01076566 Multimedia Systems

Chapter 3: Media Representation and Media Format

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Outline

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- Digital Image
- Digital Video
- Digital Audio
- Graphics

Digital Representation of Images

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- All images are represented digitally as pixels.
  - Defined by image width, height, and pixel depth
- The number of bits used per pixel in an image depends on the color space representation (gray or color and is typically segregated into channels.

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- In color image, each R, G, B channel may be represented by 8 bits each (24 bits for a pixel)
- Sometimes, an additional fourth channel called the alpha channel is used. Thus, 32 bits.
- E.g., a color image of 640 × 480. Each channel are represented by 8 bits
  - The size of color image = 640 × 480 × 3 × 8 = 7.37 Mbits
  - The size of a gray image = 640 × 480 × 1 × 8 = 2.45 Mbits

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A 24-bit RGB image

The RED channel

The GREEN channel

The BLUE channel

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A 32-bit CMYK image

The CYAN channel

The MAGENTA channel

The YELLOW channel

The KEY (black) channel

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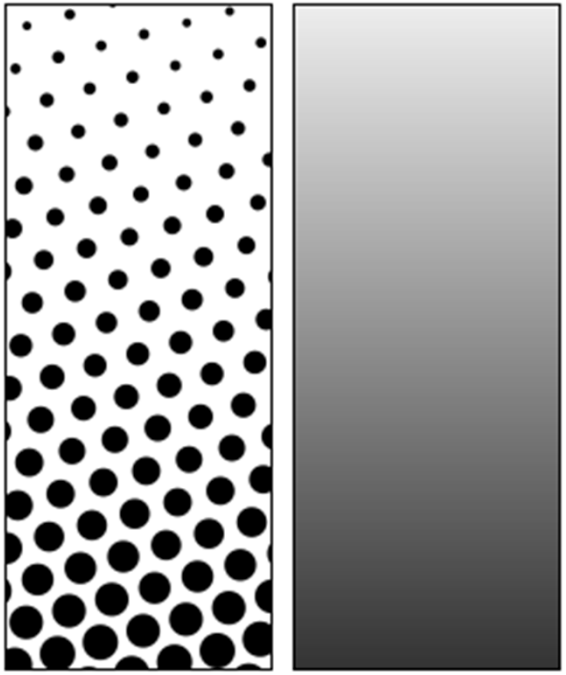

Left: Halftone dots. Right: How the human eye would see this sort of arrangement from a sufficient distance.

The first printed photo using a halftone, December 2, 1873.

- Alpha channel has a value between 0 and 1
  - A value of 0 means that the pixel does not have any coverage information and is transparent
  - A value of 1 means that the pixel is opaque because the geometry completely overlapped the pixel.

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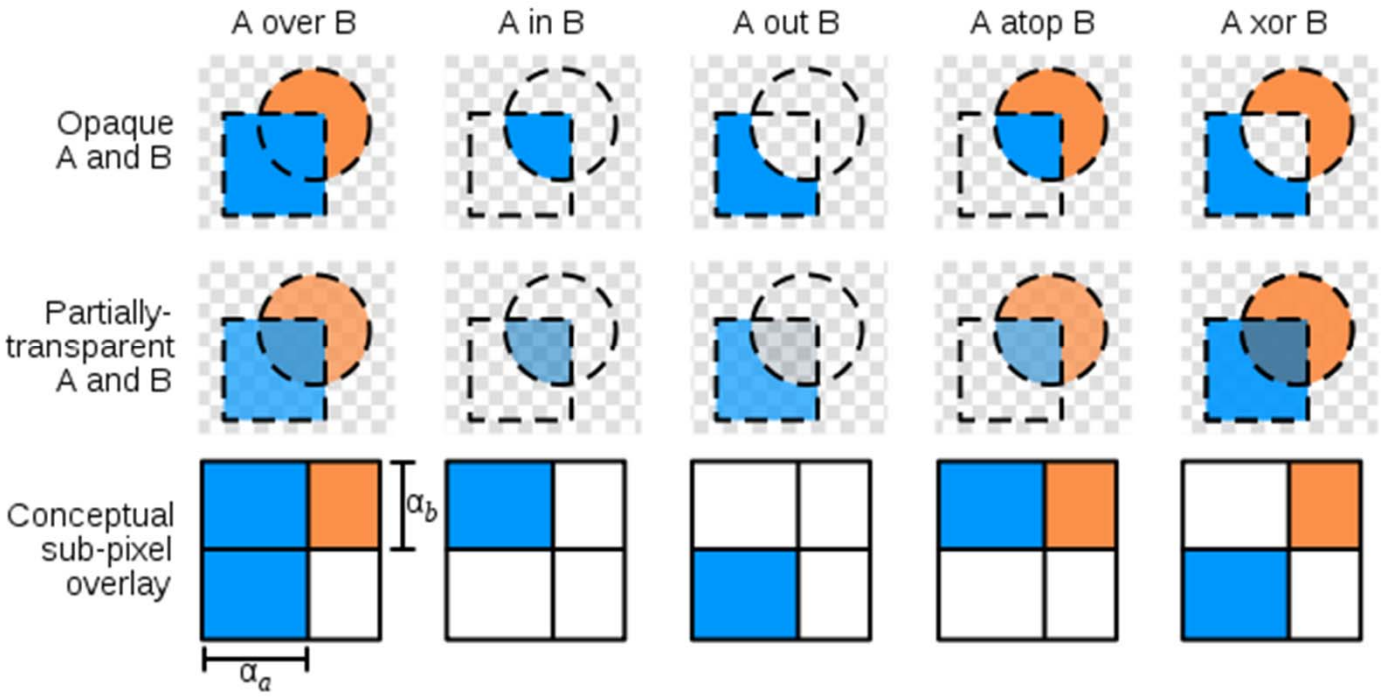

Aspect Ratios

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- Aspect ratio = the width/height ratio of the images
  - Printing photograph 3:2
  - Television image 4:3
  - High-definition image 16:9
  - Anamorphic formats used in cinemas 47:20

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4:3

16:9

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Braun HF 1 television receiver, Germany, 1958

Typical modern plasma-screen television set showing Windows Media Center.

