Multimedia Systems

Video and Animation

Er. Narayan Sapkota, M.Sc.
narayan.sapkota@eemc.edu.np

Everest Engineering College (Senior Lecturer)
Kathmandu University (Visiting Faculty)

January 7, 2025

Syllabus

1. Basic Video Concepts
   - Video Representation
   - Video Format
2. Television
3. Basic Concepts of Animation
4. Types of Animation
5. Principles of Animation
6. Techniques of Animation
7. Creating Animation
8. Animation Language, Control and Transmission
   - Animation Language
   - Animation Control
   - Animation Transmission

Table of Contents

Basic Concept of Video (1)

- Video captures and reconstructs moving images by processing a sequence of still images.
- Digital video has replaced analog video for most multimedia purposes due to its cost-efficiency.
- Digital video technology offers high-quality results at a lower cost compared to analog systems.
- Modern digital camcorders connected to computers eliminate the need for expensive video capture cards.
- This allows users to easily edit and produce videos without professional hardware.

Table of Contents

Video Representation (1)

The main objective of visual representation is to offer the viewer a sense of presence in the scene and of participation in the events portrayed. To meet this objective, the televised image should convey the spatial and temporal content of the scene. Important measures are:

1. **Vertical details and viewing distance**
   The geometry of a television image is based on the ratio of the picture width W to the picture height H. This width-to-height ratio is also called the *aspect ratio*. The conventional aspect ratio (for television) is $\frac{4}{3} = 1.33$. The viewing distance D determines the angular field of view. This angle is usually calculated as the ratio of the viewing distance to the picture height, i.e., $\frac{D}{H}$.

Video Representation (2)

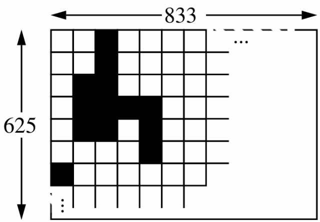

Figure 1: Decomposition of a motion picture. Width to height in ratio 4:3

Video Representation (3)

The smallest detail that can be reproduced in a picture is a pixel (picture element).In an ideal world, each detail in the image would match exactly with a pixel. However, in reality, some details fall between the scan lines. To show these details, two scan lines are needed, which leads to a loss of vertical sharpness in the image. Studies have found that only about 70% of the vertical details are visible in the scan lines. This ratio is called the Kell factor.

The Kell factor is independent of the sampling method, i.e., whether the scan lines follow one another sequentially (progressive sampling) or alternately (interlaced sampling). The picture width normally used for television is $\frac{4}{3}$ times the picture height. The horizontal field of view can be determined using the aspect ratio.

Video Representation (4)

The vertical resolution is equal to the number of picture elements in the picture height. The number of horizontal picture elements is equal to the product of the vertical resolution and the aspect ratio. The product of the picture's elements vertically and horizontally is the total number of picture elements in the image. However, in the case of television pictures, not all lines (and columns) are visible to the observer. The invisible areas are often used to transmit additional information.

2. **Depth perception**

   In nature, humans perceive the third dimension, depth, by comparing the images perceived by each eye, which view from different angles. In a flat television picture, a considerable portion of depth perception is derived from the perspective appearance of the subject matter. Further, the choice of the focal length of the camera lens and changes in depth of focus influence depth perception.

Video Representation (5)

3. **Luminance**
   Color perception is achieved by three signals, proportional to the relative intensities of red, green, and blue light (RGB) present in each portion of the scene. These signals are sent separately to the monitor, and the tube reproduces them at each point in time (unlike a camera).

   However, for transmission and storage purposes, a different division is often used: one brightness signal (luminance) and two color difference signals (chrominance).

Video Representation (6)

4. **Temporal aspects of illumination**

   Another important aspect of how humans see is the ability to perceive motion. Unlike sound, which is made up of continuous waves, we see motion by looking at a series of still pictures shown quickly one after the other. This is how television, movies, and videos work.

   The feeling of motion comes from showing many still pictures (frames) in quick succession. Between each frame, the light goes off for a brief moment. To make the motion look realistic, two things must happen:

   - The pictures must change quickly enough so that the movement appears smooth from one frame to the next.
   - The frame rate must be high enough to prevent noticeable dark gaps between the pictures, so the motion looks continuous without interruptions.

