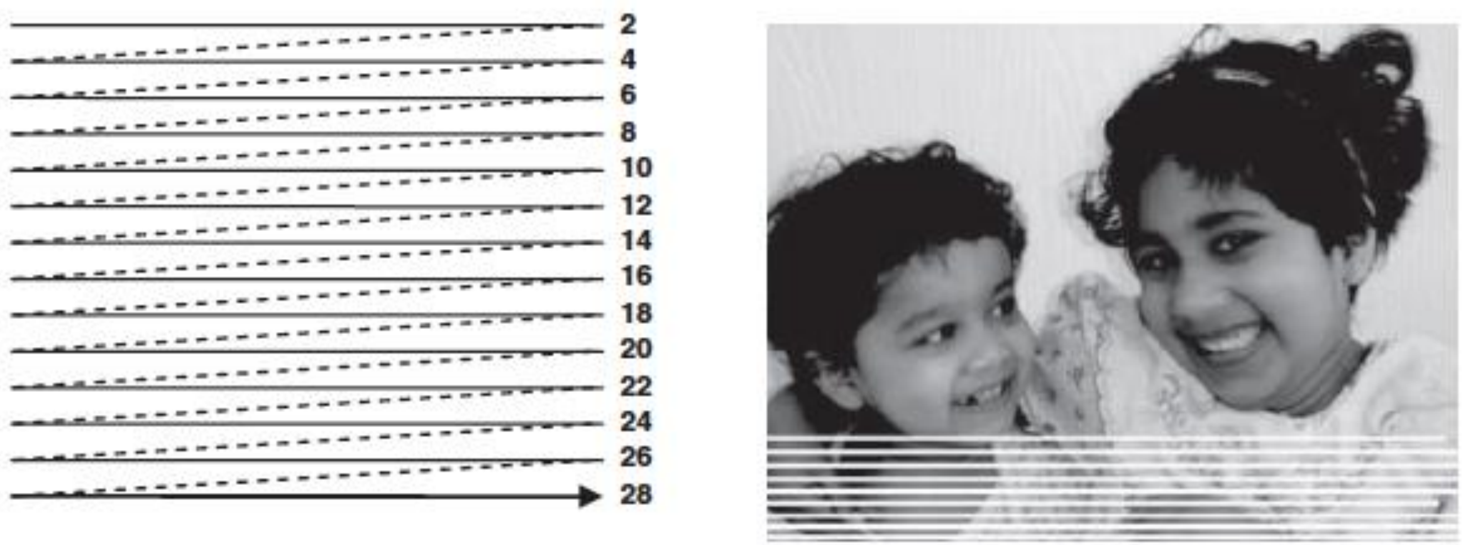
Analog video & TV

- Every 1/60 th of a second, electron gun is reset by vertical sync to draw next frame
- However, Each frame is broken down to odd and even fields. For NTSC televisions, every field is drawn at $1/60^{th}$ of a second which means each frame (2 fields) is drawn at 1/30 of second → 30 frames per second.
- This is called interlaced scanning

