Animation

Animation is the process of creating motion and shape change illusion by means of the rapid display of a sequence of static images that minimally differ from each other. The illusion—as in motion pictures in general—is thought to rely on the phi phenomenon. Animators are artists who specialize in the creation of animation.

Animations can be recorded on either analogue media, such as a flip book, motion picture film, video tape, or on digital media, including formats such as animated GIF, Flash animation or digital video. To display animation, a digital camera, computer, orprojector are used along with new technologies that are produced.

Animation creation methods include the traditional animation creation method and those involving stop motion animation of two and three-dimensional objects, such as paper cutouts, puppets and clay figures. Images are displayed in a rapid succession, usually 24, 25, 30, or 60 frames per second.

Many TV shows today use animation and animation gives them that more of a unique look, allowing them to do more than what they could do with actors.

Computer animation

Computer animation encompasses a variety of techniques, the unifying factor being that the animation is created digitally on a computer. 2D animation techniques tend to focus on image manipulation while 3D techniques usually build virtual worlds in which characters and objects move and interact. 3D animation can create images that seem real to the viewer.

2D animation

2D animation figures are created or edited on the computer using 2D bitmap graphics or created and edited using 2D vector graphics. This includes automated computerized versions of traditional animation techniques such as interpolated morphing, onion skinning and interpolated rotoscoping. 2D animation has many applications, including analog computer animation, Flash animation and PowerPoint animation. Cinemagraphs are still photographsin the form of an animated GIF file of which part is animated.

2D Terms

- **Final line advection animation**, a technique that gives the artists and animators a lot more influence and control over the final product as everything is done within the same department. Examples include *Paperman* and *Feast (2014 film)*:

  In Paperman, we didn't have a cloth department and we didn't have a hair department. Here, folds in the fabric, hair silhouettes and the like come from of the committed design decision-making that comes with the 2D drawn process. Our animators can change things, actually erase away the CG underlayer if they want, and change the profile of the arm. And they can design all the fabric in that Milt Kahl kind-of way, if they want to.

3D animation

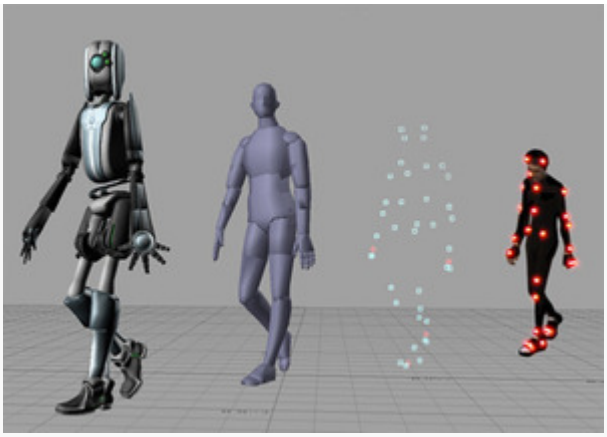
3D animation is digitally modeled and manipulated by an animator. The animator usually starts by creating a 3D polygon mesh to manipulate. A mesh typically includes many vertices that are connected by edges and faces, to give the visual appearance of form to a 3D object or 3D environment. Sometimes, the mesh is given an internal digital skeletal structure called an armature that can be used to control the mesh by weighting the vertices. This process is called rigging and can be used in conjunction with keyframes to create movement.

Other techniques can be applied, such as mathematical functions (e.g., gravity, particle simulations), simulated fur or hair, and effects such as fire and water simulations. These techniques fall under the category of 3D dynamics.

3D Terms

- Cel-shaded animation is used to mimic traditional animation using CG software. Shading looks stark, with less blending of colors. Examples include, *Skyland* (2007, France),*Appleseed Ex Machina* (2007, Japan), *The Legend of Zelda: Wind Waker* (2002, Japan)
- Machinima – Films created by screen capturing in video games and virtual worlds.
- Motion capture is used when live-action actors wear special suits that allow computers to copy their movements into CG characters. Examples include *Polar Express* (2004, US), *Beowulf* (2007, US), *A Christmas Carol* (2009, US), *The Adventures of Tintin (film)* (2011, US) *kochadiiyan*(2014, India)
- Photo-realistic animation is used primarily for animation that attempts to resemble real life, using advanced rendering that mimics in detail skin, plants, water, fire, clouds, etc. Examples include *Up* (2009, US), *How to Train Your Dragon* (2010, US), *Ice Age* (2002, US).

