The Uses of Animation

ANIMATION

Animation is the process of making the illusion of motion and change 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. Animation can be recorded with either analogue media, a flip book, motion picture film, video tape, digital media, including formats with animated GIF, Flash animation and digital video. To display animation, a digital camera, computer, or projector 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, paper cutouts, puppets and clay figures. Images are displayed in a rapid succession, usually 24, 25, 30, or 60 frames per second.

THE MOST COMMON USES OF ANIMATION

Cartoons

The most common use of animation, and perhaps the origin of it, is cartoons. Cartoons appear all the time on television and the cinema and can be used for entertainment, advertising,
presentations and many more applications that are only limited by the imagination of the designer. The most important factor about making cartoons on a computer is *reusability* and *flexibility*. The system that will actually do the animation needs to be such that all the actions that are going to be performed can be repeated easily, without much fuss from the side of the animator. Speed here is not of real importance, as once the sequence is complete, it can be recorded on film or video, frame by frame and played back at an acceptable speed.

**Simulations**

Many times it is much cheaper to train people to use certain machines on a *virtual environment* (i.e., on a computer simulation), than to actually train them on the machines themselves. Simulations of all types that use animation are supposed to respond to real-time stimuli, and hence the events that will take place are non—deterministic. The response to real-time stimuli requires a fast response and the non—determinism, requires a fast system to deal with it. This means that speed is the most important factor in simulation systems.

**Scientific Visualisation**

Graphical visualisation is very common in all areas of science. The usual form that is takes is x-y plots and when things get more complicated three dimensional graphs are used. However there are many cases that something is more complex to be visualised in a three dimensional plot, even if that has been enhanced with some other effect (e.g., colour). Here is where animation comes in. Data is represented in multiple images (frames) which differ a little from each other, and displayed one after the other to give the illusion of motion. This adds a fourth dimension and increases the information conveyed. Speed here is again the most important factor, as huge sets of data might have to be displayed in real-time. Someone might argue, that results maybe filmed and played back, but that depends on how often the sequence has to be recalculated. For example it might take a few days or weeks to generate an
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animation of a fractal, which zooms in slowly, and it might be distressing to realise that it has zoomed in at the wrong place. The uses of scientific visualisation can be classified into two main categories: analysis and teaching.

Analysis and Understanding

Very frequently, scientists have large sets of data (often in the form of lists of numbers) that need to be understood and often a theory needs to be formulated that explains their relationship. It would be very difficult to go through these lists manually or otherwise and make any sense out of them, unless some graphical technique is used for the initial approach. If the data set is massive, a short (or long) animation of the data can give the scientists a first idea of how to approach the situation.

Examples of the different uses of animation:

- Astronomers use computers to do animations if high speed jets penetrating different gases, to determine why a few galaxies flare dramatically. (This research has given out valuable information about why some galaxies flare into broad plumes and why others remain extremely straight and narrow).
- British Telecom uses sophisticated Programmes that plot on a map of the UK, the density of telephone fault reports using different colours. When a storm was plotted on top of this map and the whole system was animated it could be seen that the density of faults increased significantly at areas from which the storm had just passed.
- Animation can be used in software engineering, where an algorithm can be animated, in order to understand how it works or to debug it. Spotting errors using animation, becomes much easier.

Teaching and Communicating

One of the most difficult aspects of teaching is communicating ideas effectively. When this becomes too difficult using the classical teaching tools (speech, blackboard etc.) animation can be used to
Aspects of Animation: Steps to Learn Animated Cartoons

convey information. From its nature, an animation sequence contains much more information than a single image or page of text. This, and the fact that an animation can be very “pleasing to the eye”, makes animation the perfect tool for learning.

Two examples of the use of animation for learning are:

- Programmes that show the planetary system in action in three dimensions make it very easy for kids to understand rather than using tables of sizes, periods and diameters.
- Astrophysicists at the National Centre for Supercomputing Applications, work with artists, in order to explain some phenomena which cannot be seen such as the visualisation of the gravitational field of a Schwarzschild black hole. The latter is not visible as it absorbs all light that falls onto it. The only way of experimenting with it is to animate it on a computer.

History

Early examples of attempts to capture the phenomenon of motion into a still drawing can be found in paleolithic cave paintings, where animals are often depicted with multiple legs in superimposed positions, clearly attempting to convey the perception of motion.

An earthen goblet discovered at the site of the 5,200-year-old Burnt City in southeastern Iran, depicts what could possibly be the world’s oldest example of animation. The artifact bears five sequential images depicting a Persian Desert Ibex jumping up to eat the leaves of a tree.

Ancient Chinese records contain several mentions of devices that were said to “give an impression of movement” to human or animal figures, these accounts are unclear and may only refer to the actual movement of the figures through space.

In the 19th century, the phenakistoscope (1832), zoetrope (1834) and praxinoscope (1877) were introduced. A thaumatrope (1824) is a simple toy with a small disk with different pictures on each side; a bird in a cage, and is attached to two pieces of strings. The
common flip book were early animation devices that produced an illusion of movement from a series of sequential drawings, animation did not develop further until the advent of motion picture film and cinematography in the 1890s.

The cinématographe was a projector, printer, and camera in one machine that allowed moving pictures to be shown successfully on a screen which was invented by history’s earliest film makers, Auguste and Louis Lumière, in 1894. The first animated projection (screening) was created in France, by Charles-Émile Reynaud, who was a French science teacher. Reynaud created the Praxinoscope in 1877 and the Théâtre Optique in December 1888. On 28 October 1892, he projected the first animation in public, *Pauvre Pierrot*, at the Musée Grévin in Paris. This film is also notable as the first known instance of film perforations being used. His films were not photographed, they were drawn directly onto the transparent strip. In 1900, more than 500,000 people had attended these screenings.

The first film that was recorded on standard picture film and included animated sequences was the 1900 *Enchanted Drawing*, which was followed by the first entirely animated film - the 1906 *Humorous Phases of Funny Faces* by J. Stuart Blackton, who, because of that, is considered the father of American animation.

*The first animated film created by using what came to be known as traditional (hand-drawn) animation - the 1908 *Fantasmagorie* by Émile Cohl*
Charlie in Turkey (1916), an animated film by Pat Sullivan for Keen Cartoon Corporation.

In Europe, the French artist, Émile Cohl, created the first animated film using what came to be known as traditional animation creation methods - the 1908 Fantasmagorie. The film largely consisted of a stick figure moving about and encountering all manner of morphing objects, a wine bottle that transforms into a flower. There were also sections of live action in which the animator’s hands would enter the scene. The film was created by drawing each frame on paper and then shooting each frame onto negative film, which gave the picture a blackboard look.

The author of the first puppet-animated film (The Beautiful Lukanida (1912)) was the Russian-born (ethnically Polish) director Wladyslaw Starewicz, known as Ladislas Starevich.

More detailed hand-drawn animation, requiring a team of animators drawing each frame manually with detailed backgrounds and characters, were those directed by Winsor McCay, a successful newspaper cartoonist, including the 1911 Little Nemo, the 1914 Gertie the Dinosaur, and the 1918 The Sinking of the Lusitania.

During the 1910s, the production of animated short films, typically referred to as “cartoons”, became an industry of its own and cartoon shorts were produced for showing in movie theaters. The most successful producer at the time was John Randolph Bray, who, along with animator Earl Hurd, patented the cel animation process which dominated the animation industry for the rest of the decade.

El Apóstol (Spanish: “The Apostle”) was a 1917 Argentine animated film utilizing cutout animation, and the world’s first
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animated feature film. Unfortunately, a fire that destroyed producer Frederico Valle's film studio incinerated the only known copy of *El Apóstol*, and it is now considered a lost film.

In 1958, Hanna-Barbara released *Huckleberry Hound*, the first half hour television program to feature only in animation.

Computer animation has become popular since *Toy Story* (1995), the first feature-length animated film completely made using this technique.

In 2008, the animation market was worth US$68.4 billion. Animation as an art and industry continues to thrive as of the mid-2010s, because well-made animated projects can find audiences across borders and in all four quadrants. Animated feature-length films returned the highest gross margins (around 52%) of all film genres in the 2004–2013 timeframe.

**TECHNIQUES**

**Traditional animation**

Traditional animation (also called cel animation or hand-drawn animation) was the process used for most animated films of the 20th century. The individual frames of a traditionally animated film are photographs of drawings, first drawn on paper. To create the illusion of movement, each drawing differs slightly from the one before it. The animators' drawings are traced or photocopied onto transparent acetate sheets called cels, which are filled in with paints in assigned colors or tones on the side opposite the line drawings. The completed character cels are photographed one-by-one against a painted background by a rostrum camera onto motion picture film.

The traditional cel animation process became obsolete by the beginning of the 21st century. Today, animators' drawings and the backgrounds are either scanned into or drawn directly into a computer system. Various software programs are used to color the drawings and simulate camera movement and effects. The final animated piece is output to one of several delivery media, including
traditional 35 mm film and newer media with digital video. The “look” of traditional cel animation is still preserved, and the character animators’ work has remained essentially the same over the past 70 years. Some animation producers have used the term “tradigital” to describe cel animation which makes extensive use of computer technologies.

Examples of traditionally animated feature films include *Pinocchio* (United States, 1940), *Animal Farm* (United Kingdom, 1954), and *The Illusionist* (British-French, 2010). Traditionally animated films which were produced with the aid of computer technology include *The Lion King* (US, 1994), *The Prince of Egypt* (US, 1998), *Akira* (Japan, 1988), *Spirited Away* (Japan, 2001), *The Triplets of Belleville* (France, 2003), and *The Secret of Kells* (Irish-French-Belgian, 2009).

- Full animation refers to the process of producing high-quality traditionally animated films that regularly use detailed drawings and plausible movement, having a smooth animation. Fully animated films can be made in a variety of styles, from more realistically animated works those produced by the Walt Disney studio (*The Little Mermaid, Beauty and the Beast, Aladdin, The Lion King*) to the more ‘cartoon’ styles of the Warner Bros. animation studio. Many of the Disney animated features are examples of full animation, as are non-Disney works, *The Secret of NIMH* (US, 1982), *The Iron Giant* (US, 1999), and *Nocturna* (Spain, 2007).

- Limited animation involves the use of less detailed or more stylized drawings and methods of movement usually a choppy or “skippy” movement animation. Pioneered by the artists at the American studio United Productions of America, limited animation can be used as a method of stylized artistic expression, as in *Gerald McBoing-Boing* (US, 1951), *Yellow Submarine* (UK, 1968), and certain anime produced in Japan. Its primary use, however, has been in producing cost-effective animated content for media for television (the work of Hanna-Barbera, Filmation, and other
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TV animation studios) and later the Internet (web cartoons).

- Rotoscoping is a technique patented by Max Fleischer in 1917 where animators trace live-action movement, frame by frame. The source film can be directly copied from actors' outlines into animated drawings, as in *The Lord of the Rings* (US, 1978), or used in a stylized and expressive manner, as in *Waking Life* (US, 2001) and *A Scanner Darkly* (US, 2006). Some other examples are: *Fire and Ice* (US, 1983), *Heavy Metal* (1981), and *Aku no Hana* (2013).

- Live-action/animation is a technique combining hand-drawn characters into live action shots or live action actors into animated shots. One of the earlier uses was in *Koko the Clown* when Koko was drawn over live action footage. Other examples include *Who Framed Roger Rabbit* (US, 1988), *Space Jam* (US, 1996) and *Osmosis Jones* (US, 2001).

Stop motion animation

Stop-motion animation is used to describe animation created by physically manipulating real-world objects and photographing them one frame of film at a time to create the illusion of movement. There are many different types of stop-motion animation, usually named after the medium used to create the animation. Computer software is widely available to create this type of animation; however, traditional stop motion animation is usually less expensive and time-consuming to produce than current computer animation.

- Puppet animation typically involves stop-motion puppet figures interacting in a constructed environment, in contrast to real-world interaction in model animation. The puppets generally have an armature inside of them to keep them still and steady to constrain their motion to particular joints. Examples include *The Tale of the Fox* (France, 1937), *The Nightmare Before Christmas* (US, 1993), *Corpse Bride* (US, 2005), *Coraline* (US, 2009), the films of Jiří Trnka and the adult animated sketch-comedy television series *Robot Chicken* (US, 2005–present).
• Puppetoon, created using techniques developed by George Pal, are puppet-animated films which typically use a different version of a puppet for different frames, rather than simply manipulating one existing puppet.

• Clay animation, or Plasticine animation (often called claymation, which, however, is a trademarked name), uses figures made of clay or a similar malleable material to create stop-motion animation. The figures may have an armature or wire frame inside, similar to the related puppet animation (below), that can be manipulated to pose the figures. Alternatively, the figures may be made entirely of clay, as in the films of Bruce Bickford, where clay creatures morph into a variety of different shapes. Examples of clay-animated works include The Gumby Show (US, 1957–1967) Morph shorts (UK, 1977–2000), Wallace and Gromit shorts (UK, as of 1989), Jan Švankmajer’s Dimensions of Dialogue (Czechoslovakia, 1982), The Trap Door (UK, 1984). Films include Wallace & Gromit: The Curse of the Were-Rabbit, Chicken Run and The Adventures of Mark Twain.

• Strata-cut animation, Strata-cut animation is most commonly a form of clay animation in which a long bread-like “loaf” of clay, internally packed tight and loaded with varying imagery, is sliced into thin sheets, with the animation camera taking a frame of the end of the loaf for each cut, eventually revealing the movement of the internal images within.

• Cutout animation is a type of stop-motion animation produced by moving two-dimensional pieces of material paper or cloth. Examples include Terry Gilliam’s animated sequences from Monty Python’s Flying Circus (UK, 1969–1974); Fantastic Planet (France/Czechoslovakia, 1973); Tale of Tales (Russia, 1979), The pilot episode of the adult television sitcom series (and sometimes in episodes) of South Park (US, 1997) and the music video Live for the moment, from Verona Riots band (produced by Alberto Serrano and Nívola Uyá, Spain 2014).

• Silhouette animation is a variant of cutout animation in
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which the characters are backlit and only visible as silhouettes. Examples include The Adventures of Prince Achmed (Weimar Republic, 1926) and Princes et princesses (France, 2000).

• Model animation refers to stop-motion animation created to interact with and exist as a part of a live-action world. Intercutting, matte effects, and split screens are often employed to blend stop-motion characters or objects with live actors and settings. Examples include the work of Ray Harryhausen, as seen in films, Jason and the Argonauts (1963), and the work of Willis H. O’Brien on films, King Kong (1933).