Interlaced scanning

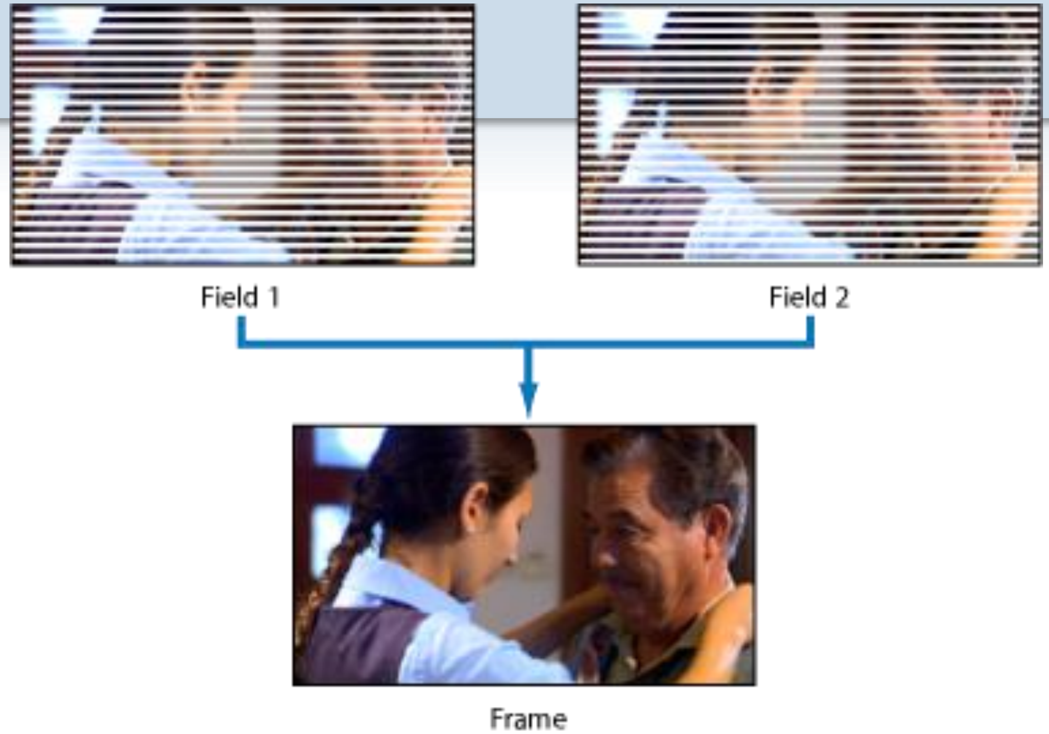


Upper field



Lower field

Interlaced scanning



Progressive scanning

Figure 3-11 Progressive scanning. All the scan lines are drawn in succession, unlike in the interlaced case.

