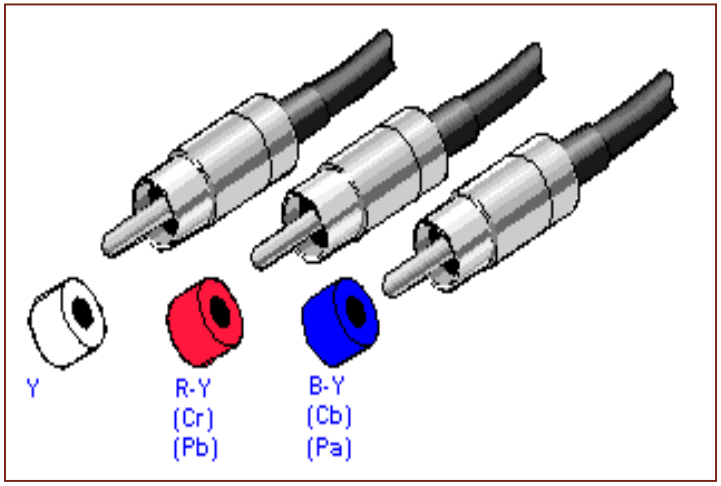
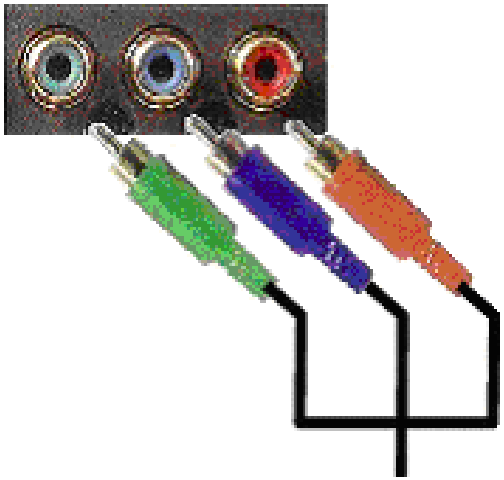
Fundamental Concepts in Video

- Types of Video Signals
- Analog Video
- Digital Video
- Video Processing Techniques
- Further Exploration

Component video — 3 signals

- Higher-end video systems make use of three separate video signals for the red, green, and blue image planes.
- Most computer systems use Component Video, with separate signals for R, G, and B signals.
- For any color separation scheme, Component Video gives the best color reproduction since there is no "crosstalk" between the three channels, unlike S-Video or Composite Video.
- Component video requires more bandwidth and good synchronization of the three components.



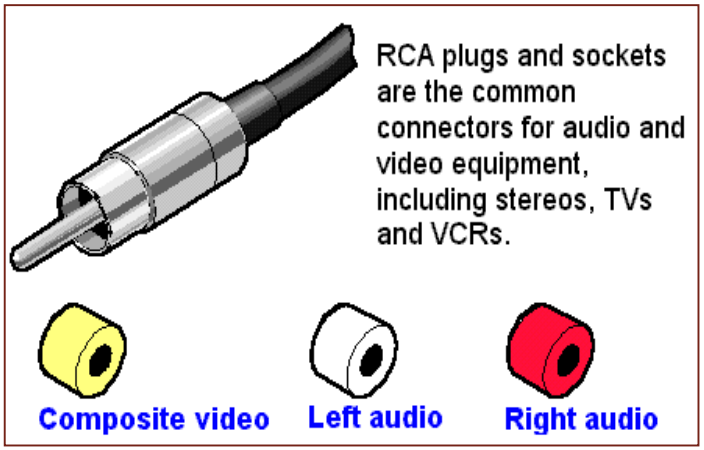


S-Video — 2 Signals

- Also known as Separated Video, or Super-video
- S-Video uses two wires, one for luminance and another for a composite chrominance signal.
  - The grayscale information is most crucial for visual perception.
  - Humans are able to differentiate spatial resolution in grayscale images much better than for the color part of color images.
  - Less crosstalk between the color information and the grayscale information
- S-video provides a sharper image than composite video, but is not as good as component video.

Composite Video — 1 Signal

- Color ("chrominance") and intensity ("luminance") signals are mixed into ***a single carrier*** wave.
- The chrominance and luminance components can be separated at the receiver end and then the color components can be further recovered.
- When connecting to TVs or VCRs
  - Composite Video uses only one wire.
  - Video color signals are mixed, not sent separately.
  - The audio and *sync* signals are additions to this one signal.
- Since color and intensity are wrapped into the same signal, some interference between the luminance and chrominance signals is inevitable.



4.2 Analog Video

- An analog signal *f(t)* samples a time-varying image.
- Two type of scanning
  - *Progressive* scanning
    - traces through a complete picture (a frame) row-wise for each time interval.
    - A HD computer monitor typically uses a time interval of 1/72 second.
  - Interlaced scanning
    - is used in TV and in some monitors and multimedia standards.
    - reduces perceived flicker since it was difficult to transmit the amount of information in a full frame quickly.