• Go motion is a variant of model animation that uses various techniques to create motion blur between frames of film, which is not present in traditional stop-motion. The technique was invented by Industrial Light & Magic and Phil Tippett to create special effect scenes for the film The Empire Strikes Back (1980). Another example is the dragon named “Vermithrax” from Dragonslayer (1981 film).

• Object animation refers to the use of regular inanimate objects in stop-motion animation, as opposed to specially created items.

• Graphic animation uses non-drawn flat visual graphic material (photographs, newspaper clippings, magazines, etc.), which are sometimes manipulated frame-by-frame to create movement. At other times, the graphics remain stationary, while the stop-motion camera is moved to create on-screen action.

• Brickfilm A subgenre of object animation involving using Lego or other similar brick toys to make an animation. These have had a recent boost in popularity with the advent of video sharing sites, YouTube and the availability of cheap cameras and animation software.

• Pixilation involves the use of live humans as stop-motion characters. This allows for a number of surreal effects, including disappearances and reappearances, allowing people to appear to slide across the ground, and other
effects. Examples of pixilation include *The Secret Adventures of Tom Thumb* and *Angry Kid* shorts.

**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, interpolated morphing, onion skinning and interpolated rotoscoping.

2D animation has many applications, including analog computer animation, Flash animation and PowerPoint animation. Cinemagraphs are still photographs in the form of an animated GIF file of which part is animated.

Final line advection animation is a technique used in 2D animation, to give artists and animators more influence and control over the final product as everything is done within the same department. Speaking about using this approach in *Paperman*, John Kahrs said that “Our animators can change things, actually erase away the CG underlayer if they want, and change the profile of the arm.”

**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, which 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, mathematical functions (e.g., gravity, particle simulations), simulated fur or hair, and effects, 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 computer software. Shading looks stark, with less blending of colors. Examples include, Skyland (2007, France), The Iron Giant (1999, United States), Futurama (Fox, 1999) Appleseed Ex Machina (2007, Japan), The Legend of Zelda: The Wind Waker (2002, Japan)
- Machinima – Films created by screen capturing in video games and virtual worlds.
- 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).

Mechanical animation

- Animatronics is the use of mechatronics to create machines which seem animate rather than robotic.
- Audio-Animatronics and Autonomatronics is a form of robotics animation, combined with 3-D animation, created by Walt Disney Imagineering for shows and attractions at Disney theme parks move and make noise (generally a recorded speech or song). They are fixed to whatever supports them. They can sit and stand, and they cannot
walk. An Audio-Animatron is different from an android-type robot in that it uses prerecorded movements and sounds, rather than responding to external stimuli. In 2009, Disney created an interactive version of the technology called Autonomatronics.

- **Linear Animation Generator** is a form of animation by using static picture frames installed in a tunnel or a shaft. The animation illusion is created by putting the viewer in a linear motion, parallel to the installed picture frames. The concept and the technical solution, were invented in 2007 by Mihai Girlovan in Romania.

- **Chuckimation** is a type of animation created by the makers of the television series *Action League Now!* in which characters/props are thrown, or chucked from off camera or wiggled around to simulate talking by unseen hands.

- **Puppetry** is a form of theatre or performance animation that involves the manipulation of puppets. It is very ancient, and is believed to have originated 3000 years BC. Puppetry takes many forms, they all share the process of animating inanimate performing objects. Puppetry is used in almost all human societies both as entertainment – in performance – and ceremonially in rituals, celebrations and carnivals. Most puppetry involves storytelling.

- **Zoetrope** is a device that produces the illusion of motion from a rapid succession of static pictures. The term zoetrope is from the Greek words ἀευτός (zoe), meaning “alive, active”, and τόπος (tropos), meaning “turn”, with “zoetrope” taken to mean “active turn” or “wheel of life”.

**Other animation styles, techniques and approaches**

- **Hydrotechnics**: a technique that includes lights, water, fire, fog, and lasers, with high-definition projections on mist screens.

- **Drawn on film animation**: a technique where footage is produced by creating the images directly on film stock, for example by Norman McLaren, Len Lye and Stan Brakhage.

- **Paint-on-glass animation**: a technique for making animated
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films by manipulating slow drying oil paints on sheets of glass, for example by Aleksandr Petrov.

World of Color hydrotechnics at Disney California Adventure creates illusion of motion using 1200 fountains with high-definition projections on mist screens.

- Erasure animation: a technique using traditional 2D media, photographed over time as the artist manipulates the image. For example, William Kentridge is famous for his charcoal erasure films, and Piotr Dumańska for his auteur technique of animating scratches on plaster.

- Pinscreen animation: makes use of a screen filled with movable pins that can be moved in or out by pressing an object onto the screen. The screen is lit from the side so that the pins cast shadows. The technique has been used to create animated films with a range of textural effects difficult to achieve with traditional cel animation.

- Sand animation: sand is moved around on a back- or front-lighted piece of glass to create each frame for an animated film. This creates an interesting effect when animated because of the light contrast.

- Flip book: a flip book (sometimes, especially in British English, called a flick book) is a book with a series of pictures that vary gradually from one page to the next, so that when the pages are turned rapidly, the pictures appear to animate by simulating motion or some other change. Flip books are often illustrated books for children, they also be geared towards adults and employ a series of photographs rather than drawings. Flip books are not
always separate books, they appear as an added feature in ordinary books or magazines, often in the page corners. Software packages and websites are also available that convert digital video files into custom-made flip books.

- Character animation
- Multi-sketching
- Special effects animation

HISTORY OF ANIMATION TECHNIQUES

Picture animation was invented in 1831 by Joseph Antoine Plateau. He used a machine called *phenakistoscope* to create the illusion of movement. The device consisted of a spinning disc that held a series of drawings and windows that framed the user’s perception of the drawings.

Many other animating machines were invented since, then, but it was not until 1906 when the first complete animated film was produced by J. Stewart Blackton. It was called “Humorous Phases of a Funny Face”. In 1915, Earl Hurd introduced the technique of *cell animation* which took its name from the transparent sheets of celluloid that was used. The father of animation, Walt Disney produced a huge cartoon world in less than ten years at 1928. The first commercial animated cartoon, “Snow White and the Seven Dwarfs”, was then produced.

Many people followed, which contributed to this evolution. The results were good, but to a certain point. When very complex animation was required, everything turned out to be extremely difficult. Something was definitely missing and technology would give the answer in the following years.

Traditional Animation Techniques

Hand-drawn animation, with each frame individually crafted by an artist, requires a lot of skill, a lot of patience and very little equipment. The drawing is usually done on a *cell* which allows multiple frames to be drawn by the same cells. Each frame can be recorded on film or video, and the amount of work going into
an animation is staggering. A feature film containing the production of 250,000 drawings would take fifty years of labour if all were to be drawn by a single artist. So usually it is coordinated by one person but the work is divided among a number of artists. Senior artists will draw the key frames and junior artists will draw in-between ones.

As we said before all the detail can be painted on to every frame; it is more likely that the frame will be compiled from several cells at the point of filming. The background may be on one cell, static characters on the other and the moving character on the top. In this way the bottom two cells can be used in a number of frames. It might also be that the cells are moved relative to one another, in successive frames, without being redrawn. Conventional animation is oriented mainly towards the production of two-dimensional cartoons. Every frame is a flat picture. In order to achieve the multiple frame design by using the same cells the multiplane technique is used. Several glass layers are placed beneath the camera at varying distances. On the layers the cells are placed and the frame is filmed. A lot of camera effects can be added into the animation but they are usually difficult to produce and sometimes are very expensive. A few of them are: zooming, fade-in, fade-out, etc.

**Computer Assisted Animation**

It is very clear that automation of the whole animation or even part of it would be very productive. Computers were used for animation for the first time in early sixties but it was mainly for scientific reasons. Ten years later animators started to consider computers to be a very powerful and useful part of their animation systems.

Today, computers can be used in animation in two main ways: as tools to improve the application of traditional methods; and as a means of generating animation which is not possible using traditional methods. Computers can considerably improve the speed, accuracy and at the same time reduce the cost of traditional
animation methods. Projects which were impossible to realise in the past could actually be attempted.

Computer animation systems are classified into several different levels. These levels define the depth of the assistance that is provided by the computer. At the lowest level the animator can use software only to design the drawings. On the other hand at the highest level the whole work drawing, modelling and motion control is produced by the system.

The second more important advantage of modern animation systems apart of the fact that make everything easier is the interactivity. Animation can not only be a visual effect that one simply sees and waits until it is finished. The user becomes a participant of the whole story and can decide upon the development of the sequence. This has a large amount of applications which give to animation systems a very important existence in life.

There are several animation software packages currently available in the market. They all have a different approach to animation but tend to work on the same principle. There is an interactive graphics interface where the drawing, paint and modelling takes place. An animation language takes care of the motion control and of any advanced animation that is required. Every language currently available requires different programming skills. However the more advanced a language is, the more enhanced the produced motion will be. The problem that arises here is that computer animators usually don’t have strong programming experience since, they mostly come from areas of traditional animation. There is not a single answer to this problem but the most satisfying one is that software should approach differently each user depending on the result that is required to produce.

Production

The creation of non-trivial animation works (i.e., longer than a few seconds) has developed as a form of filmmaking, with certain unique aspects. One thing live-action and animated feature-
length films do have in common is that they are both extremely labor-intensive and have high production costs.

The most important difference is that once a film is in the production phase, the marginal cost of one more shot is higher for animated films than live-action films. It is relatively easy for a director to ask for one more take during principal photography of a live-action film, but every take on an animated film must be manually rendered by animators (although the task of rendering slightly different takes has been made less tedious by modern computer animation). It is pointless for a studio to pay the salaries of dozens of animators to spend weeks creating a visually dazzling five-minute scene, if that scene fails to effectively advance the plot of the film. Thus, animation studios starting with Disney began the practice in the 1930s of maintaining story departments where storyboard artists develop every single scene through storyboards, then handing the film over to the animators only after the production team is satisfied that all the scenes will make sense as a whole. While live-action films are now also storyboarded, they enjoy more latitude to depart from storyboards (i.e., real-time improvisation).

Another problem unique to animation is the necessity of ensuring that the style of an animated film is consistent from start to finish, even as films have grown longer and teams have grown larger. Animators, like all artists, necessarily have their own individual styles, but must subordinate their individuality in a consistent way to whatever style was selected for a particular film. Since the early 1980s, feature-length animated films have been created by teams of about 500 to 600 people, of whom 50 to 70 are animators. It is relatively easy for two or three artists to match each other's styles; it is harder to keep dozens of artists synchronized with one another.

This problem is usually solved by having a separate group of visual development artists develop an overall look and palette for each film before animation begins. Character designers on the visual development team draw model sheets to show how each
character should look like with different facial expressions, posed in different positions, and viewed from different angles. On traditionally animated projects, maquettes were often sculpted to further help the animators see how characters would look from different angles.

Unlike live-action films, animated films were traditionally developed beyond the synopsis stage through the storyboard format; the storyboard artists would then receive credit for writing the film. In the early 1960s, animation studios began hiring professional screenwriters to write screenplays (while also continuing to use story departments) and screenplays had become commonplace for animated films by the late 1980s.

**Criticism**

Criticism of animation has become a domineering force in media and cinema since its inception. With its popularity, a large amount of criticism has arisen, especially animated feature-length films. Many concerns of cultural representation, psychological effects on children have been brought up around the animation industry, which has remained rather politically unchanged and stagnant since its inception into mainstream culture.

Certain under-representation of women has been criticized in animation films and the industry.

**Awards**

As with any other form of media, animation too has instituted awards for excellence in the field. The original awards for animation were presented by the Academy of Motion Picture Arts and Sciences for animated shorts from the year 1932, during the 5th Academy Awards function. The first winner of the Academy Award was the short *Flowers and Trees*, a production by Walt Disney Productions. The Academy Award for a feature-length animated motion picture was only instituted for the year 2001, and awarded during the 74th Academy Awards in 2002. It was won by the film *Shrek*, produced by DreamWorks and Pacific Data Images. Disney/
Pixar have produced the most films either to win or be nominated for the award. The list of both awards can be obtained here:

- Academy Award for Best Animated Feature
- Academy Award for Best Animated Short Film

Several other countries have instituted an award for best animated feature film as part of their national film awards: Africa Movie Academy Award for Best Animation (since 2008), BAFTA Award for Best Animated Film (since 2006), César Award for Best Animated Film (since 2011), Golden Rooster Award for Best Animation (since 1981), Goya Award for Best Animated Film (since 1989), Japan Academy Prize for Animation of the Year (since 2007), National Film Award for Best Animated Film (since 2006). Also since 2007, the Asia Pacific Screen Award for Best Animated Feature Film has been awarded at the Asia Pacific Screen Awards. Since 2009, the European Film Awards have awarded the European Film Award for Best Animated Film.
Analysing Animated Cartoons and their Evolution

ANIMATED CARTOON

An animated cartoon is a film for the cinema, television or computer screen, which is made using sequential drawings, as opposed to animations in general, which include films made using clay, puppet and other means.

HISTORY

Early years

Early examples of attempts to capture the phenomenon of motion into a still drawing can be found in paleolithic cave paintings, where animals are often depicted with multiple legs in superimposed positions, clearly attempting to convey the perception of motion.

The phenakistoscope (1832), zoetrope (1834) and praxinoscope (1877), as well as the common flip book, were early animation devices to produce movement from sequential drawings using technological means, but did not develop further until the advent of motion picture film.
Silent era

“Golden Age”

From the 1920s to 1960s, theatrical cartoons were produced in huge numbers, and usually shown before a feature film in a movie theater. Disney (distributed by Pat Powers, then Columbia, then United Artists, then RKO, then independently), Fleischer (distributed by Paramount), Warner Bros., MGM, and UPA (distributed by Columbia) were the largest studios producing these 5- to 10-minute “shorts.” Other studios included Walter Lantz (distributed by Universal), DePatie-Freleng (distributed by United Artists), Charles Mintz Studios (later Screen Gems) (distributed by Columbia), Famous Studios (distributed by Paramount), and Terrytoons (distributed by 20th Century Fox).