5. **Continuity of motion**
   - Continuous motion is perceived only if the frame rate exceeds 15 frames per second, with 30 frames per second required for smooth motion.
   - Films recorded at 24 frames per second may appear strange, especially with fast-moving objects.
   - The standard NTSC frame rate is 29.97Hz in the United States; PAL uses 25Hz.

6. **Flicker Effect**

The flicker effect refers to the perceptual phenomenon where a light source or display, such as a television screen or monitor, seems to rapidly change in brightness or turn on and off at a certain frequency. This flickering can happen if the refresh rate of the display is too low or if the display isn't able to keep up with the frame rate needed for smooth motion. Flicker can be annoying and cause discomfort, especially when the flickering is at a frequency that is visible to the human eye.

The flicker effect typically occurs in the following situations:

- Low Refresh Rate: If the screen refreshes too slowly (for example, 50 Hz or 60 Hz), it can cause flickering, as the light from the display turns on and off at a rate visible to the human eye.
- Inconsistent Frame Rates: When the frame rate of a video or a game is inconsistent or too low, it can create stutter or flicker, as frames may not be updated smoothly.

Video Representation (9)

- Poor Lighting Conditions: Flicker can also be caused by the interaction between the screen and ambient light, especially with certain types of lighting like fluorescent bulbs, which flicker at a frequency that can interact with the refresh rate of a screen.

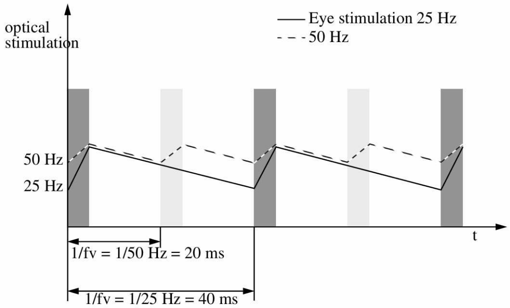

Figure 2: Flicker effect. Eye stimulation with refresh rates of 25 Hz and 50 Hz

Video Representation (10)

The human eye generally cannot see flicker above 60 Hz, but if the refresh rate drops below this threshold, the flicker becomes noticeable. To avoid flicker, displays are typically designed to refresh at higher rates (such as 120 Hz or 144 Hz), especially in modern monitors and televisions.

In simpler terms, flicker happens when a screen's brightness changes too quickly or the image isn't updated fast enough, causing it to appear like it's blinking or flashing. This can be distracting and uncomfortable for viewers.

- Techniques like display refresh buffers help reduce flicker by writing picture data at a higher rate and reading it at a lower rate to eliminate flicker.
- Interlaced scanning transmits the full picture at around 29.97Hz or 25Hz, with half pictures transmitted at 60Hz or 50Hz, respectively.

Table of Contents

Video Format (1)

Video signals are often transmitted to the receiver over a single television channel. In order to encode color, a video signal is decomposed into three subsignals. For transmission reasons, the video signal consists of a luminance signal and two chrominance (color) signals. In NTSC and PAL systems, the component transfer of luminance and chrominance in a single channel is accomplished by specifying the chrominance carrier to be an odd multiple of half the line-scanning frequency. This causes the component frequencies of chrominance to be interleaved with those of luminance. The goal is to separate these component sets in the receiver and avoid interference before the primary color signals are recovered for display.

In practice, however, there are degradations in picture quality, known as color crosstalk and luminance crosstalk. These effects have led to the reduction of luminance bandwidth in NTSC receivers to less than 3 MHz, under the carrier frequency of 3.58 MHz, far below the broadcast signal theoretical maximum limit of 4.2 MHz. This limits the vertical resolution to about 25 lines. Chrominance and luminance signals are separated using a simple notch filter tuned to the subcarrier's frequency. Today, comb filters are also used for this purpose, and the transmitter uses a comb filter in the coding process.

Several approaches to color encoding are described below.

1. **RGB Signal**
   An RGB signal consists of separate signals for red, green, and blue. Every color can be encoded as a combination of these three primary colors using additive color mixing. The values R (for red), G (for green), and B (for blue), are normalized such that white results when $R + G + B = 1$ in the normalized representation.

2. **YUV Signal**

   Since human vision is more sensitive to brightness than to color, a more suitable encoding separates the luminance from the chrominance (color information). Instead of separating colors, the brightness information (luminance Y) is separated from the color information (two chrominance channels U and V).

   For reasons of compatibility with black-and-white receivers, the luminance must always be transmitted. For black-and-white reception, the utilization of the chrominance components depends on the color capabilities of the television set.