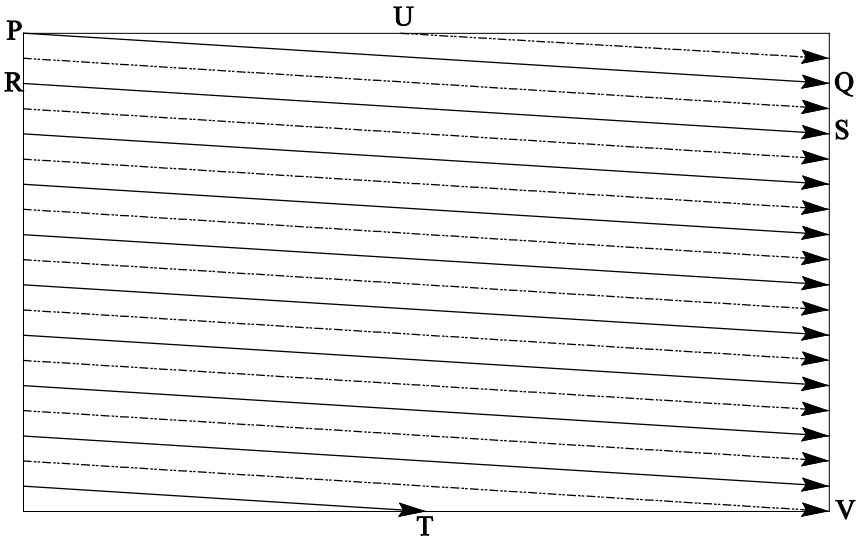
Progressive Scan
(Non-interlaced)

Interlaced scanning

- The odd-numbered lines are traced first, and then the even-numbered lines are traced.
- This results in "odd" and "even" fields — two fields make up one frame.
- In fact, the odd lines (starting from 1) end up at the middle of a line at the end of the odd field, and the even scan starts at a half-way point.

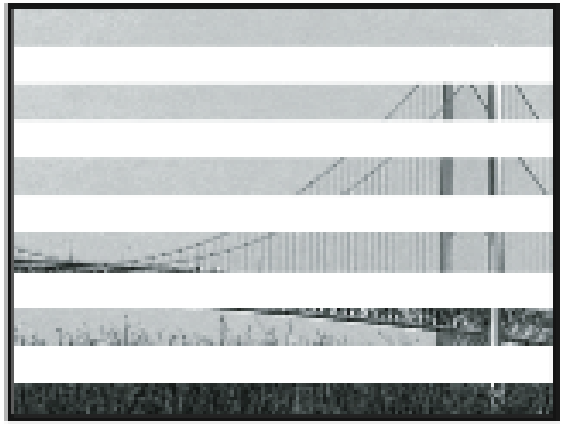
Interlaced

Interlaced scanning

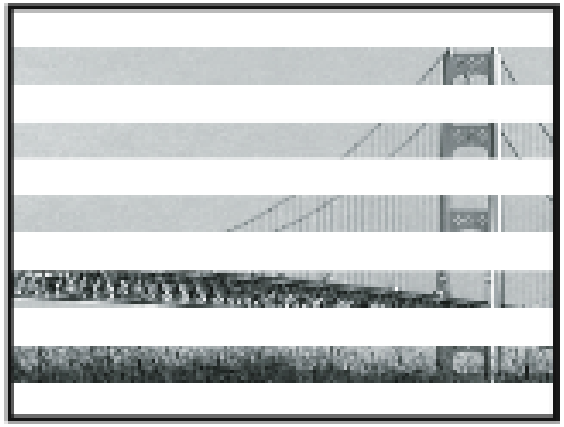


- The solid (odd) lines are traced, P to Q, then R to S,…,ending at T. The even field starts at U and ends at V.
- Horizontal retrace-the jump from Q to R, etc.
- Vertical retrace-the jump from T to U or V to P, etc.

Interlaced scanning



Field 1 is sampled first and contains only the odd lines.



Field 2 sampled 1/60th of a second later contains the even-lines.

A complete frame consists of field 1 and field 2.

Interlaced scanning

- The odd and even lines are displaced in time from each other
  - Generally not noticeable except when very fast action is taking place on screen, when blurring may occur.

- In the video in Fig. 4.2, the moving helicopter is blurred more than the still background.

Interlaced scanning

(a) The video frame

(b) Field 1

(c) Field 2

(d) Different of Fields

- De-interlacing
  - Is used to change the frame rate, resize, or produce still images from an interlaced source video.
  - The simplest de-interlacing method consists of discarding one field and duplicating the scan lines of the other field. The information in one field is lost completely using this simple technique.
- Define the beginning of a new video line
  - Voltage is one dimensional signal that varies with time.
  - Analog video use a small voltage offset from zero to indicate “black”, and another value such as zero to indicate the start of a line. Namely, we could use a "blacker-than-black" zero signal to indicate the beginning of a line.