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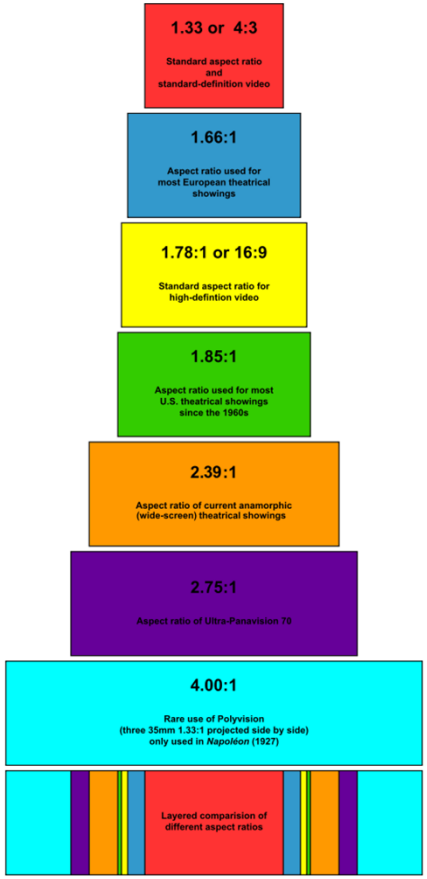