   The YUV signal can be calculated as follows:

$$Y = 0.30R + 0.59G + 0.11B$$

$$U = (B - Y) \times 0.493$$

Video Format (4)

$$V = (R - Y) \times 0.877$$

An error in the resolution of the luminance (Y) is more serious than one in the chrominance values (U, V). Thus, the luminance values can be encoded using a higher bandwidth than is used for the chrominance values.

Due to the different component bandwidths, the encoding is often characterized by the ratio between the luminance component and the two chrominance components. For example, the YUV encoding can be specified as a (4:2:2) signal. Further, the YUV encoding is sometimes called the Y, B–Y, R–Y signal, from the dependencies among U, $B–Y$, V, and $R–Y$ in the equations above.

Video Format (5)

3. **YIQ Signal**

   A similar encoding exists for NTSC's YIQ signal:

$$Y = 0.30R + 0.59G + 0.11B$$

$$I = 0.60R - 0.28G - 0.32B$$

$$Q = 0.21R - 0.52G + 0.31B$$

   A typical NTSC encoder produces the I and Q signals, then performs quadrature amplitude modulation on the suppressed chrominance subcarrier and adds the modulated signal to the luminance Y. The signals are also blanked and synchronized.

Video Format (6)

Signals	Sampling frequency [MHz]	Samples/ line	Lines	Data rate [Mbit/s]	Total rate [Mbit/s]	Format
R	13.5	864	625	108		4:4:4
G	13.5	864	625	108		ITU 601
B	13.5	864	625	108	324	
Y	13.5	864	625	108		4:2:2
Cr	6.75	432	625	54		ITU 601
Cb	6.75	432	625	54	216	
Y	13.5	720	576	83		4:2:2
Cr	6.75	360	576	41.5		
Cb	6.75	360	576	41.5	166	
Y	13.5	720	576	83		4:2:0
Cr/	6.75	360	576	41.5		
Cb					124.5	
Y	6.75	360	288	20.7		4:2:0
Cr/	3.375	180	288	10.4		SIF
Cb					31.1	

Table of Contents

Television (1)

Television is one of the most important applications driving the development of motion video. Since 1953, television has undergone many far-reaching changes. This section provides an overview of television systems, encompassing conventional black-and-white and color systems, enhanced resolution television systems intended as an intermediate solution, and digital interactive video systems and Digital Video Broadcasting (DVB).

Conventional Systems

Black-and-white and current color television is based on the properties of video signals as described in previous section. Early on, different parts of the world adopted different video standards. Conventional television systems use the following standards:

Television (2)

- NTSC stands for National Television Systems Committee and is the oldest and most widely used television standard. The standard originated in the US and uses color carriers of approximately 4.429 MHz or approximately 3.57 MHz. NTSC uses quadrature amplitude modulation with a suppressed color carrier and a refresh rate of about 30 Hz. A picture consists of 525 rows. NTSC can use 4.2 MHz for the luminance and 1.5 MHz for each of the two chrominance channels. Television sets and video recorders use only 0.5 MHz for the chrominance channels.
- SECAM stands for Sequential Couleur avec Memoire and is used primarily in France and Eastern Europe. In contrast to NTSC and PAL, it is based on frequency modulation. Like PAL, SECAM uses a refresh rate of 25 Hz. Each picture consists of 625 rows.

Television (3)

- PAL stands for Phase Alternating Line and was proposed in 1963 by W. Bruch of Telefunken. It is used in parts of Western Europe. Figure 5-5 is a schematic of the picture preparation process. The color carrier lies in the CCVS (Color Composite Video Signal) spectrum about 4.43 MHz from the picture carrier. The basic principle is quadrature amplitude modulation, whereby the color carrier and the chrominance signal U are directly multiplied. The color carrier, shifted by 90 degrees, is then multiplied by the chrominance signal V. This product is then added to the shifted color carrier. This is a normal quadrature amplitude modulation. In every other row, in addition to the actual quadrature amplitude modulation, the phase of the modulated V signal is rotated in order to reduce phase errors.

EDTV (1)

High-Definition Television (HDTV) (1)

Research in the area of High-Definition Television (HDTV) began in Japan in 1968. This phase is considered to be the third technological change in television, after black-and-white and the introduction of color television. HDTV strives for picture quality at least as good as that of 35 mm film.