The first cartoon to use a soundtrack was in 1926 with Max Fleischer’s *My Old Kentucky Home*. However the Fleischers used a De Forest sound system and the sound was not completely synchronized with the film. Walt Disney’s 1928 cartoon *Steamboat Willie* starring Mickey Mouse was the first to use a click track during the recording session, which produced better synchronism. “Mickey Mousing” became a term for any movie action (animated or live action) that was perfectly synchronized with music. The music used is original most of the time, but musical quotation is often employed. Animated characters usually performed the action in “loops,” i.e., drawings were repeated over and over.

Although other producers had made films earlier using 2-strip color, Disney produced the first cartoon in 3-strip Technicolor, *Flowers and Trees*, in 1932. Technicians at the Fleischer studio invented rotoscoping, in which animators trace live action in order to make animation look more realistic. However, rotoscoping made the animation look stiff and the technique was later used more for studying human and animal movement, rather than directly tracing and copying filmed movements.

Later, other movie technologies were adapted for use in animation, such as multiplane cameras with *The Old Mill* (1937),
stereophonic sound in *Fantasia* (1940), widescreen processes with the feature-length *Lady and the Tramp* (1955), and even 3D with *Lumber Jack-Rabbit*.

Today, traditional animation uses traditional methods, but is aided by computers in certain areas. This gives the animator new tools not available that could not be achieved using old techniques.

**Feature films**

In 1937, Disney created the first sound and color animated feature film *Snow White and the Seven Dwarfs*.

The name “animated cartoon” is generally not used when referring to full-length animated productions, since the term more or less implies a “short.” Huge numbers of animated feature films were, and are still, produced.

**Television**

Competition from television drew audiences away from movie theaters in the late 1950s, and the theatrical cartoon began its decline. Today, animated cartoons for American audiences are produced mostly for television.

American television animation of the 1950s featured quite limited animation styles, highlighted by the work of Jay Ward on *Crusader Rabbit*. Chuck Jones coined the term “illustrated radio” to refer to the shoddy style of most television cartoons that depended more on their soundtracks than visuals. Other notable 1950s programs include UPA’s *Gerald McBoing Boing*, Hanna-Barbera’s *Huckleberry Hound* and *Quick Draw McGraw*, and rebroadcast of many classic theatrical cartoons from Universal’s Walter Lantz, Warner Brothers, MGM, and Disney.

The Hanna-Barbera cartoon, *The Flintstones*, was the first successful primetime animated series in the United States, running from 1960-66 (and in reruns since). While many networks followed the show’s success by scheduling other cartoons in the early 1960s, including *Scooby-Doo, Where Are You!, The Jetsons, Top Cat*, and *The Alvin Show*, none of these programs survived more than a year
Analysing Animated Cartoons and their Evolution

(save Scooby-Doo, which, despite not being a primetime cartoon, has managed to stay afloat for over four decades). However, networks found success by running these shows as Saturday morning cartoons, reaching smaller audiences with more demographic unity among children. Television animation for children flourished on Saturday morning, on cable channels like Nickelodeon, Disney Channel and Cartoon Network, PBS Kids, and in syndicated afternoon timeslots.

The scheduling constraints of the TV animation process, notably issues of resource management, led to the development of various techniques known now as limited animation. Full-frame animation ("on ones") became rare in its use outside of theatrical productions in the United States.

Primetime cartoons for mature audiences were virtually non-existent in the mainstream of the United States until 1990s hit The Simpsons ushered in a new era of adult animation. Now, "adult animation" programs, such as Aeon Flux, Beavis and Butt-head, South Park, Family Guy, The Cleveland Show, American Dad!, Bob’s Burgers, Aqua Teen Hunger Force (currently known as Aqua TV Show Show), and Futurama have increased the number of animated sitcoms on prime-time and evening American television. In addition, animated works from other countries (notably Japan) have had varying levels of airplay in the United States since the 1960s.

Commercial animation

Animation has been very popular in television commercials, both due to its graphic appeal, and the humour it can provide. Some animated characters in commercials have survived for decades, such as Snap, Crackle and Pop in advertisements for Kellogg’s cereals.

In 1957, “Louie the Fly” made his first appearance on Australian TV as the cartoon antagonist for Mortein, an Australian brand of household insecticide and was drawn and animated by Geoffry Morgan Pike. In a jingle created by Bryce Courtenay, it has been
used in animated TV commercials since 1962, he proudly sings of his own dirtiness, claiming to be afraid of no-one except “the man with the can of Mortein.”

The legendary animation director Tex Avery was the producer of the first Raid “Kills Bugs Dead” commercials in 1966, which were very successful for the company. The concept has been used in many countries since.

EDITORIAL CARTOON

An editorial cartoon, also known as a political cartoon, is an illustration containing a commentary that usually relates to current events or personalities. An artist who draws such images is known as an editorial cartoonist.

They typically combine artistic skill, hyperbole and satire in order to question authority and draw attention to corruption and other social ills.

History

Origins

The pictorial satire of William Hogarth has been credited as the precursor to the political cartoon. His pictures combined social criticism with sequential artistic scenes. A frequent target of his satire was the corruption of early-18th-century British politics. An early satirical work was an Emblematical Print on the South Sea Scheme (c.1721), about the disastrous stock market crash of 1720 known as the South Sea Bubble, in which many English people lost a great deal of money.

His art often had a strong moralizing element to it, such as in his masterpiece of 1719, A Rake’s Progress. It consisted of eight pictures that depicted the reckless life of Tom Rakewell, the son of a rich merchant, who spends all of his money on luxurious living, services from sex workers, and gambling—the character’s life ultimately ends in Bethlem Royal Hospital. However, his work was only tangentially politicized and was primarily regarded on
its artistic merits. George Townshend, 1st Marquess Townshend produced some of the first overtly political cartoons and caricatures in the 1750s.

**Development**

*The world being carved up into spheres of influence between Pitt and Napoleon. James Gillray, “probably the most famous political cartoon of all time—it has been stolen over and over and over again by cartoonists ever since.”*

The medium began to develop in England in the latter part of the 18th century—especially around the time of the French Revolution—under the direction of its great exponents, James Gillray and Thomas Rowlandson, both from London. Gillray explored the use of the medium for lampooning and caricature, and has been referred to as the father of the political cartoon. Calling the king, prime ministers and generals to account, many of Gillray’s satires were directed against George III, depicting him as a pretentious buffoon, while the bulk of his work was dedicated to ridiculing the ambitions of Revolutionary France and Napoleon. The times in which Gillray lived were peculiarly favourable to the growth of a great school of caricature. Party warfare was carried on with great vigour and not a little bitterness; and personalities were freely indulged in on both sides. Gillray’s incomparable wit
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and humour, knowledge of life, fertility of resource, keen sense of the ludicrous, and beauty of execution, at once gave him the first place among caricaturists.

George Cruikshank became the leading cartoonist in the period following Gillray (1820s–40s). His early career was renowned for his social caricatures of English life for popular publications. He gained notoriety with his political prints that attacked the royal family and leading politicians and was bribed in 1820 “not to caricature His Majesty” (George IV) “in any immoral situation”. His work included a personification of England named John Bull who was developed from about 1790 in conjunction with other British satirical artists such as James Gillray, and Thomas Rowlandson.

Cartoonist’s magazines

The art of the editorial cartoon was further developed with the publication of the periodical Punch in 1841, founded by Henry Mayhew and engraver Ebenezer Landells (an earlier magazine that published cartoons was Monthly Sheet of Caricatures, printed from 1830 and an important influence on Punch). It was bought by Bradbury and Evans in 1842, who capitalised on newly evolving mass printing technologies to turn the magazine into a preeminent national institution. The term “cartoon” to refer to comic drawings was coined by the magazine in 1843; the Houses of Parliament were to be decorated with murals, and “cartons” for the mural were displayed for the public; the term “cartoon” then meant a finished preliminary sketch on a large piece of cardboard, or cartone in Italian. Punch humorously appropriated the term to refer to its political cartoons, and the popularity of the Punch cartoons led to the term’s widespread use.

Artists who published in Punch during the 1840s and 50s included John Leech, Richard Doyle, John Tenniel and Charles Keene. This group became known as “The Punch Brotherhood”, which also included Charles Dickens who joined Bradbury and Evans after leaving Chapman and Hall in 1843. Punch authors and
artists also contributed to another Bradbury and Evans literary magazine called *Once A Week* (est. 1859), created in response to Dickens’ departure from *Household Words*.

*The British Lion’s Vengeance...*, cartoon by John Tenniel in the aftermath of the Indian Rebellion of 1857

The most prolific and influential cartoonist of the 1850s and 60s was John Tenniel, chief cartoon artist for *Punch*, who perfected the art of physical caricature and representation to a point that has changed little up to the present day. For over five decades he was a steadfast social witness to the sweeping national changes that occurred during this period alongside his fellow cartoonist John Leech. The magazine loyally captured the general public mood; in 1857, following the Indian Rebellion and the public outrage that followed, *Punch* published vengeful illustrations such as Tenniel’s “Justice” and “The British Lion’s Vengeance on the Bengal Tiger”.

**Maturation**

By the mid 19th century, major political newspapers in many countries featured cartoons designed to express the publisher’s opinion on the politics of the day. One of the most successful was Thomas Nast in New York City, who imported realistic German drawing techniques to major political issues in the era of the Civil War and Reconstruction. Nast was most famous for his 160 editorial
cartoons attacking the criminal characteristics of Boss Tweed’s political machine in New York City. Albert Boime argues that:

As a political cartoonist, Thomas Nast wielded more influence than any other artist of the 19th century. He not only enthralled a vast audience with boldness and wit, but swayed it time and again to his personal position on the strength of his visual imagination.

Both Lincoln and Grant acknowledged his effectiveness in their behalf, and as a crusading civil reformer he helped destroy the corrupt Tweed Ring that swindled New York City of millions of dollars. Indeed, his impact on American public life was formidable enough to profoundly affect the outcome of every presidential election during the period 1864 to 1884.

Notable editorial cartoons include Benjamin Franklin’s “Join, or Die” (1754), on the need for unity in the American colonies; “The Thinkers Club” (1819), a response to the surveillance and censorship of universities in Germany under the Carlsbad Decrees; and E. H. Shepard’s “The Goose-Step” (1936), on the rearmament of Germany under Hitler. “The Goose-Step” is one of a number of notable cartoons first published in the British Punch magazine.
Recognition

Institutions which archive and document editorial cartoons include the Center for the Study of Political Graphics in the United States, and the British Cartoon Archive in the United Kingdom.

Editorial cartoons and editorial cartoonists are recognised by a number of awards, for example the Pulitzer Prize for Editorial Cartooning (for US cartoonists, since 1922) and the British Press Awards’ “Cartoonist of the Year”.

MODERN POLITICAL CARTOONS

“To begin with, I’ll paint the town red.” Grant E. Hamilton, The Judge vol. 7, 31 January 1885

Political cartoons can usually be found on the editorial page of many newspapers, although a few (such as Garry Trudeau’s Doonesbury) are sometimes placed on the regular comic strip page.
Most cartoonists use visual metaphors and caricatures to address complicated political situations, and thus sum up a current event with a humorous or emotional picture.

Yaakov Kirschen, creator of the Israeli comic strip Dry Bones, says his cartoons are designed to make people laugh, which makes them drop their guard and see things the way he does. In an interview, he defined his objective as a cartoonist as an attempt to “seduce rather than to offend.”

In modern political cartooning, two styles have begun to emerge. The traditional style uses visual metaphors and symbols like Uncle Sam, the Democratic donkey and the Republican elephant; the more recent text-heavy style, seen in *Doonesbury*, tells a linear story, usually in comic strip format. Regardless of style, editorial cartoons are a way for artists to express their thoughts about current events in a comical manner.

A political cartoon commonly draws on two unrelated events and brings them together incongruously for humorous effect. The humour can reduce people’s political anger and so serves a useful purpose. Such a cartoon also reflects real life and politics, where a deal is often done on unrelated proposals beyond public scrutiny.

**Pocket cartoons**

A pocket cartoon is a form of editorial cartoon which consists of a topical single-panel single-column drawing. It was introduced by Osbert Lancaster in 1939 at the *Daily Express*. A 2005 obituary by *The Guardian* of its pocket cartoonist David Austin said “Newspaper readers instinctively look to the pocket cartoon to reassure them that the disasters and afflictions besetting them each morning are not final. By taking a sideways look at the news and bringing out the absurd in it, the pocket cartoonist provides, if not exactly a silver lining, then at least a ray of hope.”

**Controversies**

Editorial cartoons sometimes cause controversies. Examples include the *Jyllands-Posten* Muhammad cartoons controversy
(stemming from the publication of cartoons of Muhammad) and the 2007 Bangladesh cartoon controversy. Libel lawsuits have been rare. In Britain, the first successful lawsuit against a cartoonist in over a century came in 1921 when J.H. Thomas, the leader of the National Union of Railwaymen (NUR), initiated libel proceedings against the magazine of the British Communist Party. Thomas claimed defamation in the form of cartoons and words depicting the events of “Black Friday”—when he allegedly betrayed the locked-out Miners’ Federation. Thomas won his lawsuit, and restored his reputation.

**CARTOON PORNOGRAPHY**

Cartoon pornography is the portrayal of illustrated or animated fictional cartoon characters in erotic or sexual situations. Cartoon pornography includes, but is not limited to, hentai, adult comix, and rule 34 of famous copyrighted characters.

**Non-parody artists**

Artists who draw pre-existing characters do not generally have any special notability among the cartoon pornography community; in contrast, some of the artists who draw their own characters, such as Bill Ward, Kevin J. Taylor, or John Willie, have gained a cult fan base.

**Legal status**

The legal status of cartoon pornography varies from country to country. In addition to the normal legal status of pornography, much cartoon pornography depicts potentially minor [that is, underage] characters engaging in sexual acts. One of the primary reasons for this may be due to the many cartoons featuring major characters who are not adults. Cartoon pornography does not always have depictions of minors in sexual acts or situations, but that which does may fall under the jurisdiction laws concerning child pornography. Drawings of pre-existing characters can in theory be in violation of copyright law no matter the situation the characters are shown in.
The United States

In the United States, cartoon porn that does not contain depictions of minors generally falls under the category of speech protected by the First Amendment. For more information on general legality of pornography, see Pornography in the United States. Even in the case of depiction of minors, the US Supreme Court has held that in certain conditions, banning the depiction may violate freedom of expression.