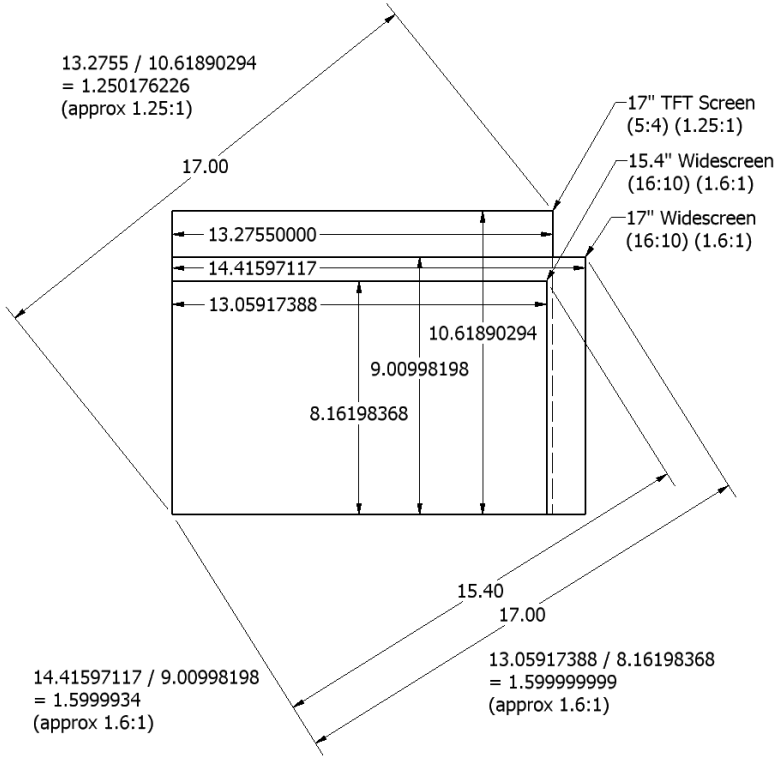

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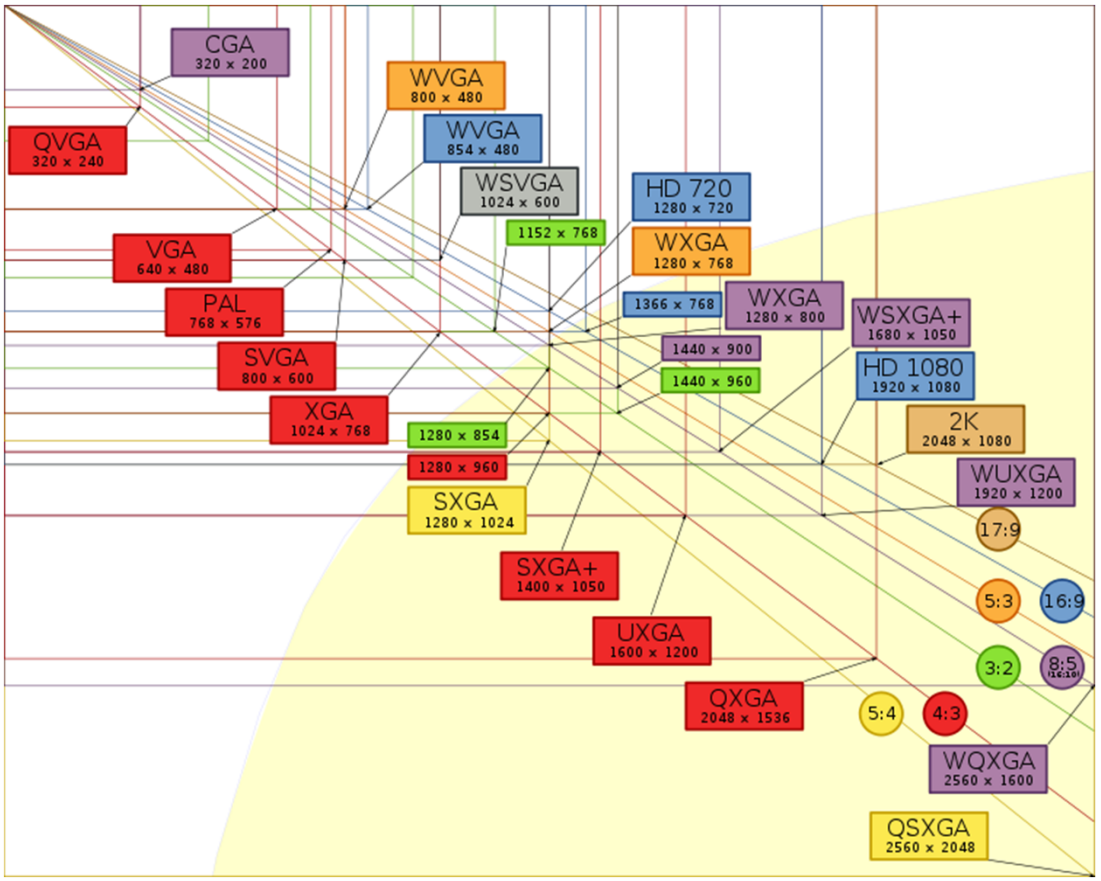

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- Pixel Aspect Ratio (PAR) or Sample Aspect Ratio (SAR)
  - An ability to change image aspect ratios can change the perceived appearance of the pixel sizes
- Most image capture instruments
  - Same sampling density in the horizontal and vertical directions
  - Therefore, square pixels
  - Thus, PAR = 1 : 1
- However, images using one aspect ratio standard are viewed on television screens supporting a different format
  - E.g., a change from 4:3 standard format to 16:9 HD format
  - Thus, PAR = 1.333 : 1

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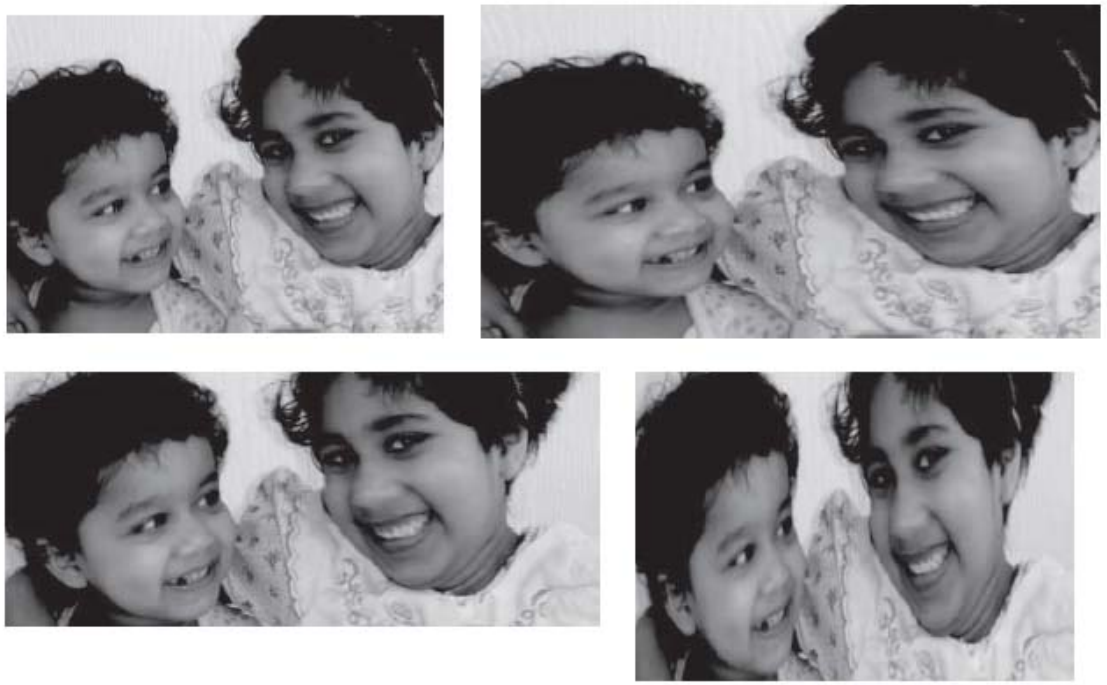

Figure 3-5 Illustration of pixel aspect ratio changes. The top two images show the 4:3 image (left) converted to a 16:9 format. The pixels appear horizontally stretched. The bottom two images show the anamorphic image resized to fit the 16:9 format (left) and a 4:3 format (right). The images appear stretched vertically because of irregular sampling in both dimensions causing nonsquare pixels.