Promoters of HDTV pursued the goal of integrating the viewer with the events taking place on the screen [**?**]. Television systems, filming techniques, and viewing requirements were chosen to give the viewer the impression of being involved in the scene. The parameters that had to be defined in order to achieve this goal were resolution, frame rate, aspect ratio, interlaced and/or progressive scanning formats, and viewing conditions.

High-Definition Television (HDTV) (2)

- Resolution: Compared to conventional systems, an HDTV picture has about twice as many horizontal and vertical columns and lines, respectively. The improved vertical resolution is achieved by using more than 1,000 scanning lines. Improved luminance details in the picture can be accomplished with a higher video bandwidth, about five times that used in conventional systems. Two resolution schemes are recommended for practical applications: the so-called "High 1440 Level" with 1,440 $\times$ 1,152 pixels and the "High Level" containing 1,920 $\times$ 1,152 pixels.
- Frame Rate: The number of frames per second was bitterly discussed in the ITU Working Groups. For practical reasons, namely compatibility with existing TV systems and with movies, agreement on a single HDTV standard valid worldwide could not be achieved; options of 50 or 60 frames per second were established. Newly developed, very efficient standard-conversion techniques, based in part on movement estimation and compensation, can mitigate this problem.

High-Definition Television (HDTV) (3)

- Aspect Ratio: The aspect ratio is defined as the ratio of picture width to picture height. Originally, a ratio of 16:9 = 1.777 was adopted; the ratio in current televisions is 4:3.
- Interlaced and/or Progressive Scanning Formats: Conventional TV systems are based on alternation of scanning lines—each frame is composed of two consecutive fields, each containing half the scanning lines of a picture, which are scanned and presented in interlaced mode. In progressive scanning, used for example in computer displays, there is only one such field per picture, and the number of scanning lines per field is doubled.

High-Definition Television (HDTV) (4)

- Viewing Conditions: The field of view and thus the screen size play an important role in visual effects and thus also for the feeling of "reality." Early studies found that the screen area must be bigger than 8,000 cm^2. The line count per picture is about twice as large as in conventional television, so the normal viewing distance can be halved compared to conventional systems and results in three times the picture height (3H).

System	Total channel width (MHz)	Video basebands (MHz)			Frame rate (Hz)	
		Y	R - Y	B - Y	Recording: camera	Playback: monitor
HDTV (USA)	9.0	10.0	5.0	5.0	59.94-p	59.94-i
NTSC	6.0	4.2	1.0	0.6	59.94-i	59.94-i
PAL	8.0	5.5	1.8	1.8	50-i	50-i
SECAM	8.0	6.0	2.0	2.0	50-i	50-i

Figure 3: Properties of TV systems (p: progressive, i: interlaced)

Table of Contents

Basic Concepts of Animation (1)

Animation is a technique used to create the illusion of motion by displaying a series of static images in rapid succession.

- Frames: An animation is made up of a series of frames. Each frame is an individual image that, when displayed quickly in sequence, creates the illusion of movement. The more frames per second (FPS), the smoother the animation appears. Typical frame rates are 24 FPS for film and 30 FPS for television.
- Frame Rate: The frame rate, also known as frames per second (FPS), refers to the number of frames displayed per second in an animation. A higher frame rate results in smoother animation, while a lower frame rate can make the motion appear choppy.
- Keyframes: Keyframes are the important frames in an animation that define the start and end points of any smooth transition or motion. The frames in between these keyframes are called *in-between frames* or *in-betweens*, and they help to fill in the motion.

Basic Concepts of Animation (2)

- Tweening: Tweening (short for “in-betweening”) refers to the process of generating intermediate frames between two keyframes to create smooth transitions. This technique is widely used to reduce the amount of work involved in animating a scene.
- Timing and Spacing: Timing refers to the speed at which an animation moves from one frame to the next. Spacing refers to how the frames are distributed, which affects the perception of speed and motion. Together, timing and spacing create the rhythm and fluidity of an animation.
- Easing: Easing refers to how the motion of an object speeds up or slows down over time. Easing can create more natural motion, such as starting slowly and gradually increasing speed or slowing down at the end of a motion.