Cartoon pornography depicting minors

As of the PROTECT Act of 2003, the legal status of cartoon pornography with minors has been more thoroughly addressed and refined than it was before under the previous law of the United States.

The new act made any realistic appearing computer generated depiction that is indistinguishable from a depiction of an actual minor in sexual situations or engaging in sexual acts illegal under 18 U.S.C. § 2252A. Drawings, cartoons, sculptures, and paintings of minors in sexual situations that do not pass the Miller test were made illegal under 18 U.S.C. § 1466A thus creating a loop hole around the Ashcroft v. Free Speech Coalition decision.

Obscenity

In October 2008, the Comic Book Legal Defense Fund became involved in a case defending an Iowan comic collector. This is related to obscenity charges involving pornography depicting minors, being applied to a fictional comic book. Judge Gritzner was petitioned to drop some of the charges. The motion was initially heard on June 24, 2008 but was not widely publicized prior to the Fund’s involvement. Handley eventually plead guilty to charges of possessing “obscene visual representations of the sexual abuse of children” and was sentenced to six months in jail.

In October 2010, a 33 year old Idaho man entered into a plea agreement concerning images of child characters from the American animated television show, The Simpsons engaged in sexual acts.
Canada

Cartoon pornography is illegal in Canada if it depicts a person under the age of 18, including fictional ones.

Australia

A recent court case in Australia has found a man possessing cartoon pornography involving the characters Bart, Lisa and Marge from *The Simpsons* guilty after the images were described as Child Pornography. According to the judge of the court case, the “purpose of anti-child pornography legislation was to stop sexual exploitation and child abuse where images of “real” children were depicted” and that the images “fuel demand for material that does involve the abuse of children.”

Germany

Virtual child pornography can be punished with up to 5 years in prison in Germany, German prosecutors investigated the video game *Second Life* because of some people role playing as underage characters with virtual underage avatars.

Netherlands

Cartoon pornography depicting minors is in principle permitted in the Netherlands, if it is clear that the pornography is not depicting real persons. The criterium used is that ‘a child should see the difference’: if such picture would be so realistic it would be ‘real’ to a child it is seen as child pornography. The consequence is that pornographic cartoons depicting are permitted, as long as they do not become so realistic that they almost look like a photo. In addition, photos of adults which have been amended to make them look like minors are seen as child pornography.

United Kingdom

The Coroners and Justice Bill (which came into force on 6 April 2010) criminalises all sexual images of under 18s (including non-realistic depictions), as well as images of adults where the predominant impression conveyed is that the person shown is
under 18 despite the fact that some of the physical characteristics shown are not those of a person under 18.

**Sweden**

The Uppsala district court punished a manga translator with a monetary fine and probation for possession of fanart computer images, deemed by the court to be underage. This was appealed and taken to the Court of Appeal. The Court of Appeal upheld the former verdict, for 39 of the 51 pictures, and the monetary fine was reduced. It was further appealed to the Supreme court, where they decided that the images where not realistic and could not be mistaken for real children, thus declaring him not guilty.

**India**

Cartoon pornography is illegal in India. Many such bans had been placed on any such cartoons strips of comics. For instance, a once popular comic strip, Savita Bhabhi was deemed illegal in India. But, the ban was removed after 2009.

**Japan**

In Japan, pornographic art depicting underage characters (*lolicon, shotacon*) is legal but remains controversial even within the country. They are commonly found in manga, erotic computer games, and doujinshi.
INTRODUCTION

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

An example of computer animation which is produced in the “motion capture” technique
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, 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 with television 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 that virtual skeleton. Then the limbs, eyes, mouth, clothes, etc. of the figure are moved by the animator on key 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, like 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. Adobe 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.
**Explanation**

To trick the eye and the brain into thinking they are seeing a smoothly moving object, the pictures should be drawn at around 12 frames per second or faster. (A frame is one complete image.) With rates above 75-120 frames per second, no improvement in realism or smoothness is perceivable due to the way the eye and the brain both process images. At rates below 12 frames per second, most people can detect jerkiness associated with the drawing of new images that detracts from the illusion of realistic movement. Conventional hand-drawn cartoon animation often uses 15 frames per second in order to save on the number of drawings needed, but this is usually accepted because of the stylized nature of cartoons. To produce more realistic imagery, computer animation demands higher frame rates.

Films seen in theaters in the United States run at 24 frames per second, which is sufficient to create the illusion of continuous movement. For high resolution, adapters are used.

**History**

Early digital computer animation was developed at Bell Telephone Laboratories in the 1960s by Edward E. Zajac, Frank W. Sinden, Kenneth C. Knowlton, and A. Michael Noll. Other digital animation was also practiced at the Lawrence Livermore National Laboratory.

An early step in the history of computer animation was the sequel to the 1973 film *Westworld*, a science-fiction film about a society in which robots live and work among humans. The sequel, *Futureworld* (1976), used the 3D wire-frame imagery, which featured a computer-animated hand and face both created by University of Utah graduates Edwin Catmull and Fred Parke. This imagery originally appeared in their student film *A Computer Animated Hand*, which they completed in 1971.

Developments in CGI technologies are reported each year at SIGGRAPH, an annual conference on computer graphics and interactive techniques that is attended by thousands of computer
professionals each year. Developers of computer games and 3D video cards strive to achieve the same visual quality on personal computers in real-time as is possible for CGI films and animation. With the rapid advancement of real-time rendering quality, artists began to use game engines to render non-interactive movies, which led to the art form Machinima.

The very first full length computer animated television series was ReBoot, which debuted in September 1994; the series followed the adventures of characters who lived inside a computer. The first feature-length computer animated film was Toy Story (1995), which was made by Pixar. It followed an adventure centered around toys and their owners. This groundbreaking film was also the first of many fully computer-animated movies.


ANIMATION METHODS

In most 3D computer animation systems, an animator creates a simplified representation of a character’s anatomy, which is analogous to a skeleton or stick figure. The position of each segment of the skeletal model is defined by animation variables, or Avars for short. In human and animal characters, many parts of the skeletal model correspond to the actual bones, but skeletal animation is also used to animate other things, with facial features (though other methods for facial animation exist). The character “Woody” in Toy Story, for example, uses 700 Avars (100 in the face alone). The computer doesn’t usually render the skeletal model directly (it is invisible), but it does use the skeletal model to compute the exact position and orientation of that certain character, which is eventually rendered into an image. Thus by changing the values of Avars over time, the animator creates motion by making the character move from frame to frame.

There are several methods for generating the Avar values to obtain realistic motion. Traditionally, animators manipulate the
Avars directly. Rather than set Avars for every frame, they usually set Avars at strategic points (frames) in time and let the computer interpolate or tween between them in a process called keyframing. Keyframing puts control in the hands of the animator and has roots in hand-drawn traditional animation.

In contrast, a newer method called motion capture makes use of live action footage. When computer animation is driven by motion capture, a real performer acts out the scene as if they were the character to be animated. His/her motion is recorded to a computer using video cameras and markers and that performance is then applied to the animated character.

Each method has its advantages and as of 2007, games and films are using either or both of these methods in productions. Keyframe animation can produce motions that would be difficult or impossible to act out, while motion capture can reproduce the subtleties of a particular actor. For example, in the 2006 film *Pirates of the Caribbean: Dead Man’s Chest*, Bill Nighy provided the performance for the character Davy Jones. Even though Nighy doesn’t appear in the movie himself, the movie benefited from his performance by recording the nuances of his body language, posture, facial expressions, etc. Thus motion capture is appropriate in situations where believable, realistic behavior and action is required, but the types of characters required exceed what can be done throughout the conventional costuming.

**Modeling**

3D computer animation combines 3D models of objects and programmed or hand “keyframed” movement. These models are constructed out of geometrical vertices, faces, and edges in a 3D coordinate system. Objects are sculpted much like real clay or plaster, working from general forms to specific details with various sculpting tools. Unless a 3D model is intended to be a solid color, it must be painted with “textures” for realism. A bone/joint animation system is set up to deform the CGI model (e.g., to make a humanoid model walk). In a process known as rigging, the
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virtual marionette is given various controllers and handles for controlling movement. Animation data can be created using motion capture, or keyframing by a human animator, or a combination of the two. 3D models rigged for animation may contain thousands of control points — for example, “Woody” from Toy Story uses 700 specialized animation controllers. Rhythm and Hues Studios labored for two years to create Aslan in the movie The Chronicles of Narnia: The Lion, the Witch and the Wardrobe, which had about 1,851 controllers (742 in the face alone). In the 2004 film The Day After Tomorrow, designers had to design forces of extreme weather with the help of video references and accurate meteorological facts. For the 2005 remake of King Kong, actor Andy Serkis was used to help designers pinpoint the gorilla’s prime location in the shots and used his expressions to model “human” characteristics onto the creature. Serkis had earlier provided the voice and performance for Gollum in J. R. R. Tolkien’s The Lord of the Rings trilogy.

Equipment

A ray-traced 3-D model of a jack inside a cube, and the jack alone below.
Computer animation can be created with a computer and an animation software. Some impressive animation can be achieved even with basic programs; however, the rendering can take a lot of time on an ordinary home computer. Because of this, video game animators tend to use low resolution and low polygon count renders so that the graphics can be rendered in real time on a home computer. Photorealistic animation would be impractical in this context.

Professional animators of movies, television, and video sequences on computer games make photorealistic animation with high detail. This level of quality for movie animation would take hundreds of years to create on a home computer. Instead, many powerful workstation computers are used. Graphics workstation computers use two to four processors, and they are a lot more powerful than an actual home computer and are specialized for rendering. A large number of workstations (known as a "render farm") are networked together to effectively act as a giant computer. The result is a computer-animated movie that can be completed in about one to five years (however, this process is not composed solely of rendering). A workstation typically costs $2,000-16,000 with the more expensive stations being able to render much faster due to the more technologically-advanced hardware that they contain. Professionals also use digital movie cameras, motion/performance capture, bluescreens, film editing software, props, and other tools used for movie animation.

FACIAL ANIMATION

The realistic modeling of human facial features is both one of the most challenging and sought after elements in computer-generated imagery. Computer facial animation is a highly complex field where models typically include a very large number of animation variables. Historically speaking, the first SIGGRAPH tutorials on *State of the art in Facial Animation* in 1989 and 1990 proved to be a turning point in the field by bringing together and consolidating multiple research elements and sparked interest
among a number of researchers. The Facial Action Coding System (with 46 “action units”, “lip bite” or “squint”), which had been developed in 1976, became a popular basis for many systems. As early as 2001, MPEG-4 included 68 Face Animation Parameters (FAPs) for lips, jaws, etc., and the field has made significant progress since then and the use of facial microexpression has increased.

In some cases, an affective space, the PAD emotional state model, can be used to assign specific emotions to the faces of avatars. In this approach, the PAD model is used as a high level emotional space and the lower level space is the MPEG-4 Facial Animation Parameters (FAP). A mid-level Partial Expression Parameters (PEP) space is then used to in a two-level structure – the PAD-PEP mapping and the PEP-FAP translation model.

**Realism**

Realism in computer animation can mean making each frame look photorealistic, in the sense that the scene is rendered to resemble a photograph or make the characters’ animation believable and lifelike. Computer animation can also be realistic with or without the photorealistic rendering.

One of the greatest challenges in computer animation has been creating human characters that look and move with the highest degree of realism. Many animated films instead feature characters who are anthropomorphic animals (*Finding Nemo, Ice Age, Bolt, Madagascar, Over the Hedge, Rio, Kung Fu Panda, Alpha and Omega, Zootopia*), machines (*Cars, WALL-E, Robots*), insects (*Antz, A Bug’s Life, The Ant Bully, Bee Movie*), fantasy creatures and characters (*Monsters, Inc., Shrek, TMNT, Brave, Epic*), or humans with non-realistic, cartoon-like proportions (*Despicable Me, Up, Megamind, Jimmy Neutron: Boy Genius, Planet 51, Hotel Transylvania, Cloudy with a Chance of Meatballs*).

Part of the difficulty in making pleasing, realistic human characters is the uncanny valley, the concept where the human audience (up to a point) tends to have an increasingly negative, emotional response as a human replica looks and acts more and
more human. Also, some materials that commonly appear in a scene (such as cloth, foliage, fluids, and hair) have proven more difficult to faithfully recreate and animate than others. Consequently, special software and techniques have been developed to better simulate these specific elements.

In theory, realistic computer animation can reach a point where it is indistinguishable from real action captured on film. When computer animation achieves this level of realism, it may have major repercussions for the film industry.

The goal of computer animation is not always to emulate live action as closely as possible. For example, animation was used in the Nautilus Productions documentary “Mystery Mardi Gras Shipwreck” to model a remotely operated underwater vehicle (ROV) and the Mardi Gras archaeological site in 4,000 feet (1,200 m) of water in the Gulf of Mexico.

Computer animation can also be tailored to mimic or substitute for other kinds of animation, traditional stop-motion animation (as shown in Flushed Away or The Lego Movie). Some of the long-standing basic principles of animation, like squash & stretch, call for movement that is not strictly realistic, and such principles still see widespread application in computer animation.

Notable examples

- **Final Fantasy: The Spirits Within**: often cited as the first computer-generated movie to attempt to show realistic-looking humans
- **The Polar Express**
- **Mars Needs Moms**
- **L.A. Noire**: received attention for its use of MotionScan technology
- **The Adventures of Tintin: The Secret of the Unicorn**
- **Heavy Rain**
- **Beyond: Two Souls**
- **Beowulf**
CGI film made using Machinima

CGI short films have been produced as independent animation since 1976, although the popularity of computer animation (especially in the field of special effects) skyrocketed during the modern era of U.S. animation. The first completely computer-animated television series was *ReBoot* in 1994, and the first completely computer-animated movie was *Toy Story* (1995).

**Animation studios**


Computer Animation


• Reel FX Animation Studios - Notable for Free Birds (2013) and The Book of Life (2014)

• Industrial Light & Magic - Notable for Rango (2011) and Strange Magic (2015),

• Notable for visual effects on live action films like Star Wars (1977) and Pirates of the Caribbean (2003)

• Weta Digital - Notable for The Adventures of Tintin (2011)

• Notable for visual effects on live action films like The Lord of the Rings film series, The Hobbit film series, King Kong (2005), Rise of the Planet of the Apes (2011), and Avatar (2009)


• Notable for visual effects on live action films like Moulin Rouge! (2001) and The Great Gatsby (2013)

AMATEUR ANIMATION

The popularity of websites that allow members to upload their own movies for others to view has created a growing community of amateur computer animators. With utilities and programs often included free with modern operating systems, many users can make their own animated movies and shorts.
Several free and open source animation software applications exist as well. A popular amateur approach to animation is via the animated GIF format, which can be uploaded and seen on the web easily.