Digital Image Formats

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- When images were not large, uncompressed formats can be used; a.k.a., raw image files
  - .bmp (bitmapped image) – images were represented as bitmaps and stored in a binary file
  - No artifacts of compression in representation and display
- Normally,
  - The initial captured or scanned images are kept in their raw uncompressed formats for processing and editing
  - Then, files are stored in a compressed format to save memory and bandwidth during network transfer
  - .jpg , .gif, .png

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File suffix	File name	File type	Features
.bmp	Windows bitmap	Uncompressed raster	Represents from 1 to 24 bits per pixel. Normally uncompressed but can use lossless run length encoding (RLE)
.pcx	Windows Paintbrush	Uncompressed/ compressed raster	Used only on Microsoft Windows platforms. Has similar features to .bmp.
.gif	Graphics Interchange Format	Compressed raster	Predominantly used on the Web. Allows 256 indexed colors and simple animations. Alpha channel supported. Uses LZW compression Proprietary to CompuServe

(Continued)

Figure 3-7 Table illustrating various commonly used file formats and the salient features each format supports

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.jpg, .jpeg	Joint Photographic Experts Group	Compressed raster	For continuous tone pictures (photographs). Lossy and lossless compression supported. No alpha channel supported. Level of compression can be specified. Commonly used on the Web
.png	Portable Network Graphics	Compressed raster	Allows 1–48 bits of color. Supports alpha channel. Designed to replace proprietary .gif files. File format approved by W3C
.psd	Adobe Photoshop	Uncompressed layered raster	Used for image editing. Supports a variety of color models. Supports varying pixel bit depths Image can be organized into layers. Commonly used processing file format.
.psp	Paint Shop Pro	Uncompressed layered raster	Similar to .psd

.tif, .tiff	Tagged Image File Format	Uncompressed raster, also compressed raster	Used in traditional print graphics. Can be compressed using lossless and lossy methods of compression, including RLE, JPEG, and LZW. TIFF comes in many flavors
.fh	Macromedia Freehand	Compressed vector format	Proprietary to Macromedia, used by Flash Players. Supports animation
.cdr	CorelDRAW	Uncompressed vector format	Proprietary to Corel
.swf	Macromedia Shockwave Flash format	Uncompressed vector format	Proprietary format created by Macromedia (now Adobe). Contains vector representations and animations that can be put on the Web.
.dxf	AutoCAD ASCII Drawing Interchange Format	Uncompressed vector format	ASCII text stores vector data. Used for 2D/3D graphical images.
.ps or .eps	Postscript, or Encapsulated Postscript	Uncompressed metafile	Supports text, fonts, vectors, and images.
.ai	Adobe Illustrator	Metafile format	Proprietary format. Similar to .eps.
.pdf (portable document format)	Adobe PDF document	Compressed metafile	Supports text, fonts, and images. Commonly used document format. Supports hyperlinks. Supports authorized access.
.pict	Macintosh Quickdraw	Compressed metafile	Used predominantly on Macintosh platforms. Can use RLE or JPEG compression. Supports grayscale, RGB, CMYK, or indexed color.

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- Raster image – images stored as row of pixels and have a width and height
- Vector image – image data are store in terms of geometric objects. The object are specified by parameters such as line styles, side lengths, radius, color, gradients, etc.

```
Object myRectangle
LineType Dotted
LineWidth 4
LineColor  0 0 0
FillColor 255 0 0
Rectangle (100,200) (200,220)
EndObject
Object myCircle
LineColor 0, 0, 0
FillColor 0 0 255
Circle (200, 200), 50
EndObject
```

Figure 3-6 Vector file description showing two objects—a red rectangle and a blue circle

Digital Video
Representation of Digital Video

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- Video
  - A sequence of discrete image shown in quick succession
  - Each image in the video is called a frame
  - A frame is represented as a matrix of pixels defined by a width, height, and pixel depth
  - The pixel depth is represented in a standardized color space such as RGB
  - Image attributes remain constant

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- Two additional properties
  - Frame rate
  - Scanning format
- Frame rate
  - Film is displayed at 24 frames per second
  - Television
    - 30 frames per second (NTSC)
    - 24 frames per second (PAL)
  - If the frame rate is too slow, the human eye perceives an unevenness of motion called flicker

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- Digital video can be considered as a three-dimensional signal
  - A 2D image changing over time
- Analog video is converted to a 1D signal of scan lines

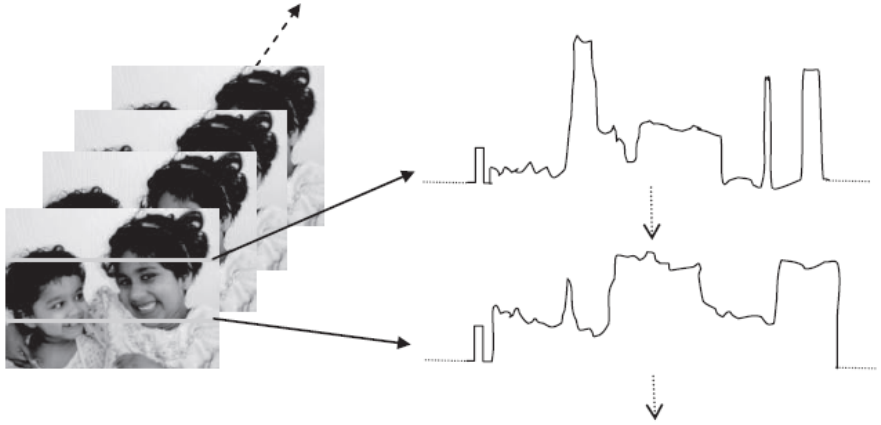

Figure 3-8 Left: Video is represented as a sequence of images. Right: Analog video of one frame scanned as a 1D signal. Each scan line is scanned from left to right as an analog signal separated by horizontal syncs. Two scan lines are shown; each begins with a horizontal sync and traces through the intensity variation on that scan line.