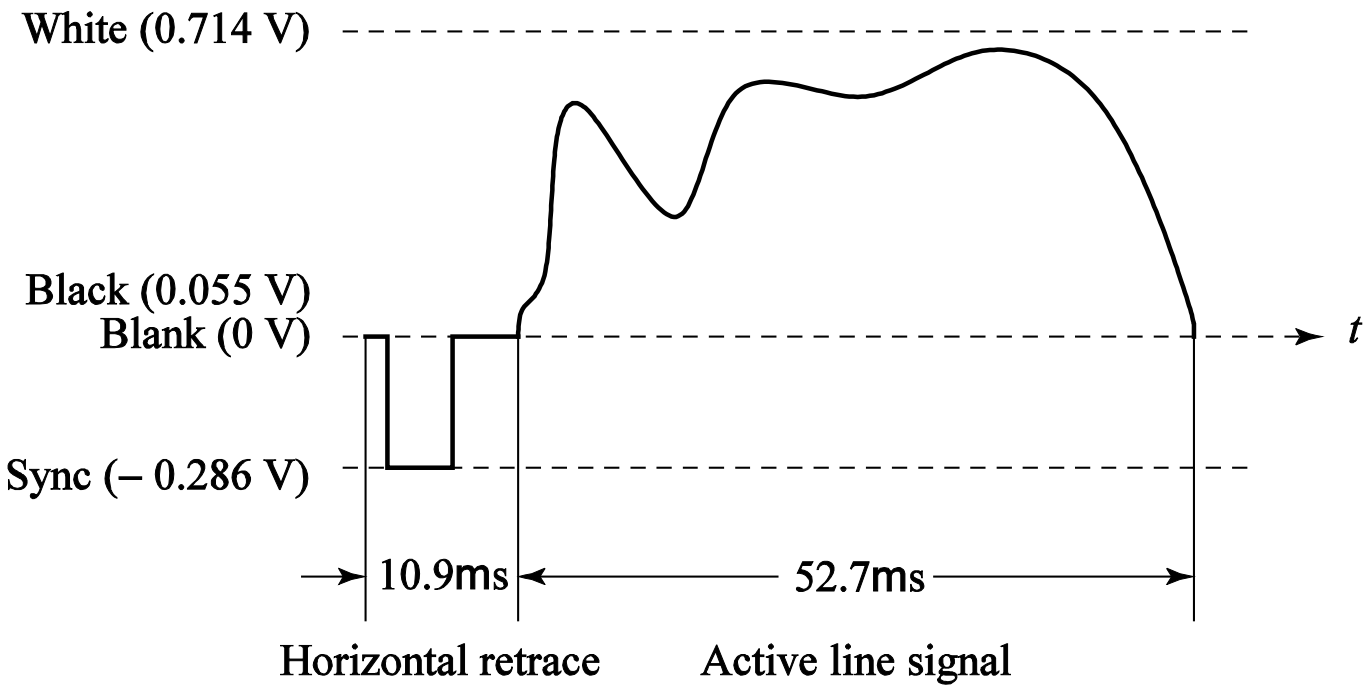


Figure. Electronic signal for one NTSC scan line.

4.3 Digital Video

- Some advantages:
  - Storing video on digital devices or in memory, ready to be processed (noise removal, cut and paste, etc.), and integrated to various multimedia applications.
  - Direct access, which makes nonlinear video editing simple.
  - Repeated recording does not degrade image quality.
  - Ease of encryption and better tolerance to channel noise.

HDTV (High Definition TV)

- High Definition Television (HDTV) is video that has resolution substantially higher than that of traditional television systems (standard-definition TV, or SDTV, or SD).
- HDTV has one or two million pixels per frame, roughly five times that of SD.
- Early HDTV broadcasting used analog techniques, but today HDTV is digitally broadcast using video compression.

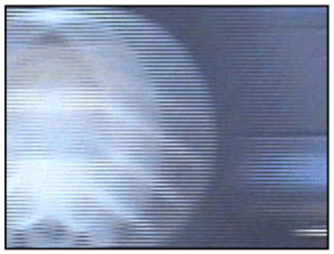
- The standard supports video scanning formats shown in Table below, where "I" mean interlaced scan and "P" means progressive (non-interlaced) scan.

- Table 1. Advanced Digital TV formats

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

- For video, *MPEG-2* is 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:
  - HDTV has a much wider aspect ratio of 16:9 instead of 4:3. (1/3 wider)
  - HDTV moves toward progressive (non-interlaced) scanning. The rationale is that interlacing introduces serrated edges to moving objects and flickers along horizontal edges.

progressive scan



interlace

progressive scan

interlace

- The FCC has planned to replace all analog broadcast services with digital TV broadcasting. The services provided include:
  - **SDTV (Standard Definition TV)**: the current NTSC TV or higher.
  - **EDTV (Enhanced Definition TV)**: 480 active lines or higher, i.e., the third and fourth rows in Table 1.
  - **HDTV (High Definition TV)**: 720 active lines or higher.
  - Popular choices:
  - 720p (720 lines, progressive, 30fps)
  - 1080I(1080 lines,interlaced,30fps or 60fps)

Data Rate and Video Storage Size

- Calculate the data rate in **bps** (bits per second) and storage requirement in **bytes** for a one-hour grayscale video with 800 X 600 frame size and 24 fps (frames per second) frame rate.

- Data rate = Resolution * Bits per pixel * Frame rate
- Storage size= Data rate * Time

4.4 Video Processing Techniques

- This section mainly discusses how animation can be produced with the help of computers.

- Other processing techniques, such as video compression and transmission, will be discussed in another course "Digital Image and Video Processing" in year 4.

Image Sequences

- Animation is the creation of moving pictures, one frame at a time.

- Traditional animators have developed many techniques, including cel animation, stop motion and claymation.

Traditional Animation

- Cel animation (classical animation or hand-drawn animation)
  - The oldest and historically the most popular form of animation.
  - Each frame is drawn by hand.
  - In contrast with the more commonly used computer animation nowadays.

https://conceptartempire.com/cel-animation/

A horse animated from Eadweard Muybridge's 19th century photos. The animation consists of 8 drawings, which are "looped", i.e. repeated over and over. This example is also "shot on twos", i.e. shown at 12 frames per second. (24fps)

Traditional Animation

- Stop motion (stop action or frame-by-frame)
  - An animation technique to make a physically manipulated object appear to move on its own.
  - The object is moved in small increments between individually photographed frames, creating the illusion of movement when the series of frames is played as a continuous sequence.

A simple stop motion animation of a moving coin.

Traditional Animation

- Claymation (or clay-animation)
  - One of many forms of stop motion animation.
  - Each animated piece, either character or background, is "deformable" — made of a malleable substance, usually Plasticine clay.

Wallace and Gromit

A clay animation scene from “A Fan Ti”.