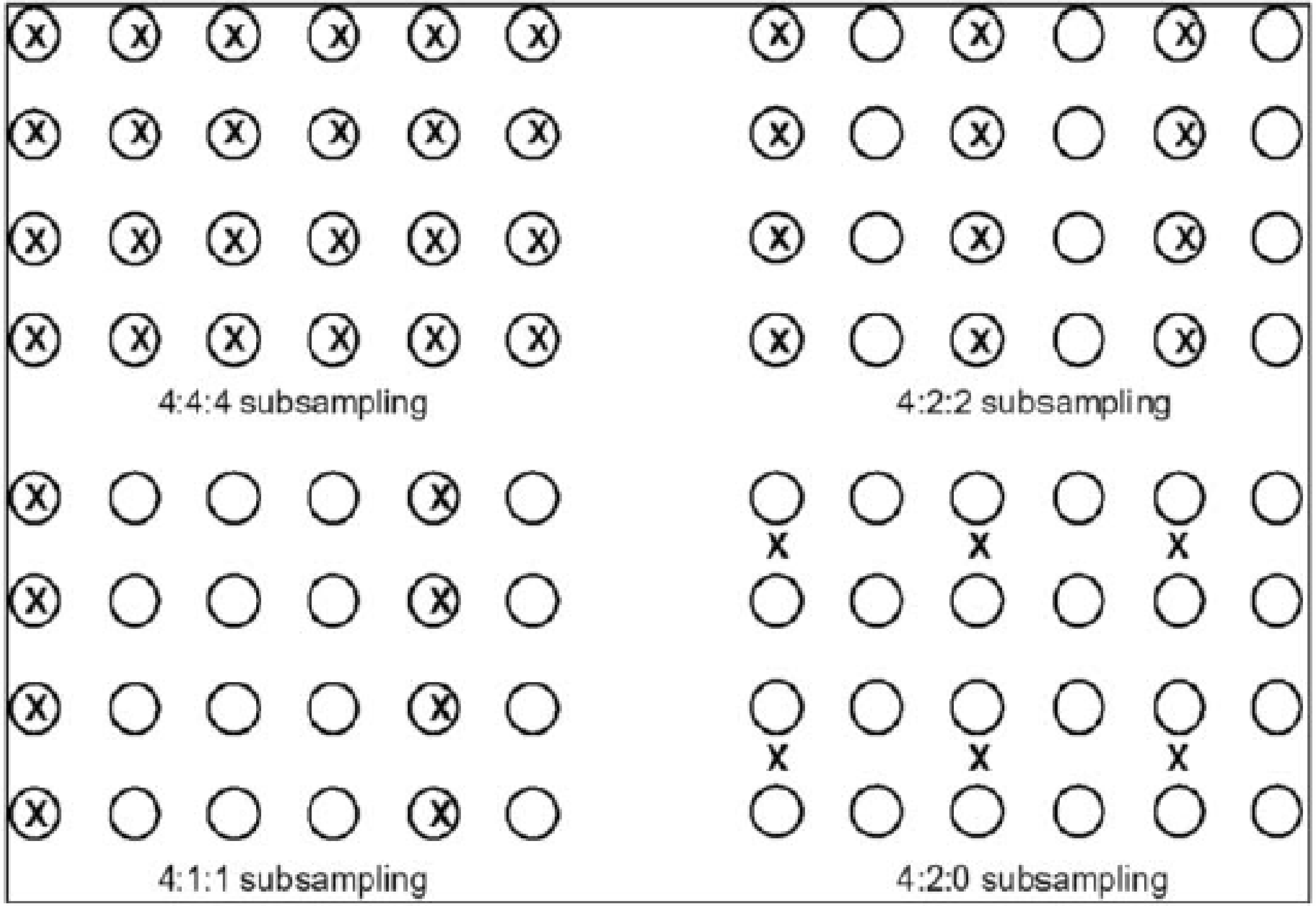
Types of Video Signals

- Video transmitted as analog $\Longrightarrow$ all information are combined in the same analog signal
- Composite video: combining luminance and chrominance for TV broadcast
  - Interference between luminance and chrominance leading bad quality especially when the broadcasted signal is weak
- Component video: transmit each channel separately
  - Require higher bandwidth but can produce higher quality
- S-video: super video Y and C, C contains U and V.
  - Y and C transmitted separately
  - Reduced interference
  - Better visual quality

YUV subsampling scheme

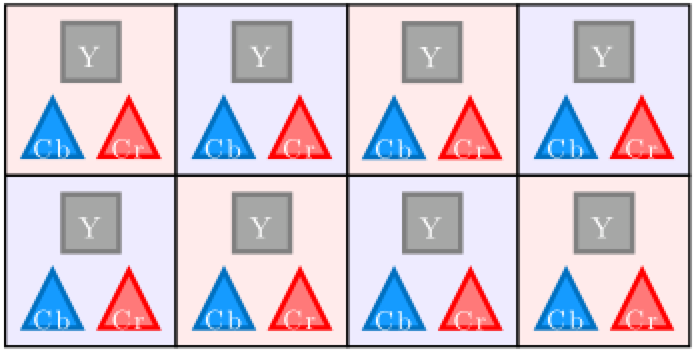
- Human eye is more sensitive to differences in brightness than to differences in color
- This is why, we can subsample the UV
- In analog, allocate half bandwidth to chrominance as to luminance.
- In Digital, reduce the number of bits per pixel for the color channels.
- Usually, 1 byte for each Y,U, V(24 bits total)
- The Y is left untouched → 1 byte
- Then we can alternate with UV

YUV subsampling scheme

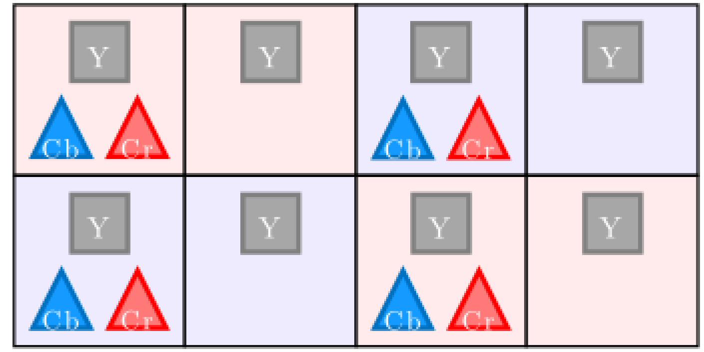


- An X inside the circle means we store the chrominance too for that pixel
- The X without circle is average of 2x2 pixel area of chrominance for U and V
- **What is the number of bits per pixel for each scheme?**

YUV subsampling scheme



4:4:4



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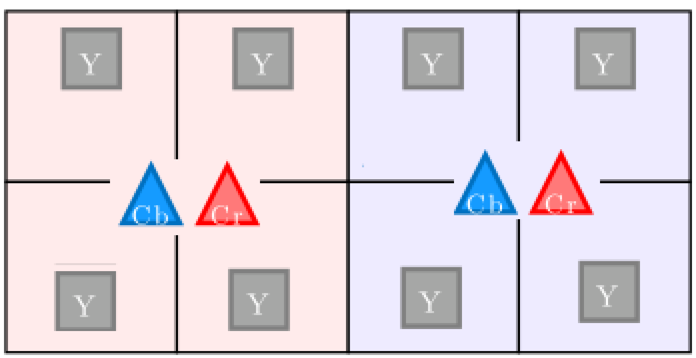