Basic Concepts of Animation (3)

- Motion Paths: Motion paths define the trajectory along which an object moves in an animation. These paths can be straight lines, curves, or more complex routes. Objects follow the motion path from the starting keyframe to the ending keyframe.
- Stop Motion: Stop motion animation is a technique where physical objects are photographed one frame at a time, with slight changes in position between each shot. When the frames are played in sequence, it creates the illusion of movement.
- 2D vs 3D Animation:
  - 2D Animation: In 2D animation, objects and characters are created and animated in two dimensions. This is the traditional form of animation, often seen in cartoons and hand-drawn animations.
  - 3D Animation: 3D animation involves creating three-dimensional objects and animating them in a 3D space. This type of animation is used in modern films, video games, and simulations.

Basic Concepts of Animation (4)

- Rotoscoping: Rotoscoping is a technique where animators trace over footage, frame by frame, to create realistic animations. This can be done manually or with digital tools. It is often used for creating lifelike character movements.
- Cel Animation: Cel animation is a traditional technique where each frame of the animation is drawn on a transparent sheet, or "cel," and then filmed. This method was commonly used in classic animation studios.

Table of Contents

Types of Animation (1)

When creating an animation, it is important to organize its execution into a series of logical steps. First, gather all the activities you wish to include in the animation. If it is complicated, you may want to create a written script with a list of activities and required objects. Choose the animation tool best suited for the job. Then, build and refine your sequences, experimenting with lighting effects. Allow plenty of time for this phase of experimenting and testing. Finally, post-process your animation by doing any special rendering and adding sound effects.

Cel Animation

The term *cel* derives from the clear celluloid sheets that were originally used for drawing each frame, which have now been replaced by acetate or plastic. Cels of famous animated cartoons have become sought-after, suitable-for-framing collector's items. Cel animation artwork begins with key frames,

Types of Animation (2)

which represent the first and last frame of an action.

For example, in an animated sequence where a man walks across the screen, he will shift his body weight onto one foot, and then the other, in a series of falls and recoveries, with the opposite foot and leg catching up to support the body. This process is similar to the techniques made famous by Disney, where a series of progressively different images are created for each frame. Since films are played at 24 frames per second, a minute of animation could require as many as 1,440 separate frames.

Computer Based Animation

Computer animation programs typically employ the same logic and procedural concepts as cel animation, using techniques like layers, key frames, and tweening, while also borrowing terminology from classic animators. On the computer, paint is most often applied with tools that feature gradients

Types of Animation (3)

and anti-aliasing. In computer animation, the term *links* generally refers to special methods used for computing RGB pixel values, edge detection, and layering, which allow images to blend or mix their colors to create effects like transparencies and inversions.

The main difference between computer animation software and traditional animation lies in how much work is done manually by the animator and how much is automatically generated by the software. In 2D animation, the animator creates an object and defines a path for it to follow. The software then automatically generates the animation as it is viewed by the user. In 3D animation, the animator's role is to create the models of individual objects and design the characteristics of their shapes and surfaces.

Types of Animation (4)

Handwritten Animation
Stop Motion Animation

Table of Contents

Principles of Animation (1)

The 12 principles of animation were introduced by Disney animators Ollie Johnston and Frank Thomas in their 1981 book, *The Illusion of Life: Disney Animation*. These principles are essential guidelines that animators use to create more realistic and engaging animations. Here are the principles:

1. Squash and Stretch:
   This principle gives a sense of weight and flexibility to objects. For example, a bouncing ball will squash when it hits the ground and stretch when it bounces back up. Squash and stretch are fundamental for creating the illusion of life, making objects appear to have mass and react to the forces acting on them. The degree of squash and stretch can vary depending on the object's material and situation, adding more realism or exaggeration as needed.

Principles of Animation (2)

2. Anticipation:
   This prepares the audience for an action that is about to happen. For example, a character may crouch down before jumping, or pull their arm back before throwing a punch. Anticipation helps set the stage for the action, making it more understandable and impactful. It also helps maintain the flow of the animation by signaling to the viewer what is about to happen.
3. Staging:
   Staging is the arrangement of elements in a scene to direct the audience's focus toward the most important action or character. It involves composition, lighting, and timing. Proper staging ensures that the main action is clear and that secondary details do not distract from it. This principle is essential in guiding the viewer's attention and making the animation visually coherent.

Principles of Animation (3)

4. Straight Ahead Action and Pose to Pose:
   These are two different approaches to creating animation.
   - Straight ahead action involves drawing frame by frame from start to finish. This technique allows for fluid and spontaneous movements but can be harder to control.
   - Pose to pose involves creating key frames first (the most important poses) and then filling in the gaps. This approach gives more control over the timing and structure of the animation.
5. Follow Through and Overlapping Action:
   This principle ensures that different parts of a character or object continue to move after the main action has stopped, creating more realistic motion. For example, when a character stops running, their arms, hair, and clothing may continue to move for a moment after the body stops. Follow through adds a natural sense of completion to the action.