**Detailed examples and pseudocode**

In 2D computer animation, moving objects are often referred to as “sprites.” A sprite is an image that has a location associated with it. The location of the sprite is changed slightly, between each displayed frame, to make the sprite appear to move. The following pseudocodemakes a sprite move from left to right:

```plaintext
var int x := 0, y := screenHeight / 2;
while x < screenWidth
  drawBackground()
  drawSpriteAtXY (x, y) // draw on top of the background
  x := x + 5 // move to the right
```

Computer animation uses different techniques to produce animations. Most frequently, sophisticated mathematics is used to manipulate complex three-dimensional polygons, apply “textures”, lighting and other effects to the polygons and finally rendering the complete image. A sophisticated graphical user interface may be used to create the animation and arrange its choreography. Another technique called constructive solid geometry defines objects by conducting boolean operations on regular shapes, and has the advantage that animations may be accurately produced at any resolution.

**COMPUTER-ASSISTED VS COMPUTER-GENERATED**

Computer-assisted animation is usually classed as two-dimensional (2D) animation. Creators drawings either hand drawn (pencil to paper) or interactively drawn(drawn on the computer) using different assisting appliances and are positioned into specific software packages. Within the software package the creator will
place drawings into different key frames which fundamentally create an outline of the most important movements. The computer will then fill in all the “in-between frames”, commonly known as Tweening. Computer-assisted animation is basically using new technologies to cut down the time scale that traditional animation could take, but still having the elements of traditional drawings of characters or objects.

Two examples of films using computer-assisted animation are *Beauty and the Beast* and *Antz*.

Computer-generated animation is known as 3-dimensional (3D) animation. Creators will design an object or character with an X, Y and Z axis. Unlike the traditional way of animation no pencil to paper drawings create the way computer generated animation works. The object or character created will then be taken into a software, key framing and tweening are also carried out in computer generated animation but are also a lot of techniques used that do not relate to traditional animation. Animators can break physical laws by using mathematical algorithms to cheat, mass, force and gravity rulings. Fundamentally, time scale and quality could be said to be a preferred way to produce animation as they are two major things that are enhanced by using computer generated animation. Another great aspect of CGA is the fact you can create a flock of creatures to act independently when created as a group. An animal’s fur can be programmed to wave in the wind and lie flat when it rains instead of programming each strand of hair separately.

**HISTORY OF COMPUTER ANIMATION**

As early as the 1940s and ’50s, experiments in computer graphics were beginning, most notably by John Whitney—but it was only by the early 1960s when digital computers had become widely established, that new avenues for innovative computer graphics blossomed. Initially, uses were mainly for scientific, engineering and other research purposes, but artistic experimentation began to make its appearance by the mid-1960s.
By the mid-70s, many such efforts were beginning to enter into public media. Much computer graphics at this time involved 2-dimensional imagery, though increasingly, as computer power improved, efforts to achieve 3-dimensional realism became the emphasis. By the late 1980s, photo-realistic 3D was beginning to appear in cinema movies, and by mid-90s had developed to the point where 3D animation could be used for entire feature film production.

The earliest pioneers: 1940s to mid-1960s

John Whitney

John Whitney, Sr was an American animator, composer and inventor, widely considered to be one of the fathers of computer animation. In the ’40s and ’50s, he and his brother James created a series of experimental films made with a custom-built device based on old anti-aircraft analog computers (Kerrison Predictors) connected by servos to control the motion of lights and lit objects — the first example of motion control photography. One of Whitney’s best known works from this early period was the animated title sequence from Alfred Hitchcock’s 1958 film *Vertigo*, which he collaborated on with graphic designer Saul Bass. In 1960, Whitney established his company Motion Graphics Inc, which largely focused on producing titles for film and television, while continuing further experimental works. In 1968, his pioneering motion control model photography was used on Stanley Kubrick’s movie *2001: A Space Odyssey*, and also for the slit-scan photography technique used in the film’s “Star Gate” finale. All of John Whitney’s sons (Michael, Mark and John Jr.) are also film-makers. John Whitney died in 1995.

The first digital image

One of the first programmable digital computers was SEAC (the Standards Eastern Automatic Computer), which entered service in 1950 at the National Bureau of Standards (NBS) in Maryland, USA. In 1957, computer pioneer Russell Kirsch and his team unveiled a drum scanner for SEAC, to “trace variations of
intensity over the surfaces of photographs”, and so doing made the first digital image by scanning a photograph. The image, picturing Kirsch’s three-month-old son, consisted of just 176×176 pixels. They used the computer to extract line drawings, count objects, recognize types of characters and display digital images on an oscilloscope screen. This breakthrough can be seen as the forerunner of all subsequent computer imaging, and recognising the importance of this first digital photograph, Life magazine in 2003 credited this image as one of the “100 Photographs That Changed the World”.

From the late 1950s and early ’60s, mainframe digital computers were becoming commonplace within large organisations and universities, and increasingly these would be equipped with graphic plotting and graphics screen devices. Consequently, a new field of experimentation began to open up.

**Boeing-Wichita**

In 1960, William Fetter was a graphic designer for Boeing at Wichita, and was credited with coining the phrase “Computer Graphics” to describe what he was doing at Boeing at the time (though Fetter himself credited this to colleague Verne Hudson). Fetter’s work included the development of ergonomic descriptions of the human body that are both accurate and adaptable to different environments, and this resulted in the first 3D animated “wire-frame” figures. Such human figures became one of the most iconic images of the early history of computer graphics, and often were referred to as the “Boeing Man”. Fetter died in 2002.

**Bell Labs**

Bell Labs in Murray Hill, New Jersey, was a leading research contributor in computer graphics, computer animation and electronic music from its beginnings in the early 1960s. Initially, researchers were interested in what the computer could be made to do, but the results of the visual work produced by the computer during this period established people like Edward Zajac, Michael Noll and Ken Knowlton as pioneering computer artists.
Edward Zajac produced one of the first computer generated films at Bell Labs in 1963, titled *A Two Gyro Gravity Gradient Attitude Control System*, which demonstrated that a satellite could be stabilized to always have a side facing the Earth as it orbited.

Ken Knowlton developed the Beflix (Bell Flicks) animation system in 1963, which was used to produce dozens of artistic films by artists Stan VanDerBeek, Knowlton and Lillian Schwartz. Instead of raw programming, Beflix worked using simple “graphic primitives”, like draw a line, copy a region, fill an area, zoom an area, and the like.

In 1965, Michael Noll created computer-generated stereographic 3D movies, including a ballet of stick figures moving on a stage. Some movies also showed four-dimensional hyper-objects projected to three dimensions. Around 1967, Noll used the 4D animation technique to produce computer animated title sequences for the commercial film short *Incredible Machine* (produced by Bell Labs) and the TV special *The Unexplained* (produced by Walt DeFaria). Many projects in other fields were also undertaken at this time.

**Ivan Sutherland**

Ivan Sutherland is considered by many to be the creator of Interactive Computer Graphics, and an internet pioneer. He worked at the Lincoln Laboratory at MIT (Massachusetts Institute of Technology) in 1962, where he developed a program called *Sketchpad I*, which allowed the user to interact directly with the image on the screen. This was the first Graphical User Interface, and is considered one of the most influential computer programs ever written by an individual.

**Mid-1960s to mid-1970s**

**The University of Utah**

Utah was a major center for computer animation in this period. The computer science faculty was founded by David Evans in 1965, and many of the basic techniques of 3D computer graphics
were developed here in the early 70s with ARPA funding (Advanced Research Projects Agency). Research results included Gouraud, Phong, and Blinn shading, texture mapping, hidden surface algorithms, curved surface subdivision, real-time line-drawing and raster image display hardware, and early virtual reality work. In the words of Robert Rivlin in his 1986 book The Algorithmic Image: Graphic Visions of the Computer Age, “almost every influential person in the modern computer-graphics community either passed through the University of Utah or came into contact with it in some way”.

**Evans & Sutherland**

In 1968, Ivan Sutherland teamed up with David Evans to found the company Evans & Sutherland—both were professors in the Computer Science Department at the University of Utah, and the company was formed to produce new hardware designed to run the systems being developed in the University. Many such algorithms have later resulted in the generation of significant hardware implementation, including the Geometry Engine, the Head-mounted display, the Frame buffer, and Flight simulators. Most of the employees were active or former students, and included Jim Clark, who started Silicon Graphics in 1981, Ed Catmull, co-founder of Pixar in 1979, and John Warnock of Adobe Systems in 1982.

**First computer animated character, Nikolai Konstantinov**

In 1968 a group of soviet physicists and mathematicians with N.Konstantinov as its head created a mathematical model for the motion of a cat. On a BESM-4 computer they devised a programme for solving the ordinary differential equations for this model. The Computer printed hundreds of frames on paper using alphabet symbols that were latter filmed in sequence thus creating the first computer animation of a character, a walking cat.

**Ohio State**

Charles Csuri, an artist at The Ohio State University (OSU), started experimenting with the application of computer graphics
to art in 1963. His efforts resulted in a prominent CG research laboratory that received funding from the National Science Foundation and other government and private agencies. The work at OSU revolved around animation languages, complex modeling environments, user-centric interfaces, human and creature motion descriptions, and other areas of interest to the discipline.

**Cybernetic Serendipity**

In July 1968, the arts journal *Studio International* published a special issue titled *Cybernetic Serendipity - the computer and the arts*, which catalogued a comprehensive collection of items and examples of work being done in the field of computer art in organisations all over the world, and shown in exhibitions in London, UK, San Francisco, CA. and Washington, DC. This marked a milestone in the development of the medium, and was considered by many to be of widespread influence and inspiration. Apart from all the examples mentioned above, two other particularly well known iconic images from this include *Chaos to Order* by Charles Csuri (often referred to as the *Hummingbird*), created at Ohio State University in 1967, and *Running Cola is Africa* by Masao Komura and Koji Fujino created at the Computer Technique Group, Japan, also in 1967.

**Scanimate**

The first machine to achieve widespread public attention in the media was Scanimate, an analog computer animation system designed and built by Lee Harrison of the Computer Image Corporation in Denver. From around 1969 onward, Scanimate systems were used to produce much of the video-based animation seen on television in commercials, show titles, and other graphics. It could create animations in real time, a great advantage over digital systems at the time.

**National Film Board of Canada**

The National Film Board of Canada, already a world center for animation art, also began experimentation with computer techniques in 1969. Most well-known of the early pioneers with
this was artist Peter Foldes, who completed *Metadata* in 1971. This film comprised drawings animated by gradually changing from one image to the next, a technique known as “interpolating” (also known as “inbetweening” or “morphing”), which also featured in a number of earlier art examples during the 1960s. In 1974, Foldes completed *Hunger / La Faim*, which was one of the first films to show solid filled (raster scanned) rendering, and was awarded the Jury Prize in the short film category at 1974 Cannes Film Festival, as well as an Academy Award nomination.

**Atlas Computer Laboratory & Antics**

The Atlas Computer Laboratory near Oxford was for many years a major facility for computer animation in Britain. The first entertainment cartoon made was *The Flexipede*, by Tony Pritchett, which was first shown publicly at the Cybernetic Serendipity exhibition in 1968. Artist Colin Emmett and animator Alan Kitching first developed solid filled colour rendering in 1972, notably for the title animation for the BBC’s *The Burke Special* TV program.

In 1973, Kitching went on to develop a software called *Antics*, which allowed users to create animation without needing any programming. The package was broadly based on conventional “cel” (celluloid) techniques, but with a wide range of tools including camera and graphics effects, interpolation (“inbetweening”/“morphing”), use of skeleton figures and grid overlays. Any number of drawings or cels could be animated at once by “choreographing” them in limitless ways using various types of “movements”. At the time, only black & white plotter output was available, but Antics was able to produce full-color output by using the Technicolor Three-strip Process. Hence the name Antics was coined as an acronym for ANimated Technicolor-Image Computer System. Antics was used for many animation works, including the first complete documentary movie *Finite Elements*, made for the Atlas Lab itself in 1975. From around the early 70s, much of the emphasis in computer animation development was towards ever increasing realism in 3D imagery, and on effects designed for use in feature movies.
**First digital animation in a feature film**

The first feature film to use digital image processing was the 1973 movie *Westworld*, a science-fiction film written and directed by novelist Michael Crichton, in which humanoid robots live amongst the humans. John Whitney, Jr, and Gary Demos at Information International, Inc. digitally processed motion picture photography to appear pixelized in order to portray the Gunslinger android's point of view. The cinegraphic block portraiture was accomplished using the Technicolor Three-strip Process to color-separate each frame of the source images, then scanning them to convert into rectangular blocks according to its tone values, and finally outputting the result back to film. The process was covered in the *American Cinematographer* article “Behind the scenes of Westworld”.

**SIGGRAPH**

Sam Matsa whose background in graphics started with the APT project at MIT with Doug Ross and Andy Van Dam petitioned ACM to form a SICGRAPH (Special Interest Committee on Computer Graphics), the forerunner of SIGGRAPH in 1968. In 1974, the first SIGGRAPH conference on computer graphics opened. This annual conference soon became the dominant venue for presenting innovations in the field.

**Towards 3D: mid-1970s into the 1980s**

**Early 3D animation in the cinema**

The first use of 3D wireframe imagery in mainstream cinema was in the sequel to *Westworld*, *Futureworld* (1976), directed by Richard T. Heffron. This featured a computer-generated hand and face created by then University of Utah graduate students Edwin Catmull and Fred Parke which had initially appeared in their 1971 experimental short *A Computer Animated Hand*. The third movie to use this technology was *Star Wars* (1977), written and directed by George Lucas, with wireframe imagery in the scenes with the Death Star plans, the targeting computers in the X-wing fighters,
and the *Millennium Falcon* spacecraft. The Oscar-winning 1975 short animated film *Great*, about the life of the Victorian engineer Isambard Kingdom Brunel, contains a brief sequence of a rotating wireframe model of Brunel’s final project, the iron steam ship SS Great Eastern.