Computer animation



An example of computer animation which is produced in the "motion capture" technique

Computer animation, or **CGI animation**, is the process used for generating animated images by using computer graphics. The more general term computer-generated imagery encompasses both static scenes and dynamic images while computer animation *only* refers to moving images.

Modern computer animation usually uses 3D computer graphics, although 2D computer graphics are still used for stylistic, low bandwidth, and faster real-time renderings. Sometimes, the target of the animation is the computer itself, but sometimes the target is another medium, such as film.

Computer animation is essentially a digital successor to the stop motion techniques used in traditional animation with 3D models and frame-by-frame animation of 2D illustrations. Computer-generated animations are more controllable than other more physically based processes, such as constructing miniatures for effects shots or hiring extras for crowd scenes, and because it allows the creation of images that would not be feasible using any other technology. It can also allow a single graphic artist to produce such content without the use of actors, expensive set pieces, or props.

To create the illusion of movement, an image is displayed on the computer monitor and repeatedly replaced by a new image that is similar to it, but advanced slightly in time (usually at a rate of 24 or 30 frames/second). This technique is identical to how the illusion of movement is achieved withtelevision and motion pictures.

For 3D animations, objects (models) are built on the computer monitor (modeled) and 3D figures are rigged with a virtual skeleton. For 2D figure animations, separate objects (illustrations) and separate transparent layers are used with or without a virtual skeleton. Then the limbs, eyes, mouth, clothes, etc. of the figure are moved by the animator onkey frames. The differences in appearance between key frames are automatically calculated by the computer in a process known as tweening or morphing. Finally, the animation is rendered.

For 3D animations, all frames must be rendered after the modeling is complete. For 2D vector animations, the rendering process is the key frame illustration process, while tweened frames are rendered as needed. For pre-recorded presentations, the rendered frames are transferred to a different format or medium, such as film or digital video. The frames may also be rendered in real time as they are presented to the end-user audience. Low bandwidth animations transmitted via the internet (e.g. 2D Flash, X3D) often use software on the end-users computer to render in real time as an alternative to streaming or pre-loaded high bandwidth animations.

Frame rate

Frame rate, also known as **frame frequency** and **frames per second** (**FPS**), is the frequency (rate) at which an imaging device produces unique consecutive images calledframes. The term applies equally well to film and video cameras, computer graphics, and motion capture systems. Frame rate is most often expressed in frames per second (FPS) and is also expressed in progressive scan monitors as hertz (Hz).

Background

The human eye and its brain interface, the human visual system, can process 10 to 12 separate images per second, perceiving them individually. The threshold of human visual perception varies depending on what is being measured. When looking at a lighted display, people begin to notice a brief interruption of darkness if it is about 16 milliseconds or longer. Observers can recall one specific image in an unbroken series of different images, each of which lasts as little as 13 milliseconds. When given very short single-millisecond visual stimulus people report a duration of between 100 ms and 400 ms due to persistence of vision in the visual cortex. This may cause images perceived in this duration to appear as one stimulus, such as a 10 ms green flash of light immediately followed by a 10 ms red flash of light perceived as a single yellow flash of light.[4] Persistence of vision may also create an illusion of continuity, allowing a sequence of still images to give the impression of motion.

Early silent films had stated frame rates anywhere from 16 to 24 FPS, but since the cameras were hand-cranked, the rate often changed during the scene to fit the mood. Projectionists could also change the frame rate in the theater by adjusting a rheostat controlling the voltage powering the film-carrying mechanism in the projector. Silent films were often intended to be shown at higher frame rates than those used during filming. These frame rates were enough for the sense of motion, but it was perceived as jerky motion. By using projectors with dual- and triple-blade shutters, the rate was multiplied two or three times as seen by the audience. Thomas Edison said that 46 frames per second was the minimum need by the visual cortex: "Anything less will strain the eye." In the mid to late 1920s, the frame rate for silent films increased to between 20 and 26 FPS.