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- Digital video display
  - LCD or plasma does not require the scanning mechanism
- However, digital video standards have their representations and formats closely tied to analog TV standards
  - NTSC (National Television Systems Committee)
  - PAL (Phase Alternating Line)
  - SECAM (Système Electronique Couleur Avec Mèmoire)

Analog Video and Television

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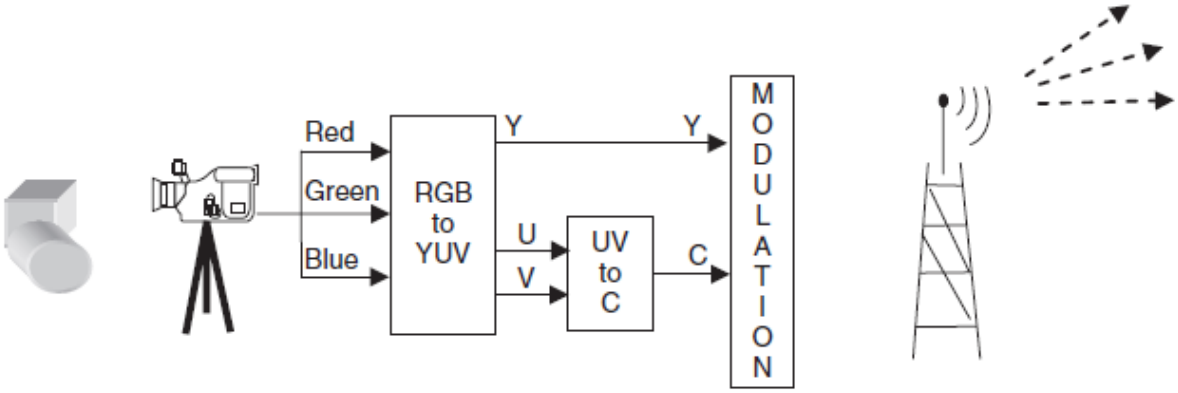

Conversion to YUV

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- Video frames are represented using a color format; e.g., RGB
- For transmission purpose the RGB signal is transformed into YUV signal
- YUV color space aims to decouple the intensity information (Y or luminance) from the color information (UV or chrominance)

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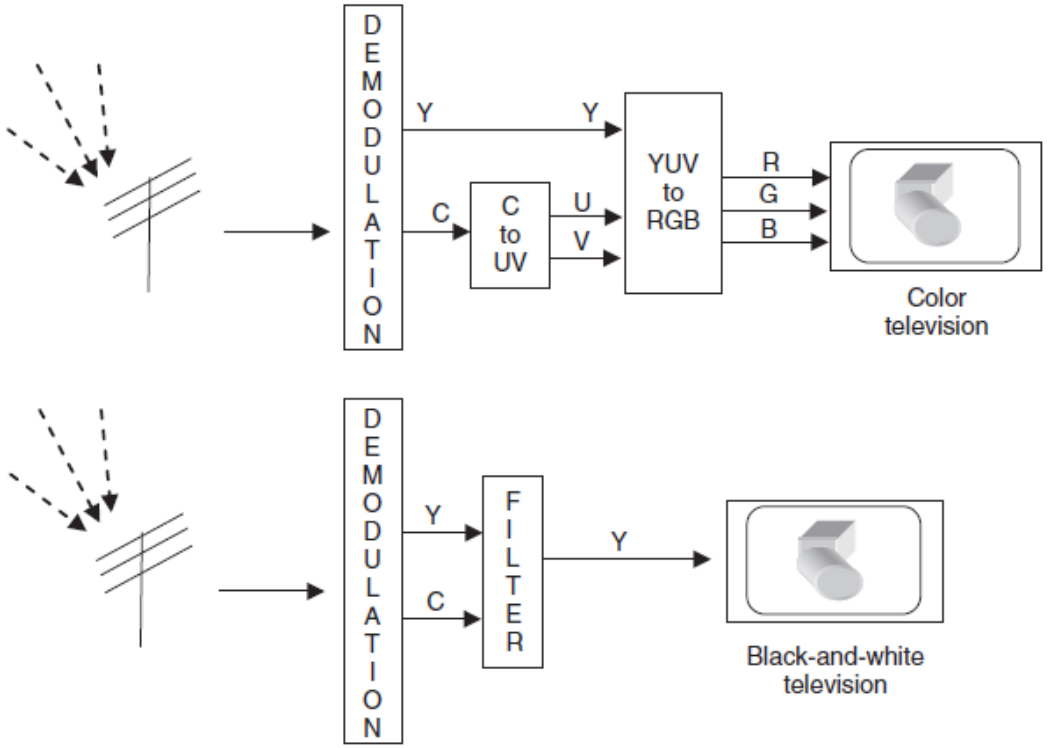

Analog Video Scanning

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- Video is scanned as a 1D signal
- Each raster line is interspaced with horizontal and vertical syncs
- The line-by-line analog raster signal has to be rendered on a TV in a corresponding manner
- The synchronization is carried out by the cycles in the power outlet (60 Hz for NTSC, 50Hz for PAL)