Image Sequences

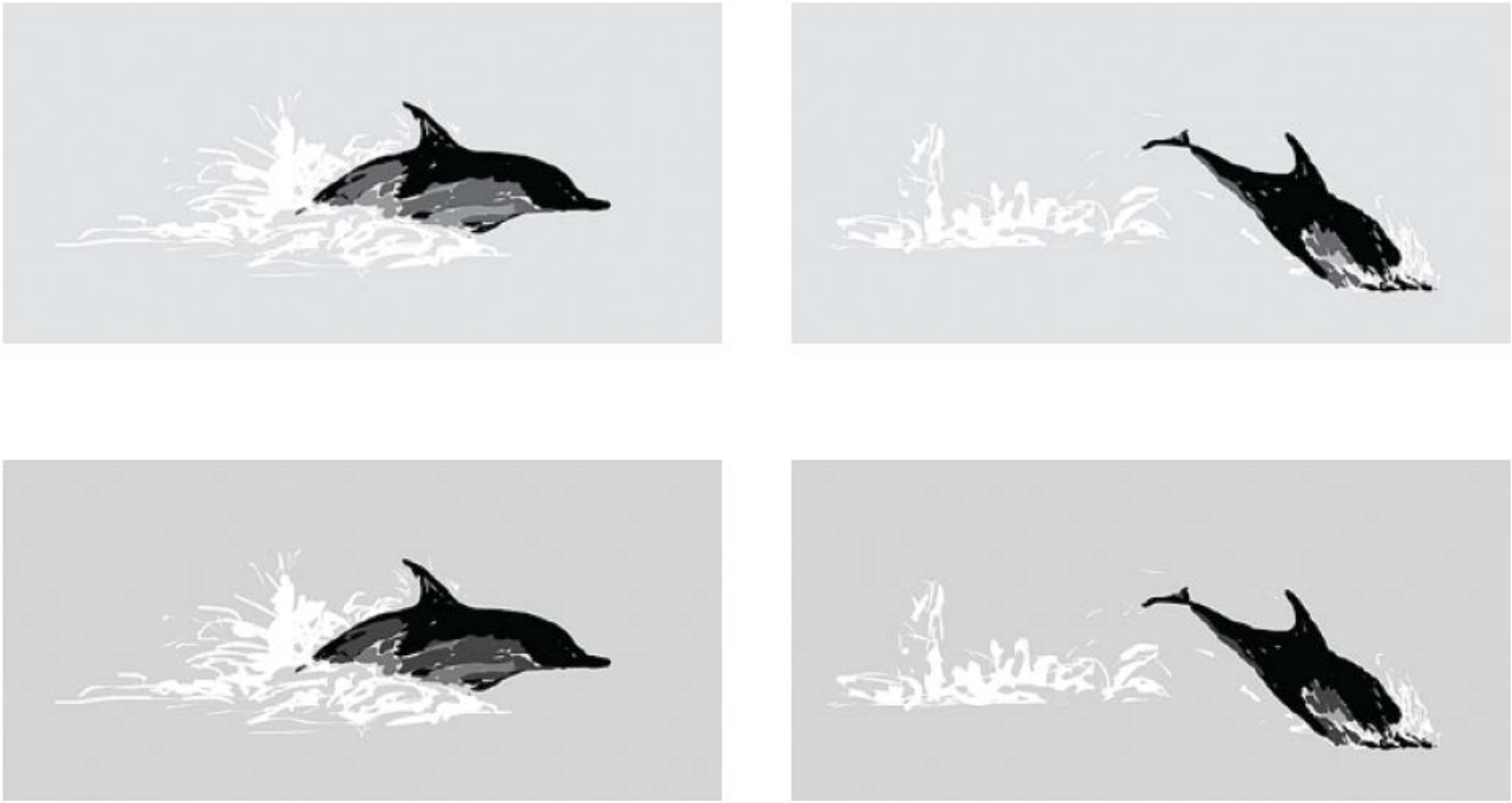
- Traditional animation can be captured one frame at a time using a camera connected to a computer, instead of being recorded on film.
- Animation can be created digitally.
- Individual frames can be created in a graphics program.
- Using layers to represent the contents of a frame can streamline the animation process.
- A sequence of images can be stored in consecutively numbered image files, which can be imported into video editing programs such as Flash.