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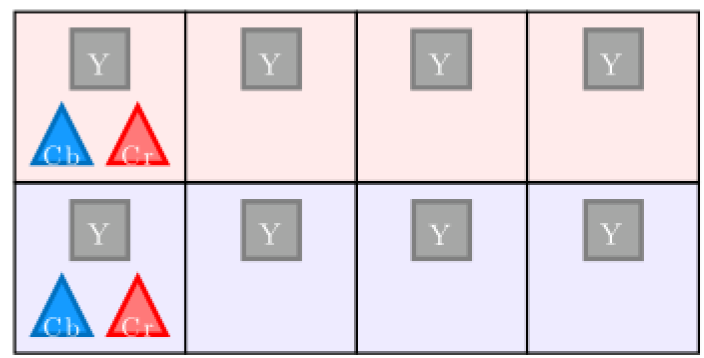


4:1:1

Analog Video Formats

- The well-known analog video formats

Property	NTSC	PAL	SECAM
Frame rate	30	25	25
Number of scan lines	525	625	625
Number of active lines	480	576	576
Aspect ratio	4:3	4:3	4:3
Color model	YIQ	YUV	YDbDr
Primary area of usage	North America (USA and Canada), Japan	Asia	France and Russia

HDTV

$720p$—1280×720 pixels progressive

$1080i$—1920×1080 pixels interlaced

$1080p$—1920×1080 pixels progressive

Digital Video Formats (1/2)

Format name	Lines per frame	Pixels per line	Frames per second	Support for interlaced format	Subsampling scheme	Image aspect ratio
CIF	288	352		N	4:2:0	4:3
QCIF	144	176		N	4:2:0	4:3
SQCIF	96	128		N	4:2:0	4:3
4CIF	576	704		N	4:2:0	4:3
SIF-525	240	352	30	N	4:2:0	4:3
SIF-625	288	352	25	N	4:2:0	4:3
CCIR 601 NTSC (DV, DVB, DTV)	480	720	29.97	Y	4:2:2	4:3
CCIR 601 PAL/SECAM	576	720	25	Y	4:2:0	4:3
EDTV (576p)	480/576	720	29.97	N	4:2:0	4:3/16:9

Digital Video Formats (2/2)

Format name	Lines per frame	Pixels per line	Frames per second	Support for interlaced format	Subsampling scheme	Image aspect ratio
HDTV (720p)	720	1280	59.94	N	4:2:0	16:9
HDTV (1080i)	1080	1920	29.97	Y	4:2:0	16:9
HDTV (1080p)	1080	1920	29.97	N	4:2:0	16:9
Digital cinema (2K)	1080	2048	24	N	4:4:4	47:20
Digital cinema (4K)	2160	4096	24	N	4:4:4	47:20

Digital Representation of Audio

- Analog audio signals are represented as waveforms, either simple or complex
- A simple waveform is a pure tone with single frequency
- A complex waveform has multiple frequencies or sinusoidal waves combined together (amplitude of complex signal is joint of all amplitudes of individual frequencies)
- Voice and music are complex of course.

Digital Representation of Audio

- To digitize, we need sampling and quantization.
- The process is known as PCM (pulse code modulation)

- Mono, stereo, or multichannel (surround)
- New technology: spatial audio

Audio formats (1/3)

File suffix or logo	Filename	File type	Features
.wav	WAV	Uncompressed PCM coded	Default standard for audio on PCs. WAV files are coded in PCM format.
.au	G.711 μ-law, or ITU μ-law	Uncompressed audio	Universal support for telephone. Packs each 16-bit sample into 8 bits, by using logarithmic table to encode with a 13-bit dynamic range. Encoding and decoding is very fast.
GSM 06.10	Global System for Mobile Communication	Lossy Compressed mobile audio	International standard for cellular telephone technology. Uses linear predictive coding to substantially compress the data. Compression/decompression is slow. Freely available and, thus, widely used
.mp3	MPEG1 Layer3	Compressed audio file format	Uses psychoacoustics for compression Very good bandwidth savings and, hence, used for streaming and Internet downloads.