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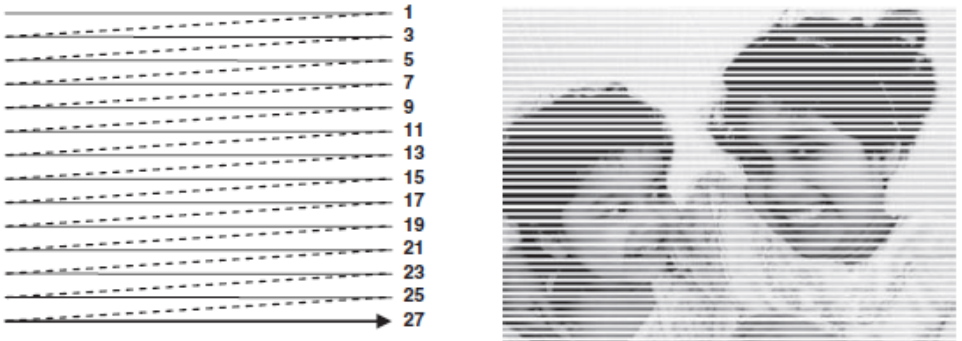
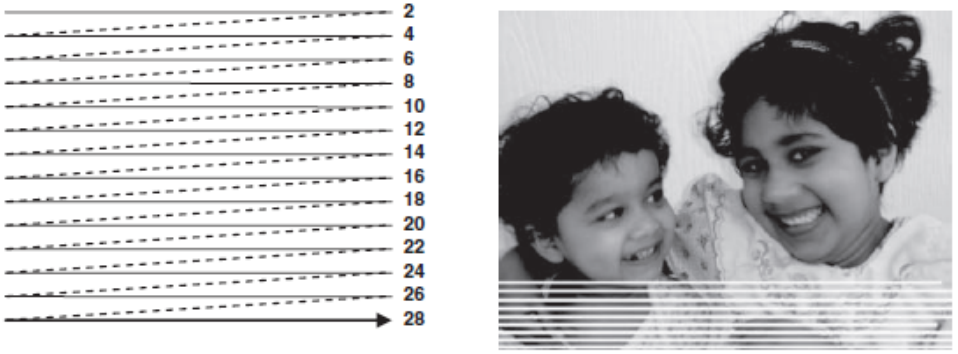


Upper field



Lower field

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

Types of Video Signals

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- Video signals combine all the color and luminance information into one signals called composite video
- With higher digital bandwidths on digital networks those can be transmitted separately to get better visual quality; e.g., S-Video or component video

Composite Video

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- A.k.a., baseband video or RCA video
- The analog waveform conveys the image data in the conventional NTSC television signal
- Contain both chrominance (color) and luminance (brightness) information along with synchronization and blanking pulses all together in a single signal
- However, interference between the chrominance and luminance information is inevitable and tends to worsen when the signal is weak

S-Video

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- Super-Video; a.k.a., Y/C video
- Luminance signal and chrominance signal are transmitted separately
- The luminance signal (Y) carries brightness information
- The chrominance signal (C) carries color information
  - C = U + V

Component Video

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- Keeping all three Y, U, V components separate

YUV Subsampling Schemes

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- Experiments with the human visual system have shown that subsampling color information (UV) reduces in bandwidth while maintains an acceptable quality of video for broadcasting
- Human eye is not as sensitive to subtle differences in color as it is to differences in brightness

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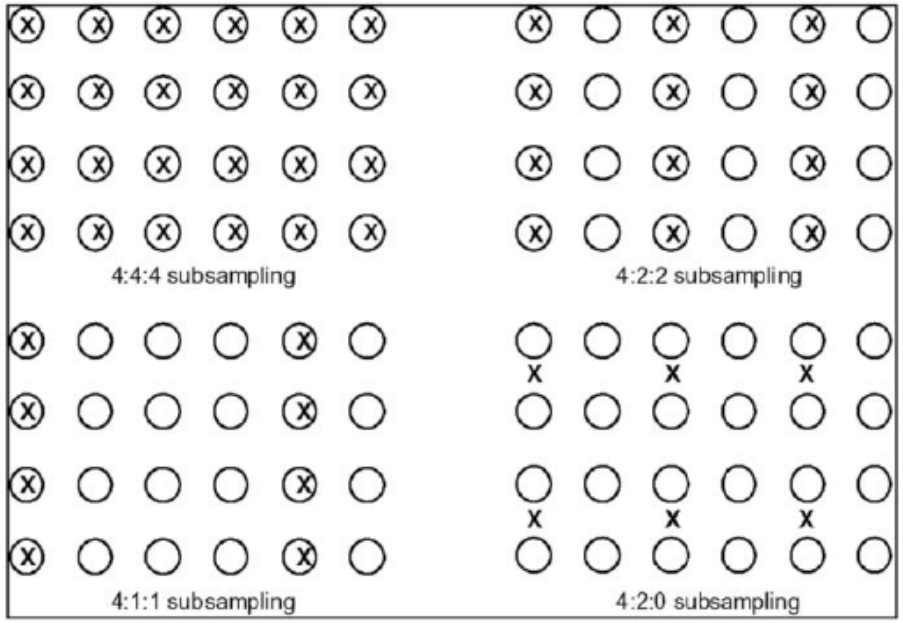

Digital Video Formats

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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