The Walt Disney film *The Black Hole* (1979, directed by Gary Nelson) used wireframe rendering to depict the titular black hole, using equipment from Disney’s engineers. In the same year, the science-fiction horror film *Alien*, directed by Ridley Scott, also used wireframe model graphics, in this case to render the navigation monitors in the spaceship. The footage was produced by Colin Emmett at the Atlas Computer Laboratory.

**Nelson Max**

Although Lawrence Livermore Labs in California is mainly known as a centre for high-level research in science, it continued producing significant advances in computer animation throughout this period. Notably, Nelson Max, who joined the Lab in 1971, and whose 1977 film *Turning a sphere inside out* is regarded as one of the classic early films in the medium (International Film Bureau, Chicago, 1977). He also produced a series of “realistic-looking” molecular model animations that served to demonstrate the future role of CGI in scientific visualization (“CGI” = Computer-generated imagery). His research interests focused on realism in nature images, molecular graphics, computer animation, and 3D scientific visualization. He later served as computer graphics director for the Fujitsu pavilions at Expo 85 and 90 in Japan.

**First architectural hidden-line movie**

The CSIRO has produced high quality research in a wide range of scientific fields, but it is not known for its animation research. Jonathan Ingram, who joined the CSIRO in 1973, produced an architectural 3d hidden-line animation of the proposed Hobart Commonwealth Courts, the first such animation. This movie was recently rediscovered hidden in an archive with other graphics material of the time. The movie is 2250 frames on black and white
16mm film. The original of the movie is stored at the “Jonathan Ingram Collection”, British Architectural Library, RIBA, Victoria & Albert Museum, London.

NYIT

In 1974, Alex Schure, a wealthy New York entrepreneur, established the Computer Graphics Laboratory (CGL) at the New York Institute of Technology (NYIT). He put together the most sophisticated studio of the time, with state of the art computers, film and graphic equipment, and hired top technology experts and artists to run it — Ed Catmull, Malcolm Blanchard, Fred Parke and others all from Utah, plus others from around the country including Ralph Guggenheim, Alvy Ray Smith and Ed Emshwiller. During the late 70s, the staff made numerous innovative contributions to image rendering techniques, and produced many influential software, including the animation program Tween, the paint program Paint, and the animation program SoftCel. Several videos from NYIT become quite famous: Sunstone, by Ed Emshwiller, Inside a Quark, by Ned Greene, and The Works. The latter, written by Lance Williams, was begun in 1978, and was intended to be the first full-length CGI film, but it was never completed, though a trailer for it was shown at SIGGRAPH 1982. In these years, many people regarded NYIT CG Lab as the top computer animation research and development group in the world.

The quality of NYIT’s work attracted the attention of George Lucas, who was interested in developing a CGI special effects facility at his company Lucasfilm. In 1979, he recruited the top talent from NYIT, including Catmull, Smith and Guggenheim to start his division, which later spun off as Pixar, founded in 1986 with funding by Apple Inc. co-founder Steve Jobs.

Framebuffer

The framebuffer or framestore is a graphics screen configured with a memory buffer that contains data for a complete screen image. Typically, it is a rectangular array (raster) of pixels, and the number of pixels in the width and the height is its “resolution”.
Color values stored in the pixels can be from 1-bit (monochrome), to 24-bit (true color, 8-bits each for RGB—Red, Green, & Blue), or also 32-bit, with an extra 8-bits used as a transparency mask (alpha channel). Before the framebuffer, graphics displays were all vector-based, tracing straight lines from one co-ordinate to another. The first known example of a framebuffer was built in 1969 at Bell Labs, where Joan Miller implemented a simple paint program to allow users to “paint” direct on the framebuffer. This device had just 3-bits (giving just 8 colors).

In 1972-73, Richard Shoup developed the SuperPaint system at Xerox PARC, which used a framebuffer displaying 640×480 pixels (standard NTSC video resolution) with eight-bit depth (256 colors). The SuperPaint software contained all the essential elements of later paint packages, allowing the user to paint and modify pixels, using a palette of tools and effects, and thereby making it the first complete computer hardware and software solution for painting and editing images. Shoup also experimented with modifying the output signal using color tables, to allow the system to produce a wider variety of colors than the limited 8-bit range it contained. This scheme would later become commonplace in computer framebuffers. The SuperPaint framebuffer could also be used to capture input images from video.

The first commercial framebuffer was produced in 1974 by Evans & Sutherland. It cost about $15,000, with a resolution of 512 by 512 pixels in 8-bit grayscale color, and sold well to graphics researchers without the resources to build their own framebuffer. A little later, NYIT created the first full-color 24-bit RGB framebuffer by using three of the Evans & Sutherland framebuffers linked together as one device by a minicomputer. Many of the “firsts” that happened at NYIT were based on the development of this first raster graphics system.

In 1975, the UK company Quantel, founded in 1973 by Peter Michael, produced the first commercial full-color broadcast framebuffer, the Quantel DFS 3000. It was first used in TV coverage of the 1976 Montreal Olympics to generate a picture-in-picture
inset of the Olympic flaming torch while the rest of the picture featured the runner entering the stadium. Framebuffer technology provided the cornerstone for the future development of digital television products.

By the late 70s, it became possible for personal computers (such as the Apple II) to contain low-color framebuffers. However, it was not until the 1980s that a real revolution in the field was seen, and framebuffers capable of holding a standard video image were incorporated into standalone workstations. By the 90s, framebuffers eventually became the standard for all personal computers.

Fractals

At this time, a major step forward to the goal of increased realism in 3D animation came with the development of “fractals”. The term was coined in 1975 by mathematician Benoit Mandelbrot, who used it to extend the theoretical concept of fractional dimensions to geometric patterns in nature, and published in English translation of his book *Fractals: Form, Chance and Dimension* in 1977.

In 1979–80, the first film using fractals to generate the graphics was made by Loren Carpenter of Boeing. Titled *Vol Libre*, it showed a flight over a fractal landscape, and was presented at SIGGRAPH 1980. Carpenter was subsequently hired by Pixar to create the fractal planet in the *Genesis Effect* sequence of *Star Trek II: The Wrath of Khan* in June 1982.

JPL and Jim Blinn

Bob Holzman of NASA’s Jet Propulsion Laboratory in California established JPL’s Computer Graphics Lab in 1977 as a group with technology expertise in visualizing data being returned from NASA missions. On the advice of Ivan Sutherland, Holzman hired a graduate student from Utah named Jim Blinn. Blinn had worked with imaging techniques at Utah, and developed them into a system for NASA’s visualization tasks. He produced a series of widely seen “fly-by” simulations, including the Voyager, Pioneer
Computer Animation

and Galileospacecraft fly-bys of Jupiter, Saturn and their moons. He also worked with Carl Sagan, creating animations for his Cosmos: A Personal Voyage TV series. Blinn developed many influential new modelling techniques, and wrote papers on them for the IEEE (Institute of Electrical and Electronics Engineers), in their journal Computer Graphics and Applications. Some of these included environment mapping, improved highlight modelling, “blobby” modelling, simulation of wrinkled surfaces, and simulation of butts and dusty surfaces.

Later in the 80s, Blinn developed CG animations for an Annenberg/CPB TV series, The Mechanical Universe, which consisted of over 500 scenes for 52 half-hour programs describing physics and mathematics concepts for college students. This he followed with production of another series devoted to mathematical concepts, called Project Mathematics!.

Motion control photography

Motion control photography is a technique that uses a computer to record (or specify) the exact motion of a film camera during a shot, so that the motion can be precisely duplicated again, or alternatively on another computer, and combined with the movement of other sources, such as CGI elements. Early forms of motion control go back to John Whitney’s 1968 work on 2001: A Space Odyssey, and the effects on the 1977 movie Star Wars Episode IV: A New Hope, by George Lucas’ newly created company Industrial Light & Magic in California (ILM). ILM created a digitally controlled camera known as the Dykstraflex, which performed complex and repeatable motions around stationary spaceship models, enabling separately filmed elements (spaceships, backgrounds, etc.) to be coordinated more accurately with one another. However, neither of these was actually computer-based — Dykstraflex was essentially a custom-built hard-wired collection of knobs and switches. The first commercial computer-based motion control and CGI system was developed in 1981 in the UK by Moving Picture Company designer Bill Mather.
The 1980s

The 80s saw a great expansion of radical new developments in commercial hardware, especially the incorporation of framebuffer technologies into graphic workstations, allied with continuing advances in computer power and affordability.

Silicon Graphics, Inc (SGI)

Silicon Graphics, Inc (SGI) was a manufacturer of high-performance computer hardware and software, founded in 1981 by Jim Clark. His idea, called the Geometry Engine, was to create a series of components in a VLSI processor that would accomplish the main operations required in image synthesis—the matrix transforms, clipping, and the scaling operations that provided the transformation to view space. Clark attempted to shop his design around to computer companies, and finding no takers, he and colleagues at Stanford University, California, started their own company, Silicon Graphics.

SGI’s first product (1984) was the IRIS (Integrated Raster Imaging System). It used the 8 MHz M68000 processor with up to 2 MB memory, a custom 1024×1024 frame buffer, and the Geometry Engine to give the workstation its impressive image generation power. Its initial market was 3D graphics display terminals, but SGI’s products, strategies and market positions evolved significantly over time, and for many years were a favoured choice for CGI companies in film, TV, and other fields.

Quantel

In 1981, Quantel released the “Paintbox”, the first broadcast-quality turnkey system designed for creation and composition of television video and graphics. Its design emphasized the studio workflow efficiency required for live news production. Essentially, it was a framebuffer packaged with innovative user software, and it rapidly found applications in news, weather, station promos, commercials, and the like. Although it was essentially a design tool for still images, it was also sometimes used for frame-by-frame animations. Following its initial launch, it revolutionised
the production of television graphics, and some Paintboxes are still in use today due to their image quality, and versatility. This was followed in 1982 by the Quantel Mirage, or DVM8000/1 “Digital Video Manipulator”, a digital real-time video effects processor. This was based on Quantel’s own hardware, plus a Hewlett-Packard computer for custom program effects. It was capable of warping a live video stream by texture mapping it onto an arbitrary three-dimensional shape, around which the viewer could freely rotate or zoom in real-time. It could also interpolate, or morph, between two different shapes. It was considered the first real-time 3D video effects processor, and the progenitor of subsequent DVE (Digital video effect) machines. In 1985, Quantel went on to produce “Harry”, the first all-digital non-linear editing and effects compositing system.

**Osaka University**

In 1982, Japan’s Osaka University developed the LINKS-1 Computer Graphics System, a supercomputer that used up to 257 Zilog Z8001 microprocessors, used for rendering realistic 3D computer graphics. According to the Information Processing Society of Japan: “The core of 3D image rendering is calculating the luminance of each pixel making up a rendered surface from the given viewpoint, light source, and object position. The LINKS-1 system was developed to realize an image rendering methodology in which each pixel could be parallel processed independently using ray tracing. By developing a new software methodology specifically for high-speed image rendering, LINKS-1 was able to rapidly render highly realistic images.” It was “used to create the world’s first 3D planetarium-like video of the entire heavens that was made completely with computer graphics. The video was presented at the Fujitsu pavilion at the 1985 International Exposition in Tsukuba.” The LINKS-1 was the world’s most powerful computer, as of 1984.

**3D Fictional Animated Films at the University of Montreal**

In the 80’s, University of Montreal was at the front run of
Computer Animation with three successful short 3D animated films with 3D characters:

In 1983, Philippe Bergeron, Nadia Magnenat Thalmann, and Daniel Thalmann directed Dream Flight, considered as the first 3D generated film telling a story. The film was completely programmed using the MIRA graphical language, an extension of the Pascal programming language based on abstract graphical data types. The film got several awards and was shown at the SIGGRAPH ’83 Film Show.

In 1985, Pierre Lachapelle, Philippe Bergeron, Pierre Robidoux and Daniel Langlois directed Tony de Peltrie, which shows the first animated human character to express emotion through facial expressions and body movements, which touched the feelings of the audience. *Tony de Peltrie* premiered as the closing film of SIGGRAPH ’85.

In 1987, the Engineering Institute of Canada celebrated its 100th anniversary. A major event, sponsored by Bell Canada and Northern Telecom (now Nortel), was planned for the Place des Arts in Montreal. For this event, Nadia Magnenat Thalmann and Daniel Thalmann simulated Marilyn Monroe and Humphrey Bogart meeting in a cafe in the old town section of Montreal. The short movie, called Rendez-vous in Montreal was shown in numerous festivals and TV channels all over the world.

**Sun Microsystems, Inc**

The Sun Microsystems company was founded in 1982 by Andy Bechtolsheim with other fellow graduate students at Stanford University. Bechtolsheim originally designed the SUN computer as a personal CAD workstation for the Stanford University Network (hence the acronym “SUN”). It was designed around the Motorola 68000 processor with the Unix operating system and virtual memory, and, like SGI, had an embedded frame buffer. Later developments included computer servers and workstations built on its own RISC-based processor architecture and a suite of software products such as the Solaris operating system, and the Java...
platform. By the ’90s, Sun workstations were popular for rendering in 3D CGI filmmaking—for example, Disney-Pixar’s 1995 movie *Toy Story* used a render farm of 117 Sun workstations. Sun was a proponent of open systems in general and Unix in particular, and a major contributor to open source software.

**National Film Board of Canada**

The NFB’s French-language animation studio founded its Centre d’animatique in 1980, at a cost of $1 million CAD, with a team of six computer graphics specialists. The unit was initially tasked with creating stereoscopic CGI sequences for the NFB’s 3-D IMAX film *Transitions* for Expo 86. Staff at the Centre d’animatique included Daniel Langlois, who left in 1986 to form Softimage.

**First turnkey broadcast animation system**

Also in 1982, the first complete turnkey system designed specifically for creating broadcast-standard animation was produced by the Japanese company Nippon Univac Kaisha (“NUK”, later merged with Burroughs), and incorporated the Antics 2-D computer animation software developed by Alan Kitching from his earlier versions. The configuration was based on the VAX 11/780 computer, linked to a Bosch 1-inch VTR, via NUK’s own framebuffer. This framebuffer also showed realtime instant replays of animated vector sequences (“line test”), though finished full-color recording would take many seconds per frame. The full system was successfully sold to broadcasters and animation production companies across Japan. Later in the 80s, Kitching developed versions of Antics for SGI and Apple Macplatforms, and these achieved a wider global distribution.