Image Sequences

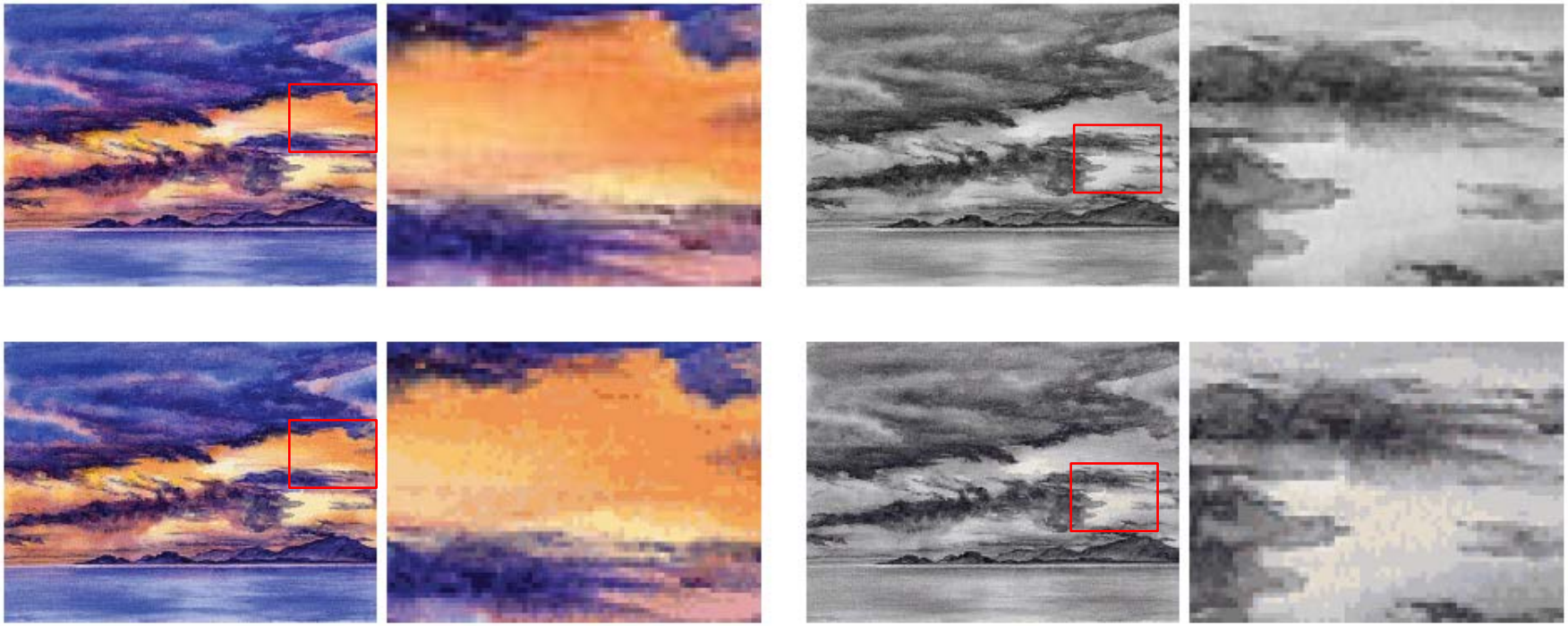
- An animation is a sequence of frames, each one a still image.
- Either bitmapped images or vector graphics can be used for the individual frames.
  - Vector graphics offer more possibilities for creating and manipulating frames using computer programs.
  - Bitmapped images are conceptually simpler, though, and correspond more closely to the traditional animations consisting of a sequence of photographed images on film.

Image Sequences

- An animated GIF contains multiple bitmapped images in a single file.
- The individual images can be displayed in sequence by Web browsers and other programs, without plug-in.
- GIFs are only suitable for short simple animations.
- GIFs use indexed color and lossless intra-frame compression, whose effectiveness depends on the nature of the images in the animation.
- GIFs cannot have a soundtrack or player controls.



Original (top) and animated GIF (bottom) frames, suitable material



Original (top) and animated GIF (bottom) frames, unsuitable material

Interpolation

- In traditional animation, chief animators draw key frames at important points; in-betweeners create intervening frames.
- Interpolation: the calculation of values lying between known points.
- Animation programs perform equivalent in-betweening by interpolating the values of properties such as position between key frames.
- Interpolation can be applied to layers in bitmapped images or to properties of vector objects.

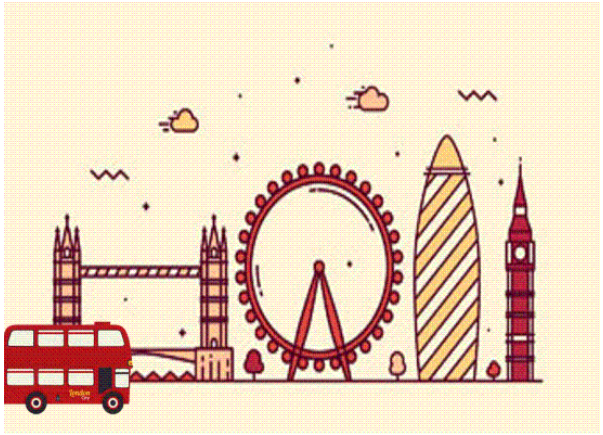
Interpolation

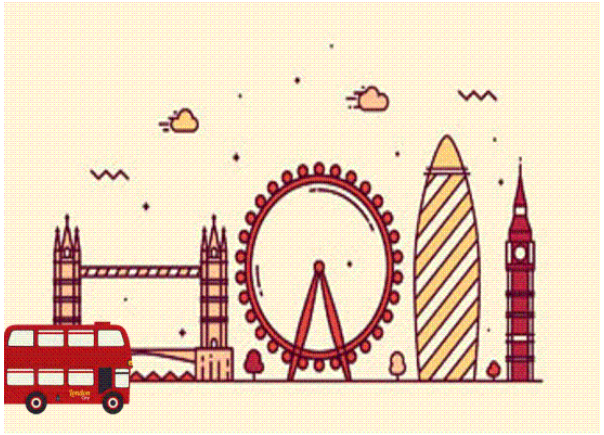
- Bitmaps do not contain identifiable objects
  - Use layers to isolate different elements of an animation if we wish to change them independently.

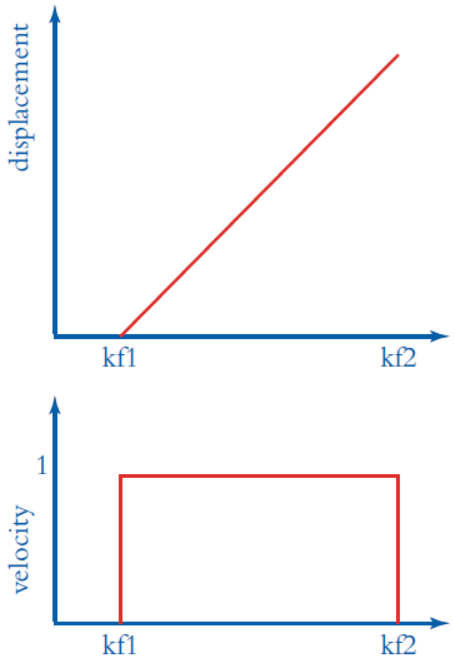
- Vector animations, we do have identifiable objects, and their properties are represented entirely numerically.
  - Makes interpolating the position, size, color and other properties of vector objects conceptually and practically easier.