Figure 3-13 Table illustrating analog video formats and their details

- Digital video formats have been established for digital video applications
- The CCIR (Consultative Committee for International Radio) has established the ITU-R 601 standard

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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

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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

High-Definition Television

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- The usual NTSC analog TV has picture resolution of about 210,000 pixels (525 × 480)
- HDTV supports a higher resolution display format along with surround sound
  - 720p : 1280 x 720 pixels progressive
  - 1080i : 1920 x 1080 pixels interlaced
  - 1080p : 1920 x 1080 pixels progressive
- Use the MPEG2 based video compression format with a 17 Mbps bandwidths
- The aspect ration is 16:9 (1.78:1), which is closer to the ratio used in theatrical movies, typically 1.85:1 or 2.35:1

4K Ultra HD

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Format	Resolution	Display Aspect Ratio	Pixels
4K Ultra high definition television	3840 × 2160	1.78 : 1	8,294,400
Academy 4K (storage format)	3656 × 2664	1.37 : 1	9,739,584
DCI 4K (CinemaScope cropped)	4096 × 1714	2.39 : 1	7,020,544
DCI 4K (flat cropped)	3996 × 2160	1.85 : 1	8,631,360
Digital Cinema Initiatives 4K (native resolution)	4096 × 2160	1.90 : 1	8,847,360
Full aperture 4K (storage format)	4096 × 3112	1.32 : 1	12,746,752

Digital Audio
Digital Representation of Audio

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- Analog audio signals are typically represented as waveforms,
  - A simple sinusoidal wave corresponds to a pure tone at a single frequency, or pitch
  - The amplitude of the wave gives the strength of the sinusoid at that time
  - A complex wave consists of multiple frequencies or sinusoidal waves combined together
- Digitizing an analog audio signal requires sampling and quantization
- The process of conversion to digital sound is known as pulse code modulation (PCM)

Surround Sound

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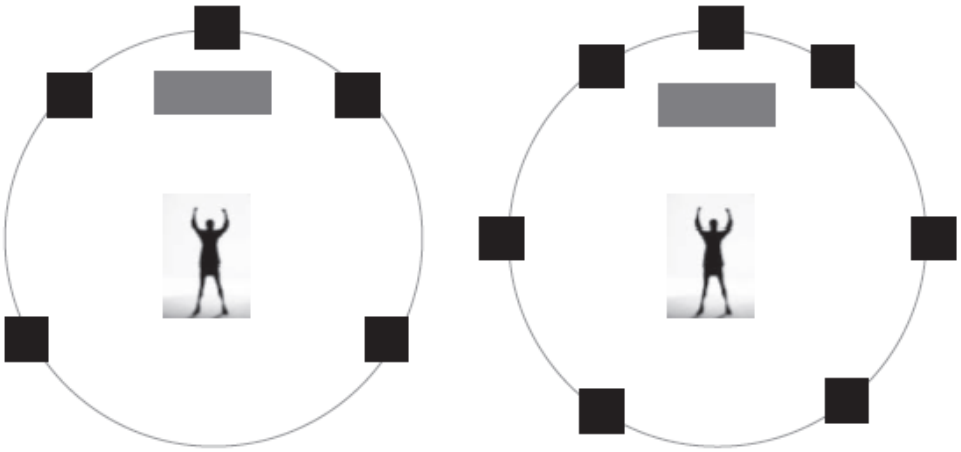

Figure 3-15 5.1 surround sound system (left) and 7.1 surround sound system (right). The black squares show the surround sound speaker placement in reference to a listener in the center, while the light gray rectangle shows the placement of the low-frequency subwoofer.

Spatial Audio

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- Spatial audio attempts to create directional effects using fewer channels, typically two stereo channels.
- Can be classified as virtual surround sound process
- E.g., Sound Retrieval System (SRS)

Commonly Used Audio Formats

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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.

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.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.

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	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.
	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.
	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

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- Graphics objects can be represented as vectors or rasters
  - Vector graphics are geometric entities saved in a vector format having attributes such as color
  - Raster images are represented as a grid of pixels, each pixel having x, y coordinates and a value that compositing, and filtering effects

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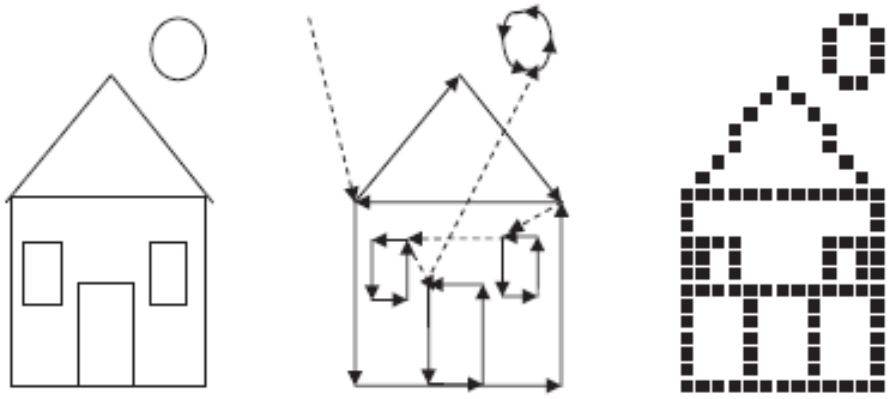