Audio formats (2/3)

File suffix or logo	Filename	File type	Features
.ra	Real Audio	Compressed format	Proprietary to Real Audio. Capable of streaming and downloading. Comparable quality to mp3 at high data rates but not so at low data rates
AAC	Advanced Audio Codec MPEG4	Compressed format	Superior quality to .mp3.
.mid	MIDI—Musical Instrument Digital Interface	Descriptive format	MIDI is a language of communication among musical instruments. Description achieved by frequencies, decays, transients, and event lists. Sound has to be synthesized by the instrument.
DOLBY DIGITAL	Dolby Digital (formerly called	Compressed 5.1 surround sound	De facto standard of home entertainment (Dolby AC-3) Distributed with DVD, HDTV systems. Provides five discrete channels—center, left, right, surround left, and surround right—plus an additional six for LFE.

Audio formats (3/3)

File suffix or logo	Filename	File type	Features
DIGITAL dts SURROUND	DTS Surround Sound	Compressed 5.1 surround sound	Alternate to Dolby Digital. Distributed with DVDs, but not HDTV. Has higher data rate compared with Dolby Digital.
LUCASFILM THX ULTRA	THX Surround Sound	Compressed 5.1 surround sound	Designed for movie theaters (THX Ultra) as well home theaters (THX Select). Has become the select brand for surround sound today.
LUCASFILM THX ULTRA	THX Surround Sound Extended	Compressed 6.1 or 7.1 surround sound	Jointly developed by Lucasfilm, THX and Dolby Laboratories. Also known as Dolby Digital ES. Has a surround back channel, placed behind audience achieving 360^0 of sound.

Graphics

- Graphics started as 2D
- Now evolved to 3D
- Can be represented as vectors or rasters
- Vectors are geometric entities saved in a vector format (attributes such as color)
- Vector graphics need to be converted to raster to be displayed → grid of pixels with x,y coordinates and color values