When sound film was introduced in 1926, variations in film speed were no longer tolerated as the human ear is more sensitive to changes in audio frequency. Many theaters had shown silent films at 22 to 26 FPS which is why 24 FPS was chosen for sound. From 1927 to 1930, as various studios updated equipment, the rate of 24 FPS became standard for 35 mm sound film. At 24 FPS the film travels through the projector at a rate of 456 millimetres (18.0 in) per second. This allowed for simple two-blade shutters to give a projected series of images at 48 per second, satisfying Edison's recommendation. Many modern 35 mm film projectors use three-blade shutters to give 72 images per second—each frame is flashed on screen three times.

Motion picture film

In the motion picture industry, where traditional film stock is used, the industry standard filming and projection formats are 24 frames per second (fps). Historically, 25 fps was used in some European countries. Shooting at a slower frame rate would create fast motion when projected, while shooting at a frame rate higher than 24 fps would create slow motion when projected. Other examples of historical experiments in frame rates that were not widely accepted were Maxivision 48 and Showscan, developed by*2001: A Space Odyssey* special effects creator Douglas Trumbull.

The silent home movie film frame rate was 16 fps or 18 fps for 16 mm and standard 8 mm, 18 fps for Super 8. Sound speed was normally 24 fps for all formats.

Digital video and television

There are three main frame rate standards in the TV and digital cinema business: 24p, 25p, and 30p. However, there are many variations on these as well as newer emerging standards.

- 24p is a progressive format and is now widely adopted by those planning on transferring a video signal to film. Film and video makers use 24p even if they are not going to transfer their productions to film, simply because of the on-screen "look" of the (low) frame rate, which matches native film. When transferred to NTSC television, the rate is effectively slowed to 23.976 FPS (24×1000÷1001 to be exact), and when transferred to PAL or SECAM it is sped up to 25 FPS. 35 mm movie cameras use a standard exposure rate of 24 FPS, though many cameras offer rates of 23.976 FPS for NTSC television and 25 FPS for PAL/SECAM. The

24 FPS rate became the de facto standard for sound motion pictures in the mid-1920s.[8] Practically all hand-drawn animation is designed to be played at 24 FPS. Actually hand-drawing 24 unique frames per second ("1's") is costly. Even in big budget films, usually hand-draw animation is done shooting on "2's" (one hand-drawn frame is shown twice, so only 12 unique frames per second)[10] and some animation is even drawn on "4's" (one hand-drawn frame is shown four times, so only six unique frames per second).

- **25p** is a progressive format and runs 25 progressive frames per second. This frame rate derives from the PAL television standard of 50i (or 50 interlaced fields per second). Film and television companies use this rate in 50 Hz regions for direct compatibility with television field and frame rates. Conversion for 60 Hz countries is enabled by slowing down the media to 24p then converting to 60 Hz systems using pulldown. While 25p captures half the temporal resolution or motion that normal 50i PAL registers, it yields a higher vertical spatial resolution per frame. Like 24p, 25p is often used to achieve "cine"-look, albeit with virtually the same motion artifacts. It is also better suited to progressive-scan output (e.g., on LCD displays, computer monitors and projectors) because the interlacing is absent.

- **30p** is a progressive format and produces video at 30 frames per second. Progressive (noninterlaced) scanning mimics a film camera's frame-by-frame image capture. The effects of inter-frame judder are less noticeable than 24p yet retains a cinematic-like appearance. Shooting video in 30p mode gives no interlace artifacts but can introduce judder on image movement and on some camera pans. The widescreen film process Todd-AO used this frame rate in 1954–1956.

- 48p is a progressive format and is currently being trialled in the film industry. At twice the traditional rate of 24p, this frame rate attempts to reduce motion blur and flicker found in films. Director James Cameron stated his intention to film the two sequels to his film *Avatar* higher than 24 frames per second to add a heightened sense of reality. The first film to be filmed at 48 FPS was *The Hobbit: An Unexpected Journey*, a decision made by its director Peter Jackson. At a preview screening at CinemaCon, the audience's reaction was mixed after being shown some of the film's footage at 48p, with some arguing that the feel of the footage was too lifelike (thus breaking the suspension of disbelief).

- **50i** is an interlaced format and is the standard video field rate per second for PAL and SECAM television.