**First solid 3D CGI in the movies**

The first cinema feature movie to make extensive use of solid 3D CGI was Walt Disney’s *Tron*, directed by Steven Lisberger, in 1982. The film is celebrated as a milestone in the industry, though less than twenty minutes of this animation were actually used—mainly the scenes that show digital “terrain”, or include vehicles such as *Light Cycles*, tanks and ships. To create the CGI scenes,
Disney turned to the four leading computer graphics firms of the day: Information International Inc, Robert Abel and Associates (both in California), MAGI, and Digital Effects (both in New York). Each worked on a separate aspect of the movie, without any particular collaboration. *Tron* was a box office success, grossing $33 million on a budget of $17 million.

In 1984, *Tron* was followed by *The Last Starfighter*, a Universal Pictures / Lorimar production, directed by Nick Castle, and was one of cinema’s earliest films to use extensive CGI to depict its many starships, environments and battle scenes. This was a great step forward compared with other films of the day, such as *Return of the Jedi*, which still used conventional physical models. The computer graphics for the film were designed by artist Ron Cobb, and rendered by Digital Productions on a Cray X-MP supercomputer. A total of 27 minutes of finished CGI footage was produced—considered an enormous quantity at the time. The company estimated that using computer animation required only half the time, and one half to one third the cost of traditional special effects. The movie was a financial success, earning over $28 million on an estimated budget of $15 million.

**Inbetweening and morphing**

The terms inbetweening and morphing are often used interchangeably, and signify the creating of a sequence of images where one image transforms gradually into another image smoothly by small steps. Graphically, an early example would be Charles Philipon’s famous 1831 caricature of French King Louis Philippe turning into a pear (metamorphosis). “Inbetweening” (AKA “tweening”) is a term specifically coined for traditional animation technique, an early example being in E.G. Lutz’s 1920 book *Animated Cartoons*. In computer animation, inbetweening was used from the beginning (e.g., John Whitney in the 50s, Charles Csuri and Masao Komura in the 60s). These pioneering examples were vector-based, comprising only outline drawings (as was also usual in conventional animation technique), and would often be described mathematically as “interpolation”. Inbetweening with solid-filled
colors appeared in the early 70s, (e.g., Alan Kitching’s *Antics* at Atlas Lab, 1973, and Peter Foldes’ *La Faim* at NFBC, 1974), but these were still entirely vector-based.

The term “morphing” did not become current until the late ’80s, when it specifically applied to computer inbetweening with photographic images—for example, to make one face transform smoothly into another. The technique uses grids (or “meshes”) overlaid on the images, to delineate the shape of key features (eyes, nose, mouth, etc.). Morphing then inbetweens one mesh to the next, and uses the resulting mesh to distort the image and simultaneously dissolve one to another, thereby preserving a coherent internal structure throughout. Thus, several different digital techniques come together in morphing. Computer distortion of photographic images was first done by NASA, in the mid-1960s, to align Landsat and Skylab satellite images with each other. Texture mapping, which applies a photographic image to a 3D surface in another image, was first defined by Jim Blinn and Martin Newell in 1976. A 1980 paper by Ed Catmull and Alvy Ray Smith on geometric transformations, introduced a mesh-warping algorithm. The earliest full demonstration of morphing was at the 1982 SIGGRAPH conference, where Tom Brigham of NYIT presented a short film sequence in which a woman transformed, or “morphed”, into a lynx.

The first cinema movie to use morphing was Ron Howard’s 1988 fantasy film *Willow*, where the main character, Willow, uses a magic wand to transform animal to animal to animal and finally, to a sorceress.

**3D inbetweening**

With 3D CGI, the inbetweening of photo-realistic computer models can also produce results similar to morphing, though technically, it is an entirely different process (but is nevertheless often also referred to as “morphing”). An early example is Nelson Max’s 1977 film *Turning a sphere inside out*. The first cinema feature film to use this technique was the 1986 *Star Trek IV: The Voyage*
Home, directed by Leonard Nimoy, with visual effects by George Lucas’s company Industrial Light & Magic (ILM). The movie includes a dream sequence where the crew travel back in time, and images of their faces transform into one another. To create it, ILM employed a new 3D scanning technology developed by Cyberware to digitize the cast members’ heads, and used the resulting data for the computer models. Because each head model had the same number of key points, transforming one character into another was a relatively simple inbetweening.

The Abyss

In 1989 James Cameron’s underwater action movie The Abyss was released. This was the first cinema movie to include photorealistic CGI integrated seamlessly into live-action scenes. A five-minute sequence featuring an animated tentacle or “pseudopod” was created by ILM, who designed a program to produce surface waves of differing sizes and kinetic properties for the pseudopod, including reflection, refraction and a morphing sequence. Although short, this successful blend of CGI and live action is widely considered a milestone in setting the direction for further future development in the field.

Walt Disney & CAPS

The late 80s saw another milestone in computer animation, this time in 2D: the development of Disney’s “Computer Animation Production System”, known as “CAPS”. This was a custom collection of software, scanners and networked workstations developed by The Walt Disney Company in collaboration with Pixar. Its purpose was to computerize the ink-and-paint and post-production processes of traditionally animated films, to allow more efficient and sophisticated post-production by making the practice of hand-painting cels obsolete. The animators’ drawings and background paintings are scanned into the computer, and animation drawings are inked and painted by digital artists. The drawings and backgrounds are then combined, using software that allows for camera movements, multiplane effects, and other
techniques—including compositing with 3D image material. The system’s first feature film use was in *The Little Mermaid* (1989), for the “farewell rainbow” scene near the end, but the first full-scale use was for *The Rescuers Down Under* (1990), which therefore became the first traditionally animated film to be entirely produced on computer—or indeed, the first 100% digital feature film of any kind ever produced.

**3D animation software in the 1980s**

The 80s saw the appearance of many notable new commercial software products:

- **1982**: Autodesk Inc was founded in California by John Walker, with a focus on design software for the PC, with their flagship CAD package *AutoCAD*. In 1986, Autodesk’s first animation package was *AutoFlix*, for use with AutoCAD. Their first full 3D animation software was *3D Studio* for DOS in 1990, which was developed under license by The Yost Group.

- **1983**: Alias Research was founded in Toronto, Canada, by Stephen Bingham and others, with a focus on industrial and entertainment software for SGI workstations. Their first product was *Alias-1* and shipped in 1985. In 1989, Alias was chosen to animate the pseudopod in James Cameron’s *The Abyss*, which gave the software high-profile recognition in movie animation. In 1990 this developed into *PowerAnimator*, often known just as *Alias*.

- **1984**: Wavefront was founded by Bill Kovacs and others, in California, to produce computer graphics for movies and television, and also to develop and market their own software based on SGI hardware. Wavefront developed their first product, *Preview*, during the first year of business. The company’s production department helped tune the software by using it on commercial projects, creating opening graphics for television programs. In 1988, the company introduced the *Personal Visualiser*.

- **1984**: TDI (Thomson Digital Image) was created in France as a subsidiary of aircraft simulator company Thomson-
CSF, to develop and commercialise on their own 3D system *Explore*, first released in 1986.

- **1984**: Sogitec Audiovisuel, was a division of Sogitec avionics in France, founded by Xavier Nicolas for the production of computer animation films, using their own 3D software developed from 1981 by Claude Mechoulam and others at Sogitec.

- **1986**: Softimage was founded by National Film Board of Canada filmmaker Daniel Langlois in Montreal. Its first product was called the *Softimage Creative Environment*, and was launched at SIGGRAPH '88. For the first time, all 3D processes (modelling, animation, and rendering) were integrated. Creative Environment (eventually to be known as *Softimage 3D* in 1988), became a standard animation solution in the industry.

- **1987**: Side Effects Software was established by Kim Davidson and Greg Hermanovic in Toronto, Canada, as a production/software company based on a 3D animation package called *PRISMS*, which they had acquired from their former employer *Omnibus*. Side Effects Software developed this procedural modelling and motion product into a high-end, tightly integrated 2D/3D animation software which incorporated a number of technological breakthroughs.

- **1989**: the companies TDI and Sogitec were merged to create the new company ExMachina.

### CGI in the 1990s

*Computer animation expands in film and TV*

The 90s began with much of CGI technology now sufficiently developed to allow a major expansion into film and TV production. 1991 is widely considered the “breakout year”, with two major boxoffice successes, both making heavy use of CGI.

First of these was James Cameron’s movie *Terminator 2: Judgment Day*, and was the one that first brought CGI to widespread public attention. The technique was used to animate the two
“Terminator” robots. The “T-1000” robot was given a “mimetic poly-alloy” (liquid metal) structure, which enabled this shapeshifting character to morph into almost anything it touched. Most of the key Terminator effects were provided by Industrial Light & Magic, and this film was the most ambitious CGI project since the 1982 film *Tron*.

The other was Disney’s *Beauty and the Beast*, the second traditional 2D animated film to be entirely made using CAPS. The system also allowed easier combination of hand-drawn art with 3D CGI material, notably in the “waltz sequence”, where Belle and Beast dance through a computer-generated ballroom as the camera “dollies” around them in simulated 3D space. Notably, *Beauty and the Beast* was the first animated film ever to be nominated for a Best Picture Academy Award.

Another significant step came in 1993, with Steven Spielberg’s *Jurassic Park*, where 3D CGI dinosaurs were integrated with life-sized animatronic counterparts. The CGI animals were created by ILM, and in a test scene to make a direct comparison of both techniques, Spielberg chose the CGI. Also watching was George Lucas who remarked “a major gap had been crossed, and things were never going to be the same.”

**Flocking**

Flocking is the behavior exhibited when a group of birds (or other animals) move together in a flock. A mathematical model of flocking behavior was first simulated on a computer in 1986 by Craig Reynolds, and soon found its use in animation. *Jurassic Park* notably featured flocking, and brought it to widespread attention by mentioning it in the actual script. Other early uses were the flocking bats in Tim Burton’s *Batman Returns* (1992), and the wildebeest stampede in Disney’s *The Lion King* (1994).

With improving hardware, lower costs, and an ever-increasing range of software tools, CGI techniques were soon rapidly taken up in both film and television production. In 1993, J. Michael Straczynski’s *Babylon 5* became the first major television series to
use CGI as the primary method for their visual effects (rather than using hand-built models), followed later the same year by Rockne S. O’Bannon’s SeaQuest DSV.

Also the same year, the French company Studio Fantome produced the first full-length completely computer animated TV series, Insektors (26×13’), though they also produced an even earlier all 3D short series, Geometric Fables (50 x 5’) in 1991. A little later, in 1994, the Canadian TV CGI series ReBoot (48×23’) was aired, produced by Mainframe Entertainment.

In 1995, there came the first fully computer-animation feature film, Disney-Pixar’s Toy Story, which was a huge commercial success. This film was directed by John Lasseter, a co-founder of Pixar, and former Disney animator, who started at Pixar with short movies such as Luxo Jr. (1986), Red’s Dream (1987), and Tin Toy (1988), which was also the first computer-generated animated short film to win an Academy Award. Then, after some long negotiations between Disney and Pixar, a partnership deal was agreed in 1991 with the aim of producing a full feature movie, and Toy Story was the result.

The following years saw a greatly increased uptake of digital animation techniques, with many new studios going into production, and existing companies making a transition from traditional techniques to CGI. Between 1995 and 2005 in the USA, the average effects budget for a wide-release feature film leapt from $5 million to $40 million. According to Hutch Parker, President of Production at 20th Century Fox, as of 2005, “50 percent of feature films have significant effects. They’re a character in the movie.” However, CGI has made up for the expenditures by grossing over 20% more than their real-life counterparts, and by the early 2000s, computer-generated imagery had become the dominant form of special effects.

Motion capture

Motion capture, or ”Mocap”, records the movement of external objects or people, and has applications for medicine, sports, robotics,
and the military, as well as for animation in film, TV and games. The earliest example would be in 1878, with the pioneering photographic work of Eadweard Muybridge on human and animal locomotion, which is still a source for animators today. Before computer graphics, capturing movements to use in animation would be done using Rotoscoping, where the motion of an actor was filmed, then the film used as a guide for the frame-by-frame motion of a hand-drawn animated character. The first example of this was Max Fleischer’s *Out of the Inkwell* series in 1915, and a more recent notable example is the 1978 Ralph Bakshi 2D animated movie *The Lord of the Rings*.

Computer-based motion capture started as a photogrammetric analysis tool in biomechanics research in the 70s and 80s. A performer wears markers near each joint to identify the motion by the positions or angles between the markers. Many different types of markers can be used—lights, reflective markers, LEDs, infra-red, inertial, mechanical, or wireless RF—and may be worn as a form of suit, or attached direct to a performer’s body. Some systems include details of face and fingers to capture subtle expressions, and such is often referred to as “performance capture”. The computer records the data from the markers, and uses it to animate digital character models in 2D or 3D computer animation, and in some cases this can include camera movement as well. In the 90s, these techniques became widely used for visual effects. Video games also began to use motion capture to animate in-game characters in 1995, the earliest examples of this being the Atari Jaguar CD-based game *Highlander: The Last of the MacLeods*, and the arcade fighting game *Soul Edge*, which was the first video game to use passive optical motion-capture technology.

Another breakthrough where a cinema film used motion capture was creating hundreds of digital characters for the film *Titanic* in 1997. The technique was used extensively in 1999 to create Jar-Jar Binks and other digital characters in *Star Wars: Episode I – The Phantom Menace*. 
Match moving

Match moving (also known as motion tracking or camera tracking), although related to motion capture, is a completely different technique. Instead of using special cameras and sensors to record the motion of subjects, match moving works with pre-existing live-action footage, and uses computer software alone to track specific points in the scene through multiple frames, and thereby allow the insertion of CGI elements into the shot with correct position, scale, orientation, and motion relative to the existing material. The terms are used loosely to describe several different methods of extracting subject or camera motion information from a motion picture. The technique can be 2D or 3D, and can also include matching for camera movements. The earliest commercial software examples being 3D-Equalizer from Science.D.Visions and rastrack from Hammerhead Productions, both starting mid-90s.

The first step is identifying suitable features that the software tracking algorithm can lock onto and follow. Typically, features are chosen because they are bright or dark spots, edges or corners, or a facial feature—depending on the particular tracking algorithm being used. When a feature is tracked it becomes a series of 2D coordinates that represent the position of the feature across the series of frames. Such tracks can be used immediately for 2D motion tracking, or then be used to calculate 3D information. In 3D tracking, a process known as “calibration” derives the motion of the camera from the inverse-projection of the 2D paths, and from this a “reconstruction” process is used to recreate the photographed subject from the tracked data, and also any camera movement. This then allows an identical virtual camera to be moved in a 3D animation program, so that new animated elements can be composited back into the original live-action shot in perfectly matched perspective.