Graphics

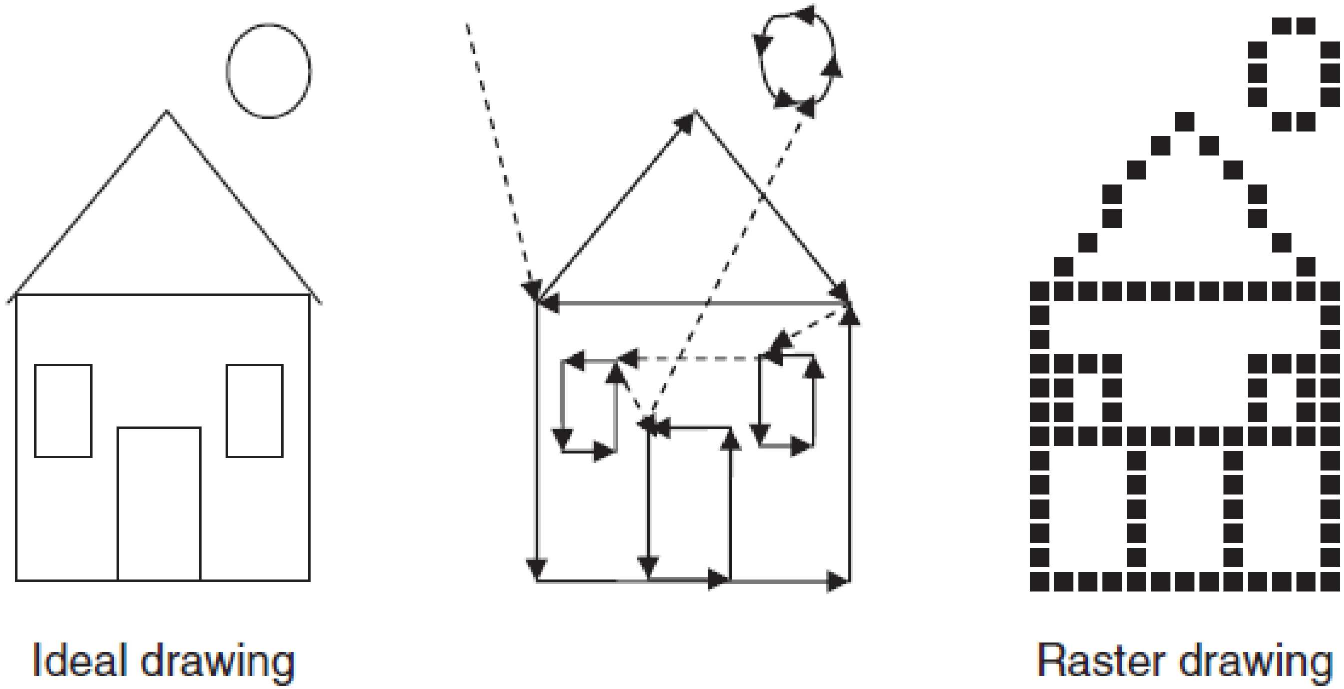


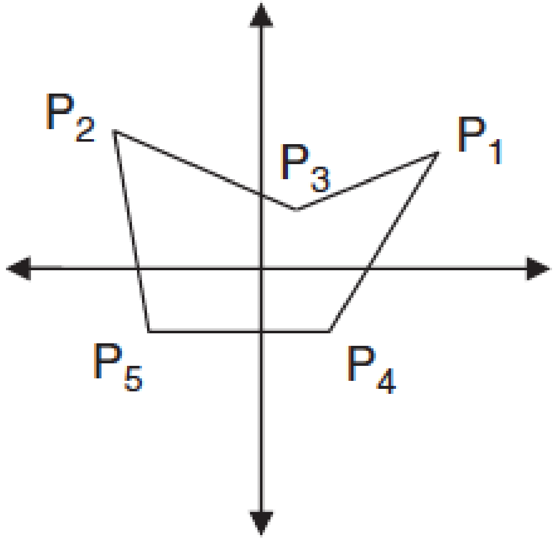
Figure 3-17 The left image shows a drawing that needs to be represented graphically. The middle image shows the corresponding representation using vectors. This is shown as a sequence of points joined by lines. The dotted lines show cursor movements. The right image shows a raster representation of the drawing.

2-D Graphics representation

- Entities can be smooth (circles, ellipses) or discrete (rectangles, triangles…)
- Discrete entities are points connected with lines called edges
- A polygon can be defined by a number of points connected in a sequence.

2-D Graphics representation

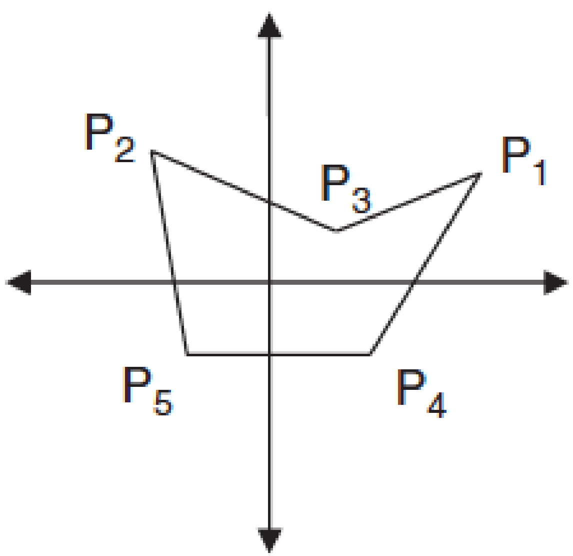
$$P_1 = \begin{bmatrix} x_1 \\ y_1 \end{bmatrix} \quad P_2 = \begin{bmatrix} x_2 \\ y_2 \end{bmatrix} \quad P_3 = \begin{bmatrix} x_3 \\ y_3 \end{bmatrix} \quad P_4 = \begin{bmatrix} x_4 \\ y_4 \end{bmatrix} \quad P_5 = \begin{bmatrix} x_5 \\ y_5 \end{bmatrix}$$