- **60i** is an interlaced format and is the standard video field rate per second for NTSC television (e.g., in the US), whether from a broadcast signal, DVD, or home camcorder. This interlaced field rate was developed separately by Farnsworth and Zworykin in 1934,[15] and was part of the NTSC television standards mandated by the FCC in 1941. When NTSC color was introduced in 1953, the older rate of 60 fields per second was reduced by a

factor of 1000/1001 to avoid interference between the chroma subcarrier and the broadcast sound carrier. (Hence the usual designation "29.97 fps" = 30 frames (60 fields)/1.001)

- **50p**/**60p** is a progressive format and is used in high-end HDTV systems. While it is not technically part of the ATSC or DVB broadcast standards yet, reports suggest that higher progressive frame rates will be a feature of the next-generation high-definition television broadcast standards. In Europe, the EBU considers 1080p50 the next stepfuture proof system for TV broadcasts and is encouraging broadcasters to upgrade their equipment for the future. Many modern cameras can shoot video at 50p and 60p in various resolutions.

- **72p** is a progressive format and is currently in experimental stages. Major institutions such as Snell have demonstrated 720p72 pictures as a result of earlier analogueexperiments, where 768 line television at 75 FPS looked subjectively better than 1150 line 50 FPS progressive pictures with higher shutter speeds available (and a corresponding lower data rate). Modern cameras such as the Red One can use this frame rate to produce slow motion replays at 24 FPS. Douglas Trumbull, who undertook experiments with different frame rates that led to the Showscan film format, found that emotional impact peaked at 72 FPS for viewers.

- **90p**/**100p** is a commercial format found on higher end cameras such as GoPro Hero cameras.

- **120p** (120.00 Hz exactly) is a progressive format and is standardized for UHDTV by the ITU-R BT.2020 recommendation. It will be the single global "double-precision" frame rate for UHDTV (instead of using 100 Hz for PAL-based countries and 119.88 Hz for NTSC-based countries). GoPro Hero 3, 3+ and Hero 4 can shoot video at 720p and 1080p at 120p. There are also an array of modern monitors that now have refresh rates capable of 120 Hz which allows users to view content at 120 fps.[19]

- **144 Fps** Various gaming monitors can display 144 Hz.

- **240 Fps** Some gaming monitors now can display 240 Hz. These monitors, using various backlight flickers and backlight scanning to make 120p looks 'like' 240p, however are still very new and very expensive as of 2014.

- **300 Fps**, interpolated 300 FPS along with other high frame rates, have been tested by BBC Research for use in sports broadcasts. 300 FPS can be converted to both 50 and 60 FPS transmission formats without major issues.

Persistence of vision

Persistence of vision is the theory where an afterimage is thought to persist for approximately one sixteenth of a second on the retina, and believed to be the explanation for motion perception; however, it only explains why the black spaces that come between each "real" movie frame are

not perceived. The true reason for motion perception is the phi phenomenon while the true reason for perception of continuous light is Flicker fusion.

The theory of persistence of vision is the belief that human perception of motion (brain centered) is the result of persistence of vision (eye centered). The theory was disproved in 1912 by Wertheimer[1] but persists in many citations in many classic and modern film-theory texts. A more plausible theory to explain motion perception (at least on a descriptive level) are two distinct perceptual illusions: phi phenomenon and beta movement.

A visual form of memory known as iconic memory has been described as the cause of this phenomenon.[5] Althoughpsychologists and physiologists have rejected the relevance of this theory to film viewership, film academics and theorists generally have not. Some scientists nowadays consider the entire theory a myth.

In contrasting persistence of vision theory with phi phenomena, a critical part of understanding that emerges with these visual perception phenomena is that the eye *is not a camera* and does not see in frames per second. In other words vision is not as simple as light registering on a medium, since the brain has to make sense of the visual data the eye provides and construct a coherent picture of reality. Joseph Anderson and Barbara Fisher argue that the phi phenomena privileges a more constructionist approach to the cinema (David Bordwell, Noël Carroll, Kirsten Thompson), whereas the persistence of vision privileges a realist approach (André Bazin, Christian Metz, Jean-Louis Baudry).

The discovery of persistence of vision is attributed to the Roman poet Lucretius, although he only mentions it in connection with images seen in a dream. In the modern era, some stroboscopic experiments performed by Peter Mark Roget in 1824 were also cited as the basis for the theory.