Principles of Animation (4)

6. Slow In and Slow Out:
   This principle makes movements more natural by having more frames at the beginning and end of an action, and fewer in the middle. This mimics the way physical objects speed up and slow down due to inertia. It helps to soften the movement, making it less mechanical and more fluid, improving the overall animation's appeal.
7. Arcs:
   Most natural actions follow an arched trajectory. For example, a thrown ball follows a curved path. This principle emphasizes that movements should have a natural arc rather than a stiff or linear motion. Arcs add grace and fluidity to animation, making actions more realistic.

Principles of Animation (5)

8. Secondary Action:
   This principle adds more dimension to a character's action. For instance, a character running may have their facial expression change or their hair bounce with the movement. Secondary actions are subtle movements or changes that enrich the main action, helping to create a more immersive and believable scene.
9. Timing:
   Timing refers to the number of frames used for an action, which affects its speed and fluidity. Proper timing is crucial for conveying the correct emotional tone and realism. Faster actions may use fewer frames to create a sense of urgency, while slower actions may use more frames to create a feeling of weight or tension.

Principles of Animation (6)

10. Exaggeration:
    This principle involves amplifying actions to make them more dynamic and interesting. Exaggeration can be used to emphasize the emotional state of a character or the impact of an event. While the exaggeration should still be grounded in reality, it helps bring out the essence of the action, adding energy and appeal to the animation.
11. Solid Drawing:
    Solid drawing ensures that forms feel like they are in three-dimensional space, giving them volume and weight. Even in 2D animation, artists must consider the structure and perspective of characters and objects to ensure that they look believable. This principle is fundamental in preventing characters from appearing flat or stiff.

Principles of Animation (7)

12. Appeal:
    This principle ensures that characters are engaging and interesting to the audience. Appeal involves creating designs that are visually appealing, with clear silhouettes, distinctive personalities, and emotional expressions. It doesn't necessarily mean that characters must be cute or beautiful, but they should have a quality that draws the viewer's attention and makes them care about the character's story.

Table of Contents

Techniques of Animation (1)

1. **Traditional Animation**
   - Hand-drawn frame-by-frame animation, also known as *cel animation*.
   - Each frame is drawn by hand on transparent sheets (cels).
   - Pioneered by studios like Disney, such as in *Snow White and the Seven Dwarfs*.
   - Time-consuming and labor-intensive but has a classic, artistic feel.
   - Examples: Early Disney films, Looney Tunes.
2. **2D Animation**
   - Digital version of traditional 2D animation.
   - Created using vector graphics or bitmap images.
   - Involves techniques like *keyframe animation* and *tweening* (interpolation between key frames).
   - Faster and more flexible than traditional hand-drawn methods.
   - Software tools: Adobe Animate, Toon Boom, OpenToonz.
   - Examples: *SpongeBob SquarePants*, *Avatar: The Last Airbender*.
3. **3D Animation**

Techniques of Animation (2)

- Uses 3D computer graphics to create models, textures, and movements.
- Objects are modeled in 3D space and animated using *keyframe animation* or *motion capture*.
- Includes lighting, rendering, and camera techniques to simulate realism.
- Popular in modern animation films and video games.
- Software tools: Blender, Autodesk Maya, Cinema 4D.
- Examples: *Toy Story*, *Frozen*, *Avatar*.

4. **Stop Motion**
    - Involves photographing physical objects (puppets, clay, etc.) one frame at a time, with slight adjustments between each shot.
    - Can be very time-consuming due to the meticulous nature of the process.
    - Includes sub-techniques such as *Claymation*, *Puppet Animation*, and *Cut-out Animation*.
    - Often creates a tactile, "real-world" feel that is difficult to replicate in other methods.
    - Software tools: Dragonframe, Stop Motion Studio.
    - Examples: *Wallace & Gromit*, *The Nightmare Before Christmas*.