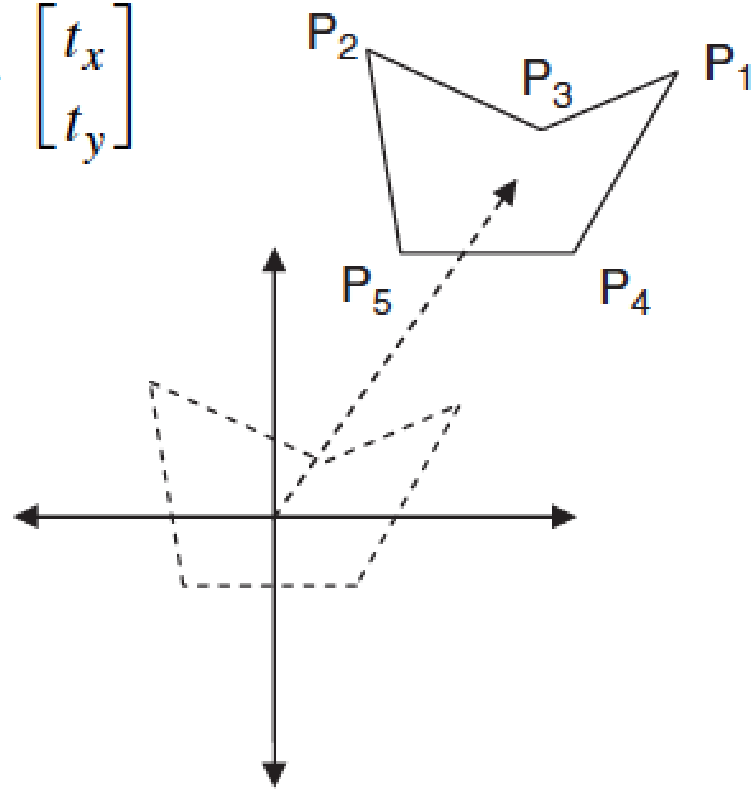


$$Polygon\ O = \begin{bmatrix} x_1 & x_4 & x_5 & x_2 & x_3 \\ y_1 & y_4 & y_5 & y_2 & y_3 \end{bmatrix}$$

Animation using 2-D (Translation)

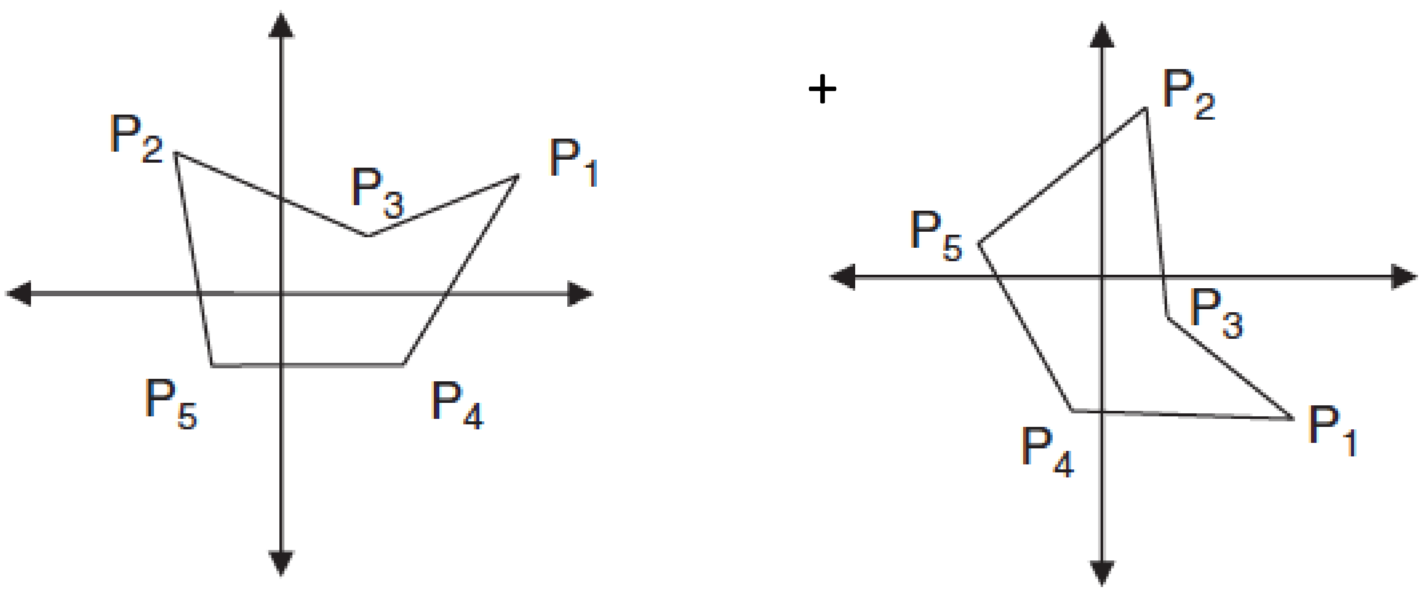
$$\begin{bmatrix} x_i + t_x \\ y_i + t_y \end{bmatrix} = \begin{bmatrix} x_i \\ y_i \end{bmatrix} + \begin{bmatrix} t_x \\ t_y \end{bmatrix}$$