Interpolation

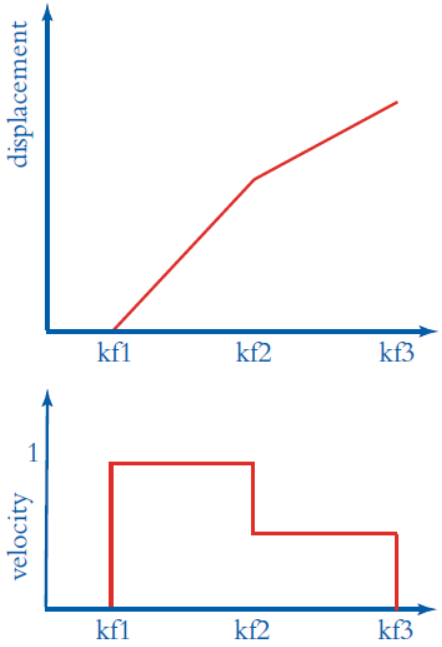
- Walt Disney developed a mass production approach to animation.
- Disney's approach create animations relied on breaking down the production of a sequence of drawings into sub-tasks.
- If motion is interpolated linearly, movement begins and ends instantaneously. And there may be unnatural discontinuities between interpolated sequences.







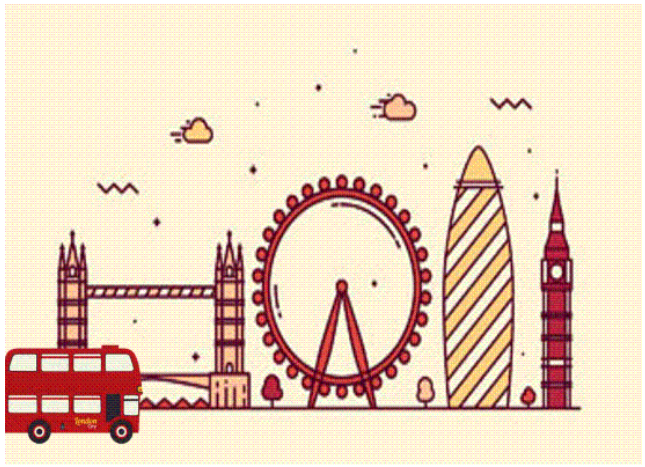
Linearly interpolated motion

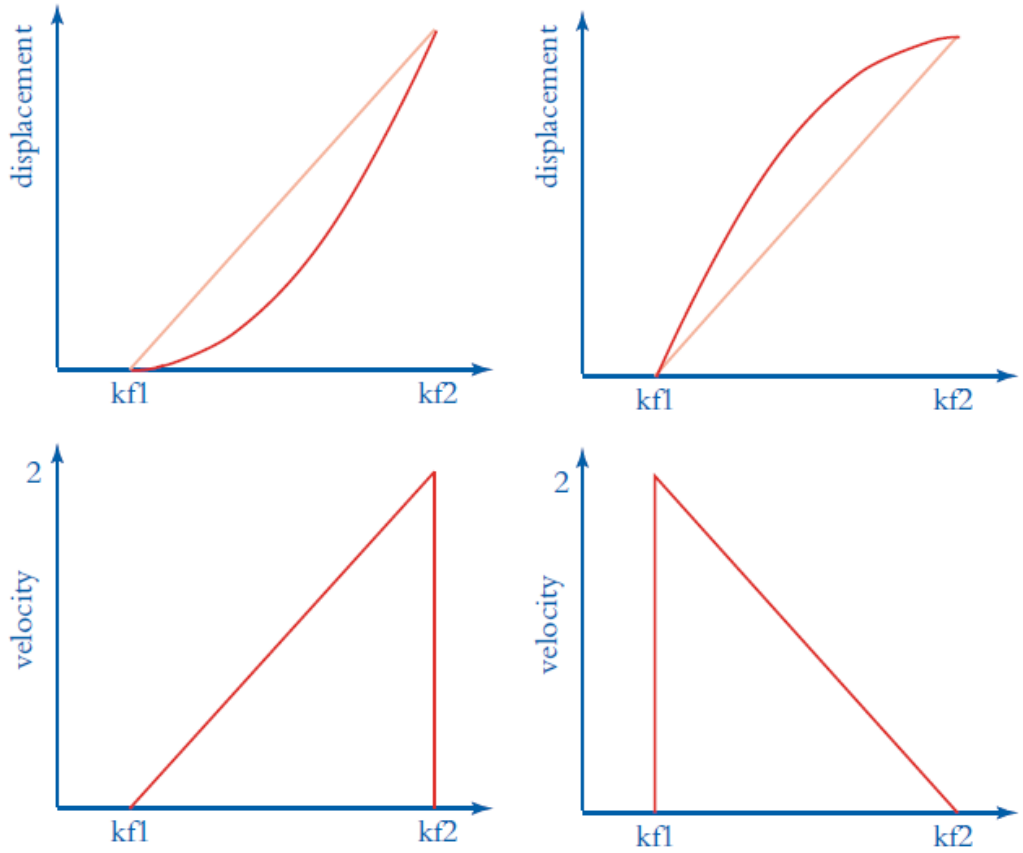


Abrupt change of velocity caused by linear interpolation

Interpolation

- Easing in and out can be used to cause the motion to increase or decrease gradually.