Techniques of Animation (3)

5. **Motion Capture (MoCap)**
   - Captures the movements of real people using sensors and then applies them to digital models.
   - Often used for character animation in films and video games to create realistic movements.
   - It provides highly detailed motion data but may lack the expressiveness and stylization of hand-keyed animation.
   - Works in conjunction with 3D animation to enhance realism.
   - Software tools: Vicon, OptiTrack, MotionBuilder.
   - Examples: *The Lord of the Rings* (Gollum), *Avatar*, *The Matrix*.
6. **Rotoscoping**
   - Technique of tracing over footage, frame-by-frame, to create realistic animation.
   - Often used for creating lifelike character movements or special effects in live-action films.

- The traced animation can be used for stylization or compositing into other scenes.
- Often combined with live-action footage.
- Software tools: Adobe After Effects, Toon Boom, Silhouette.
- Examples: *A Scanner Darkly*, *The Lord of the Rings* (1978).

7. **Computer-Generated Imagery (CGI)**
   - Broad term referring to any visual content created using computer software.
   - Often used in combination with 3D animation, visual effects, and compositing.
   - Offers high flexibility for producing complex scenes and visual effects.
   - Examples: *Jurassic Park*, *The Lion King* (2019).

Table of Contents

Creating Animation (1)

Table of Contents

Table of Contents

Animation Language (1)

There are many different languages used to describe animations, and new ones are constantly being developed. These languages fall into three main categories:

1. **Linear-list Notations**

   In linear-list notations, each event in the animation is described by a starting and ending frame number, along with the action that is to take place. These actions often take parameters that define their characteristics. This type of notation is simple and efficient for defining straightforward animations. An example of a linear-list notation is:

   $$42, 53, B, \text{ROTATE}\,"PALM", 1, 30$$

   This notation means: "Between frames 42 and 53, rotate the object called PALM about axis 1 by 30 degrees, with the amount of rotation at each frame determined from tabled B." The linear-list format is a

Animation Language (2)

concise way to define transformations and actions, but it can become cumbersome for more complex animations that involve many objects and parameters.

Linear-list notations are best suited for simple animations that don't require complex interactions between multiple elements. This notation is typically used in early animation systems or for animation sequences that can be broken down into a series of linear events.

2. **General-purpose Language**

   General-purpose animation languages allow the use of variables and parameters in the routines that perform the animation. These languages are more flexible and powerful compared to linear-list notations, as they can describe dynamic relationships between objects, transformations, and camera movements.

   An example of such a language is ASAS (Animation System for Advanced Simulation), which is built on top of LISP. ASAS allows complex geometric transformations and object manipulation, and its primitives include vectors, colors, polygons, solids, groups, points of view, subworlds, and lights. Here's a sample program fragment in ASAS:

   `(grasp my-cube)` The cube becomes the current object.

   `(cw 0.05)` Spin it clockwise by a small amount.

Animation Language (4)

`(grasp camera)` Make the camera the current object.

`(right panning-speed)` Move the camera to the right.

In this example, the cube is spun while the camera pans, with both transformations happening concurrently. The use of parameters like `0.05` for rotation and `panning-speed` for camera movement allows precise control over the animation.

General-purpose animation languages are well-suited for simulations, interactive animations, and scenarios where objects interact dynamically in a complex environment. These languages offer a high degree of flexibility but can be challenging to learn due to their complex syntax and structure.

3. **Graphical Languages**

   Graphical animation languages describe animations in a more visual way. These languages use graphical elements to represent actions and transformations, making them easier to understand, edit, and manipulate. The primary advantage of graphical languages is their intuitive nature; animators can directly see the changes occurring in the animation rather than writing them out in code.

   In these systems, the principal notion is the substitution of a visual paradigm for a textual one. Instead of explicitly writing out descriptions of actions, the animator provides a visual representation of the action, often in the form of diagrams, flowcharts, or animated icons.
   Examples of graphical animation languages include:

Animation Language (6)

- GENESYS: A graphical animation language used for simulation and modeling, where animators create and manipulate animations using a visual interface.
- DIAL: A system that allows the animator to visually program actions and transitions in an animation using a flowchart-like approach.
- S-Dynamics System: A system that uses graphical notation to express complex dynamic interactions and animations, focusing on real-time simulations.

Graphical languages are often used in educational and industrial settings, where ease of use and the ability to visualize complex animations are highly valued. These languages are particularly effective for non-programmers and those who prefer a hands-on approach to creating animations without dealing with code.

The choice of animation language depends on the complexity of the animation, the level of control required, and the target platform.