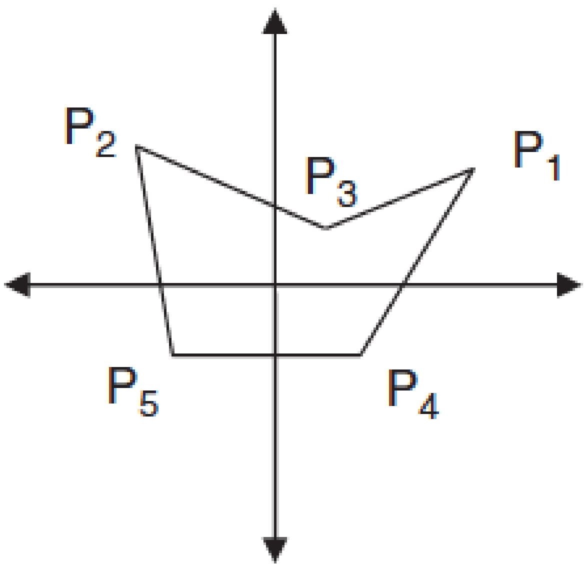
Animation using 2-D (Rotation)

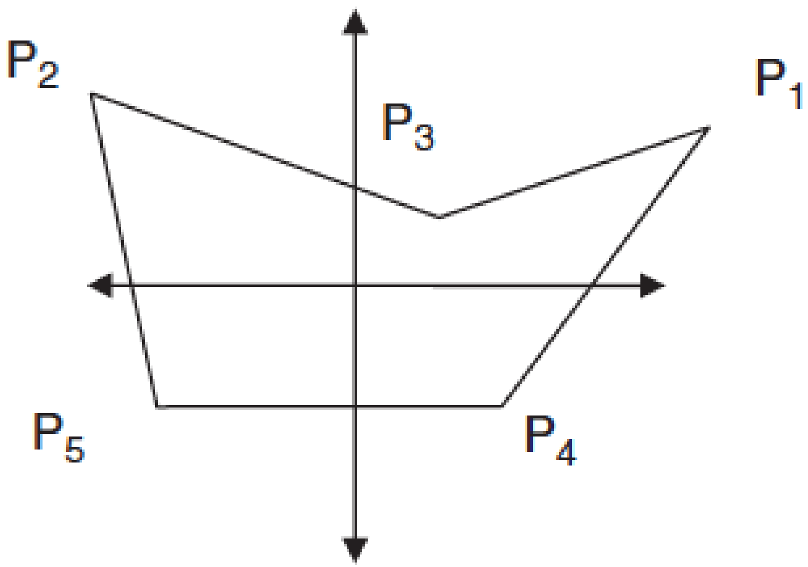
$$\begin{bmatrix} x_i \,\mathrm{Cos}\alpha & - & y_i \,\mathrm{Sin}\alpha \\ x_i \,\mathrm{Sin}\alpha & + & y_i \,\mathrm{Cos}\alpha \end{bmatrix} = \begin{bmatrix} \mathrm{Cos}\alpha & - & \mathrm{Sin}\alpha \\ \mathrm{Sin}\alpha & & \mathrm{Cos}\alpha \end{bmatrix} \times \begin{bmatrix} x_i \\ y_i \end{bmatrix}$$



Animation using 2-D (Scaling)

$$\begin{bmatrix} s_x \, X_i \\ s_y \, y_i \end{bmatrix} = \begin{bmatrix} s_x & 0 \\ 0 & s_y \end{bmatrix} \times \begin{bmatrix} x_i \\ y_i \end{bmatrix}$$





Combining RST needs a little extra step

Translations:
$$\begin{bmatrix} x_i + t_x \\ y_i + t_y \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & t_x \\ 0 & 1 & t_y \\ 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} x_i \\ y_i \\ 1 \end{bmatrix}$$

Rotations:
$$\begin{bmatrix} x_i \cos\alpha - y_i \sin\alpha \\ x_i \sin\alpha + y_i \cos\alpha \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\alpha & -\sin\alpha & 0 \\ \sin\alpha & \cos\alpha & 0 \\ 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} x_i \\ y_i \\ 1 \end{bmatrix}$$

Scaling:
$$\begin{bmatrix} s_x x_i \\ s_y y_i \\ 1 \end{bmatrix} = \begin{bmatrix} s_x & 0 & 0 \\ 0 & s_y & 0 \\ 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} x_i \\ y_i \\ 1 \end{bmatrix}.$$