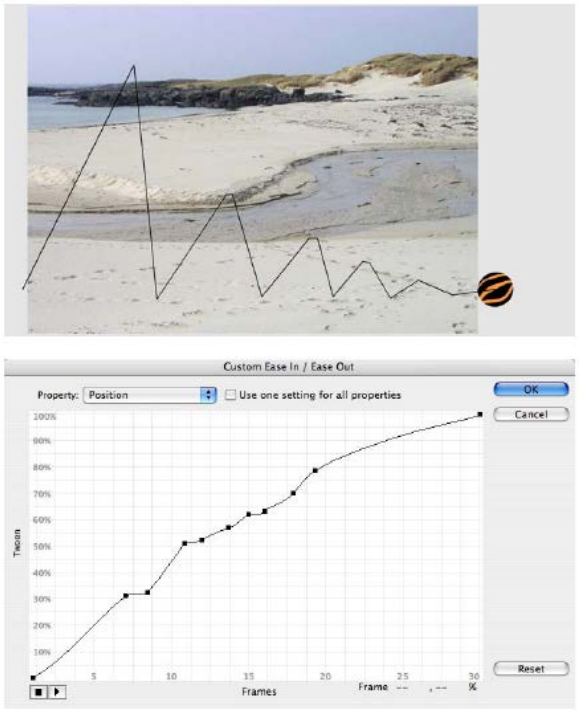




Quadratic easing in (left) and out (right)

Interpolation

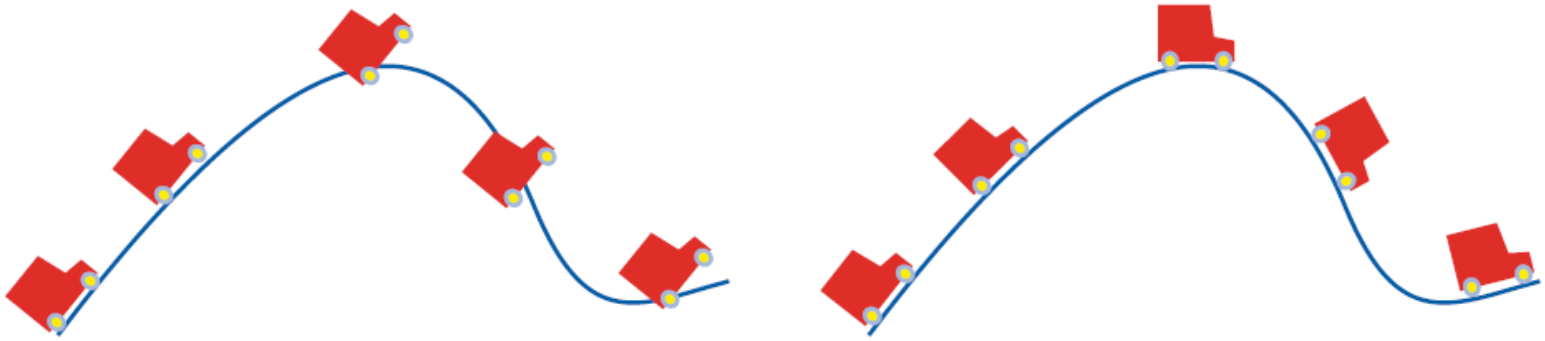
- Custom easing using Bézier curves is used to control the rate of change in arbitrarily complex ways.



Interpolating motion along a path with custom easing

Interpolation

- Objects or layers can be made to move along motion paths.
- When using motion paths, it is usually necessary to orient the moving object to the path to achieve a realistic effect.



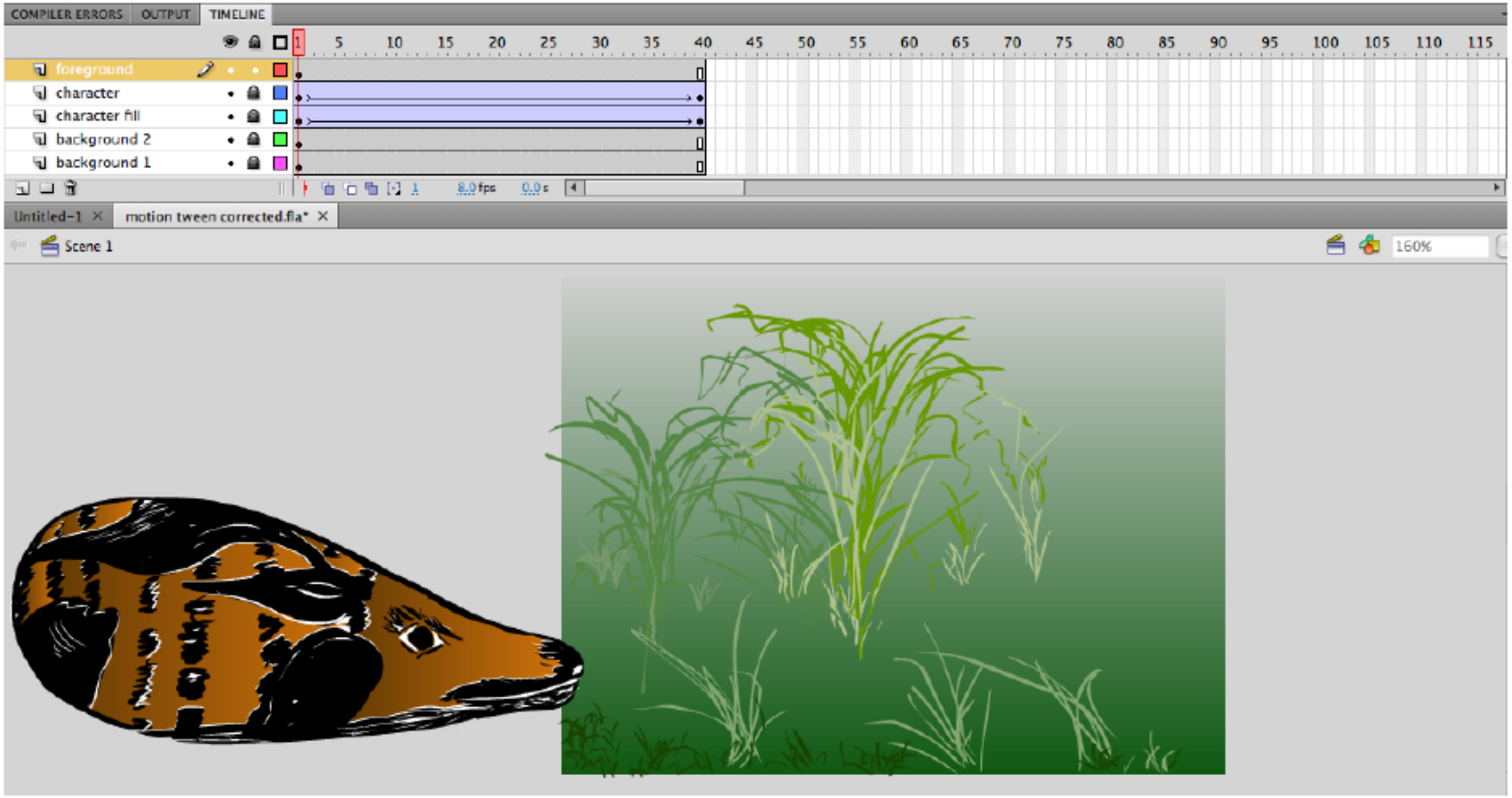
Fixed orientation (left) and orientation to the motion path (right)