Ideal drawing

Raster drawing

2D Vector Graphics Representations

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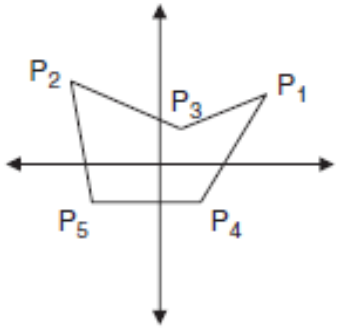
$$P_1 = \begin{bmatrix} x_1 \\ y_1 \end{bmatrix} \quad P_2 = \begin{bmatrix} x_2 \\ y_2 \end{bmatrix} \quad P_3 = \begin{bmatrix} x_3 \\ y_3 \end{bmatrix} \quad P_4 = \begin{bmatrix} x_4 \\ y_4 \end{bmatrix} \quad P_5 = \begin{bmatrix} x_5 \\ y_5 \end{bmatrix}$$



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

Figure 3-18 An example of a polygon and its representation. Five 2D points P_1, P_2, P_3, P_4 and P_5 are connected to form polygon o.

Animation Using 2D Graphics

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

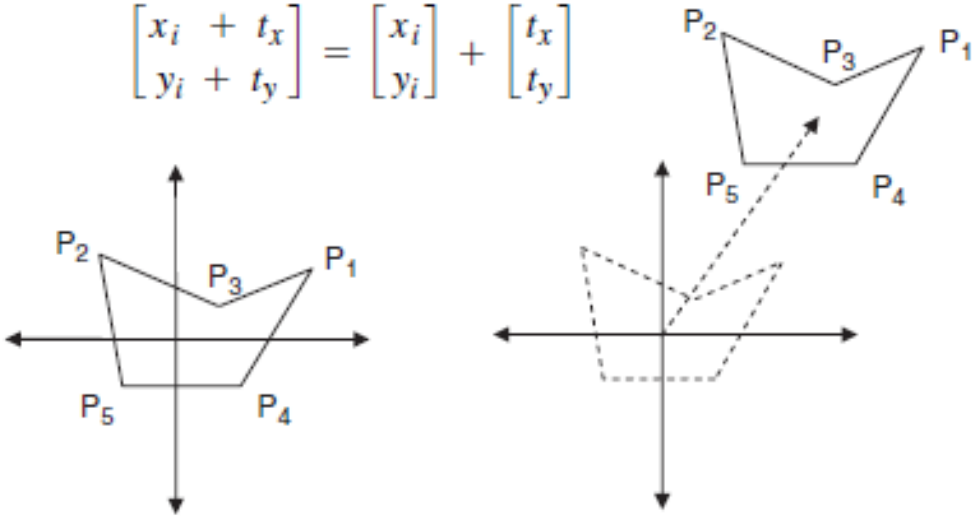

Figure 3-19 Translation – The polygon shown on the left is translated by a vector (t_x, t_y) as illustrated on the right

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

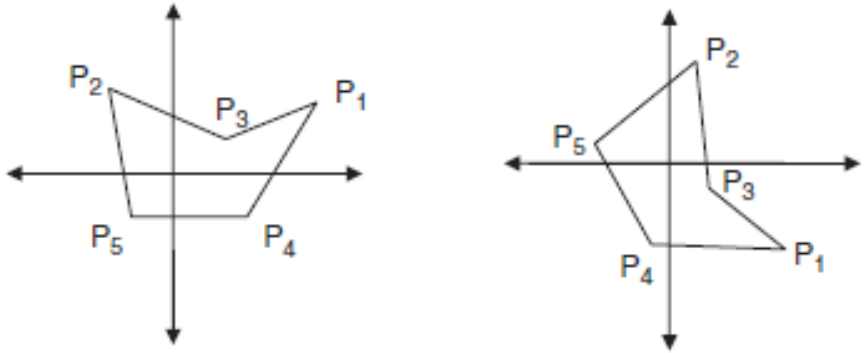

Figure 3-20 Rotation – The polygon shown on the left is rotated by an angle α about an axis that passes through the origin and is perpendicular to the plane of the paper

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

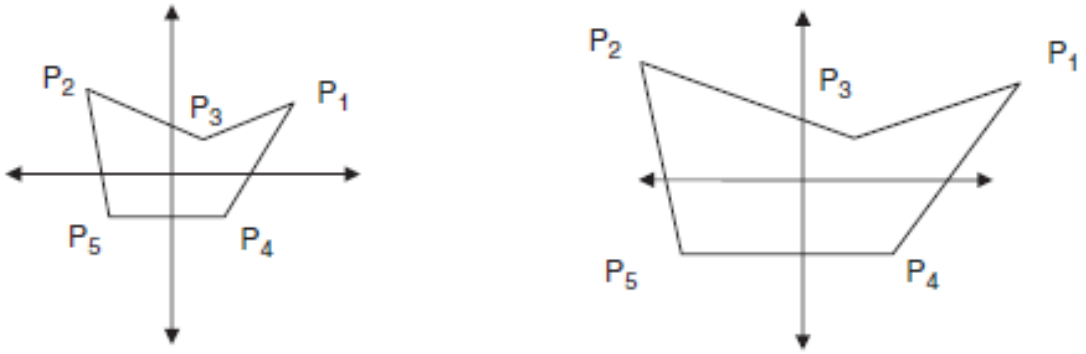

Figure 3-21 Scaling – The polygon shown on the left is scaled non-uniformly by an amount s_x in the horizontal direction and s_y in the vertical direction about the origin

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

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Q & A