Animation Language (7)

- Linear-list Notations: Best for simple animations with few objects and actions.
- General-purpose Languages: Suitable for complex animations that require detailed control and dynamic interactions between objects.
- Graphical Languages: Ideal for animators who prefer a visual, intuitive approach to creating animations without needing to write extensive code.

Table of Contents

Animation Control (1)

Animation control is independent of the language used to describe animation. There are various techniques for controlling animation.

1. **Explicitly Declared Control**
   Explicit control is the simplest type of animation control. In explicit control, the animator provides a description of all events that could occur in an animation. This can be done by specifying simple transformations—such as scalings, translations, and rotations—or by specifying key frames and methods for interpolating between them. Interpolation can be specified either explicitly or, in an interactive system, through direct manipulation with a mouse, joystick, data glove, or other input device. An example of this type of control is the BBOP system.

Animation Control (2)

2. **Procedural Control**

   Procedural control is based on communication among different objects whereby each object obtains knowledge about the static or dynamic properties of other objects. This information can be used to verify that objects move in a consistent fashion. In particular, in systems that represent physical processes, the position of an object can influence the movement of other objects (for example, ensuring that balls cannot move through walls). In actor-based systems, individual actors can pass their positions along to others in order to influence their behavior.

Animation Control (3)

3. **Constraint-Based Control**

   Although some objects in the real world move along straight lines, this is not always the case. Many objects' movements are determined by other objects with which they come in contact. It is thus much simpler to specify an animation sequence using constraints (usually determined by the environment) instead of explicit control. Sutherland's Sketchpad and Borning's ThingLab are examples of systems using constraints for control.

   Currently, much work is underway on support for hierarchies of conditions and on the determination of motion. Many of these efforts allow for the specification of constraints that take into account the dynamics of real bodies and the structural properties of their materials.

4. **Control by Analyzing Live Action**

   By examining the motions of objects in the real world, one can animate the same movement by creating corresponding sequences of objects. Traditional animation uses rotoscoping. A film is made in which people or animals act out the parts of the performers in the animation. Afterwards, animators process the film, enhancing the background and replacing the human actors with the animated equivalents they have created.

   Another such technique is to attach indicators to key points on the body of a human actor. The coordinates of the corresponding key points in an animated model can be calculated by observing the position of these indicators. An example of this sort of interaction mechanism is the data glove, which measures the position and orientation of the wearer's hand, as well as the flexion and hyperextension of each finger.

5. **Kinematic and Dynamic Control**

   Kinematics refers to the position and velocity of points. A kinematic description of a scene, for example, might say, "The cube is at the origin at time t=0. Thereafter it moves with constant acceleration in the direction (1 meter, 1 meter, 5 meters)." In contrast, dynamics takes into account the physical laws that govern kinematics (for example, the Newtonian laws for the movement of large bodies, or the Euler-Lagrange equations for fluids). A particle moves with an acceleration proportional to the forces acting on it; the proportionality constant is the mass of the particle.

   A dynamic description of a scene might be: "At time t=0, the cube is at position (0 meter, 100 meter, 0 meter). The cube has a mass of 100 grams. The force of gravity acts on the cube." The natural reaction in a dynamic simulation is that the cube would fall.

Table of Contents

Animation Transmission (1)

Animated objects can be represented symbolically using graphical objects or scan-converted pixmap images. Hence, the transmission of an animation may be performed using one of two approaches:

1. **Symbolic Representation**
   In the symbolic representation approach, the objects of the animation (e.g., a ball) are represented symbolically (e.g., a circle). The operations performed on these objects (e.g., rolling the ball) are also transmitted. The receiver then displays the animation as described earlier.
   - The byte size of the symbolic representation is much smaller than a pixmap representation, which results in a shorter transmission time.
   - However, the display time is longer, as the receiver must generate the corresponding pixmaps for each frame.
   - The bandwidth (e.g., bytes per second) required to transmit an animation in this approach depends on:
     1. The size of the symbolic representation structure used to encode the animated object.
     2. The size of the structure used to encode the operation command.

Animation Transmission (2)

3. The number of animated objects and operation commands sent per second.

2. **Pixmap Representation**
   In this approach, the pixmap representations of the animated objects are transmitted and displayed by the receiver. While the transmission time is longer compared to the symbolic representation approach due to the size of the pixmap, the display time is shorter.
   - The bandwidth required in this case is at least proportional to the size of a single pixmap image and to the image repetition rate.
   - These bandwidth requirements are significantly higher than those for the symbolic representation approach.