Vector Animation

- Flash movies, also known as SWF files, a popular Web animation format. They are usually created in Flash, but SWFs may also be exported from other programs.

- An animation being created in Flash is organized using a timeline.

- The vector objects used in the animation are created on the stage, using conventional vector drawing tools and techniques.



The timeline (top) and stage (below) in a simple Flash movie

Vector Animation

- Onion-skinning can be used to help align and change objects in consecutive frames.
- Key frames are drawn in their entirety on the stage.
- Ordinary frames have no content, they just hold the picture from the preceding key frame.

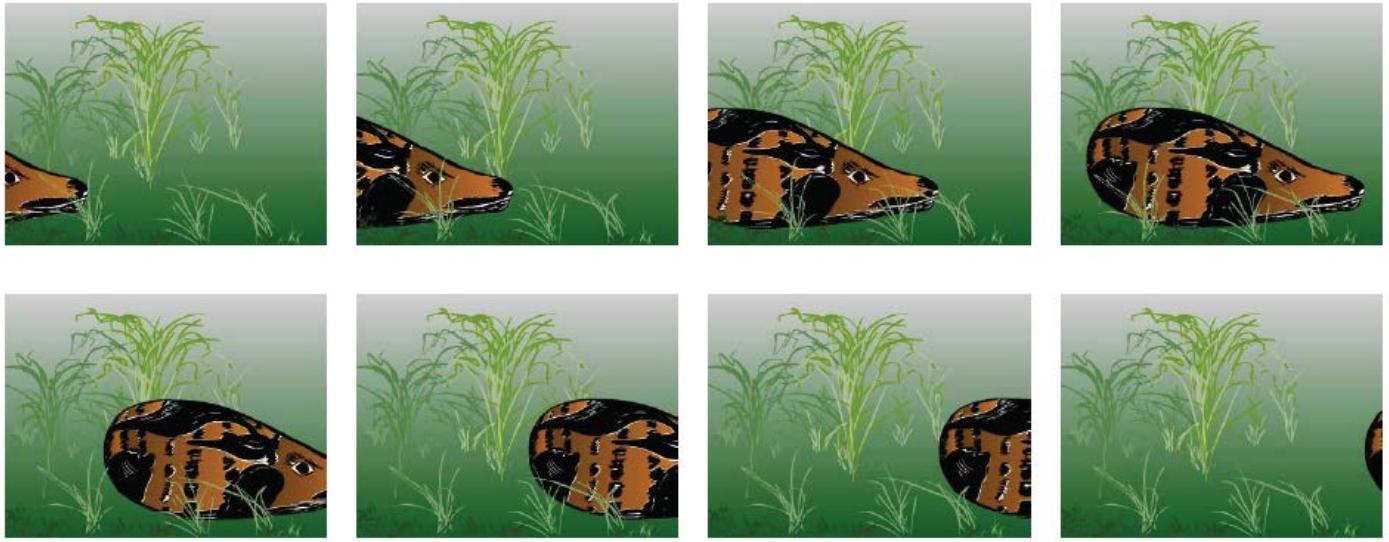
Vector Animation

- Graphical objects can be stored in a library as **symbols**.
- Instances of symbols can be created on the stage, allowing objects to be reused.
- Instances can be transformed independently and have different visual effects applied to them.

Instances of a symbol

Vector Animation

- Interpolation ("tweening") is applied to symbol instances.
- Easing can be applied to tweened motion.
- An object's size, orientation, opacity and color may also be interpolated.



Simple tweened motion of a symbol instance

Vector Animation

- Shape tweening ("morphing") is used to transform one shape into another.

4.5 Further Exploration

http://www.cs.sfu.ca/mmbook/ Further Exploration-Chapter5

- Tutorials on NTSC television
- The latest news on the digital TV front
- Introduction to HDTV
- Adobe Flash Software