In the 90s, the technology progressed to the point that it became possible to include virtual stunt doubles. Camera tracking software was refined to allow increasingly complex visual effects
developments that were previously impossible. Computer-generated extras also became used extensively in crowd scenes with advanced flocking and crowd simulation software. Being mainly software-based, match moving has become increasingly affordable as computers become cheaper and more powerful. It has become an essential visual effects tool and is even used providing effects in live television broadcasts.

**Virtual studio**

In television, a virtual studio, or virtual set, is a studio that allows the real-time combination of people or other real objects and computer generated environments and objects in a seamless manner. It requires that the 3D CGI environment is automatically locked to follow any movements of the live camera and lens precisely. The essence of such system is that it uses some form of camera tracking to create a live stream of data describing the exact camera movement, plus some realtime CGI rendering software that uses the camera tracking data and generates a synthetic image of the virtual set exactly linked to the camera motion. Both streams are then combined with a video mixer, typically using chroma key. Such virtual sets became common in TV programs in the 90s, with the first practical system of this kind being the *Synthevision virtual studio* developed by the Japanese broadcasting corporation NHK (Nippon Hoso Kyokai) in 1991, and first used in their science special, *Nano-space*. Virtual studio techniques are also used in filmmaking, but this medium does not have the same requirement to operate entirely in realtime. Motion control or camera tracking can be used separately to generate the CGI elements later, and then combine with the live-action as a post-production process. However, by the 2000s, computer power had improved sufficiently to allow many virtual film sets to be generated in realtime, as in TV, so it was unnecessary to composite anything in post-production.

**Machinima**

Machinima uses realtime 3D computer graphics rendering engines to create a cinematic production. Most often, video games
machines are used for this. The Academy of Machinima Arts & Sciences (AMAS), a non-profit organization formed 2002, and dedicated to promoting machinima, defines machinima as “animated filmmaking within a real-time virtual 3-D environment”. AMAS recognizes exemplary productions through awards given at its annual The practice of using graphics engines from video games arose from the animated software introductions of the ‘80s “demoscene”, Disney Interactive Studios’ 1992 video game Stunt Island, and ‘90s recordings of gameplay in first-person shooter video games, such as id Software’s Doom and Quake.

Machinima Film Festival. Machinima-based artists are sometimes called machinimists or machinimators.

3D animation software in the 1990s

There were many developments, mergers and deals in the 3D software industry in the ‘90s and later.

• Wavefront followed the success of Personal Visualiser with the release of Dynamation in 1992, a powerful tool for interactively creating and modifying realistic, natural images of dynamic events. In 1993, Wavefront acquired Thomson Digital Images (TDI), with their innovative product Explore, a tool suite that included 3Design for modelling, Anim for animation, and Interactive Photorealistic Renderer (IPR) for rendering. In 1995, Wavefront was bought by Silicon Graphics, and merged with Alias.

• Alias Research continued the success of PowerAnimator with movies like Terminator 2: Judgment Day, Batman Returns and Jurassic Park, and in 1993 started the development of a new entertainment software, which was later to be named Maya. Alias found customers in animated film, TV series, visual effects, and video games, and included many prominent studios, such as Industrial Light & Magic, Pixar, Sony Pictures Imageworks, Walt Disney, and Warner Brothers. Other Alias products were developed for applications in architecture and engineering. In 1995, SGI purchased both Alias Research and Wavefront in a 3-way
deal, and the merged company Alias Wavefront was launched.

- Alias Wavefront’s new mission was to focus on developing the world’s most advanced tools for the creation of digital content. *PowerAnimator* continued to be used for visual effects and movies (such as *Toy Story* and *Batman Forever*), and also for video games. Further development of the *Maya* software went ahead, adding new features such as motion capture, facial animation, motion blur, and “time warp” technology. CAD industrial design products like *AliasStudio* and *Alias Designer* became standardized on Alias|Wavefront software. In 1998, Alias|Wavefront launched *Maya* as its new 3D flagship product, and this soon became the industry’s most important animation tool. *Maya* was the merger of three packages—Wavefront’s *Advanced Visualizer*, Alias’s *Power Animator*, and TDI’s *Explore*. In 2003 the company was renamed simply “Alias”. In 2004, SGI sold the business to a private investment firm, and it was later renamed to Alias Systems Corporation. In 2006, the company was bought by Autodesk.

- Softimage developed further features for *Creative Environment*, including the *Actor Module* (1991) and *Eddie* (1992), including tools such as inverse kinematics, enveloping, metaclay, flock animation, and many others. Softimage customers include many prominent production companies, and Softimage has been used to create animation for hundreds of major feature films and games. In 1994, Microsoft acquired Softimage, and renamed the package *Softimage 3D*, releasing a Windows NT port two years later. In 1998, after helping to port the products to Windows and financing the development of *Softimage* and *Softimage|DS*, Microsoft sold the Softimage unit to Avid Technology, who was looking to expand its visual effect capabilities. Then, in 2008, Autodesk acquired the brand and the animation assets of Softimage from Avid, thereby ending Softimage Co. as a distinct entity. The video-related assets of Softimage, including *Softimage|DS* (now *Avid|DS*) continue to be owned by Avid.
Aspects of Animation: Steps to Learn Animated Cartoons

• Autodesk Inc’s PC DOS-based 3D Studio was eventually superseded in 1996 when The Yost Group developed 3D Studio Max for Windows NT. Priced much lower than most competitors, 3D Studio Max was quickly seen as an affordable solution for many professionals. Of all animation software, 3D Studio Max serves the widest range of users. It is used in film and broadcast, game development, corporate and industrial design, education, medical, and web design. In 2006, Autodesk acquired Alias, bringing the StudioTools and Maya software products under the Autodesk banner, with 3D Studio Max rebranded as Autodesk 3ds Max, and Maya as Autodesk Maya. Now one of the largest software companies in the world, Autodesk serves more than 4 million customers in over 150 countries.

• Side Effects Software’s PRISMS was used extensively to create visual effects for broadcast and feature films into the ’90s, with projects like Twister, Independence Day, and Titanic. In 1996, Side Effects Software introduced Houdini, a next-generation 3D package that proved to be more sophisticated and artist-friendly than its predecessor. Houdini is used around the world to develop cutting edge 3D animation in the film, broadcast and gaming industries, and Side Effects Software has consistently proved itself to be an industry innovator.

CGI in the 2000s

2000 breakthrough capture of the reflectance field over the human face

In 2000, a team led by Paul Debevec managed to adequately capture (and simulate) the reflectance field over the human face using the simples of light stages, which was the last missing piece of the puzzle to make digital look-alikes of known actors.

Motion capture, photorealism, and uncanny valley

The first mainstream cinema film fully made with motion capture was the 2001 Japanese-American Final Fantasy: The Spirits Within directed by Hironobu Sakaguchi, which was also the first
to use photorealistic CGI characters. The film was not a box-office success. Some commentators have suggested this may be partly because the lead CGI characters had facial features which fell into the “uncanny valley”. In 2002, Peter Jackson’s *The Lord of the Rings: The Two Towers* was the first feature film to use a real-time motion capture system, which allowed the actions of actor Andy Serkis to be fed direct into the 3D CGI model of Gollum as it was being performed.

Motion capture is seen by many as replacing the skills of the animator, and lacking the animator’s ability to create exaggerated movements that are impossible to perform live. The end credits of Pixar’s film *Ratatouille* (2007) carry a stamp certifying it as “100% Pure Animation — No Motion Capture!” However, proponents point out that the technique usually includes a good deal of adjustment work by animators as well. Nevertheless, in 2010, the US Film Academy (AMPAS) announced that motion-capture films will no longer be considered eligible for “Best Animated Feature Film” Oscars, stating “Motion capture by itself is not an animation technique.”

**Virtual cinematography**

The early 2000s saw the advent of fully virtual cinematography with its audience debut considered to be in the 2003 movies Matrix Reloaded and Matrix Revolutions with its digital look-alikes so convincing that it is often impossible to know if some image is a human imaged with a camera or a digital look-alike shot with a simulation of a camera. The scenes built and imaged within virtual cinematography are the “*Burly brawl*” and the end showdown between Neo and Agent Smith. With conventional cinematographic methods the burly brawl would have been prohibitively time consuming to make with years of compositing required for a scene of few minutes. Also a human actor could not have been used for the end showdown in Matrix Revolutions: Agent Smith’s cheekbone gets punched in by Neo leaving the digital look-alike naturally unhurt.
3D animation software in the 2000s

- Blender (software) is a free open source virtual cinematography package, used by professionals and enthusiasts alike.
- Poser is another DIY 3D graphics program especially aimed at user-friendly animation of soft objects
- Pointstream Software is a professional optical flow program that uses a pixel as its basic primitive form usually tracked over a multi-camera setup from the esteemed Arius3D, makers of the XYZRGB scanner, used in the production process of the Matrix sequels

CGI in the 2010s

In SIGGRAPH 2013 Activision and USC presented a real-time digital face look-alike of “Ira” utilizing the USC light stage X by Ghosh et al. for both reflectance field and motion capture. The end result, both precomputed and real-time rendered with the state-of-the-art Graphics processing unit: Digital Ira, looks fairly realistic. Techniques previously confined to high-end virtual cinematography systems are rapidly moving into the video games and leisure applications.

Further developments

New developments in computer animation technologies are reported each year in the USA at SIGGRAPH, the largest annual conference on computer graphics and interactive techniques, and also at Eurographics, and at other conferences around the world.
Limited Animation

INTRODUCTION

Limited animation is a process of making animated cartoons that does not redraw entire frames but variably reuses common parts between frames. One of its major characteristics is stylized design in all forms and shapes, which in the early days was referred to as modern design. The short-subject and feature-length cartoons of Walt Disney from the 1930s and 1940s are widely acclaimed for depicting animated simulations of reality, with exquisite detail in every frame. This style of animation is time-consuming and expensive. “Limited” animation creates an image with abstract art, symbolism, and fewer drawings to create the same effect, at a much lower cost. This style of animation depends upon animators’ skill in emulating change without additional drawings; improper use of limited animation is easily recognized as unnatural. It also encourages the animators to indulge in artistic styles that are not bound to real-world limits. The result is an artistic style that could not have developed if animation was solely devoted to producing simulations of reality. Without limited animation, such groundbreaking films as *Yellow Submarine*, Chuck Jones’ *The Dot and the Line*, and many others could never have been produced.

The process of limited animation aims to reduce the overall number of drawings. Film is projected at 24 frames per second.
For movements in normal speed, most animation in general is done “on twos,” meaning each drawing is displayed twice, for a total of 12 drawings per 24 frames per second. Faster movements may demand animation “on ones” with a new drawing in each frame, while characters that do not move may be done with a single drawing (a “hold”) for a certain amount of time. It is said that the Disney average was about 18 drawings per second, pretending that all characters of a scene share the same sheet of paper. Limited animation mainly reduces the number of inbetweens, the drawings between the keyframes which define a movement, and can cause stuttering if inbetweens are poorly set up. Overall, the use of limited animation does not necessarily imply lower quality as it allows the use of many time-saving techniques that can improve the quality and flow of the keyframes and overall presentation of an animation.

HISTORY

The use of budget-cutting and time-saving animation measures in animation dates back to the earliest commercial animation, including cycled animations, mirror-image and symmetrical drawings, still characters, and other labor-saving methods were employed. In general, the progression was from early productions in which every frame was drawn by hand, independent of each other drawing, toward more limited animation that made use of the same drawings in different ways. Winsor McCay, a man who put an unprecedented amount of detail into his animations, boasted that in his 1914 film *Gertie the Dinosaur* that everything moved, including the rocks and blades of grass in the background. In contrast, his 1918 film *The Sinking of the Lusitania* progressed to using cels over still backgrounds, while still maintaining a level of detail comparable to that of *Gertie*. The 1942 *Merrie Melodies* short *The Dover Boys* was the first Warner Bros. cartoon to employ some techniques of what would become known as “limited animation”, but their use was sparse and pressure from Warner Bros. curtailed further use of these techniques.
Limited animation as an artistic device and a style was pioneered in the animation studio UPA, which made the first serious effort to abandon the keyframe-heavy approach perfected by Disney. UPA’s first effort at limited animation, *Gerald McBoing-Boing*, won an Oscar, and it provided the impetus for this animation method to be accepted at the major Hollywood cartoon studios, including Warner Brothersand MGM. However, the real attraction of limited animation was the reduction in costs: because limited animation does not require as many drawings as fully keyframed animations, it is much less expensive to produce. The 1950s saw all of the major cartoon studios change their style to limited animation, to the point where painstaking detail in animation occurred only rarely.

Limited animation techniques in America were used during the 1960s, 1970s and 1980s to produce a great number of inexpensive Saturday morning cartoons. Such TV series as *Clutch Cargo* are known for being produced on extremely low budgets, with camera tricks used in place of actual animation. Despite the low quality of the animation, the TV cartoon studios Hanna-Barbera, DePatie-Freleng Enterprises, Jay Ward and Filmation thrived during this period. The desire of the time to emulate full animation with limited animation led to many highly apparent visual issues.

**TECHNIQUES**

Techniques used to produce cartoons on a reduced budget include:

- Cels, and sequences of cels, used repeatedly; animators only have to draw a character walking once.
- Characters are split up into different levels: only portions of a character, such as the mouth or an arm, would be animated on top of a static cel.
- Clever choice of camera angles and editing.
- Suggesting movement by either moving the camera or by moving the cel across a background. A famous implementation of this is the “crash” technique, which
involves the camera shaking rapidly back and forth or up and down to simulate a shock wave.

- “Smear animation”: movement is rapid and portrayed in only three frames: the beginning state, the ending state, and a “blur” frame similar to that of a picture taken with a camera that had a low shutter speed.

- Cel reversal (simply using a mirror image of the cel to represent the opposite angle). Many cartoon characters are drawn symmetrically to expedite this technique.

- Visual elements made subsidiary to audio elements, so that verbal humor, voice talent and script writing become more important factors for success.

- Silhouette, to help avoid having to keep track of shading on an animated character or object.

- Stock footage: sequences that are reused frequently. This is the case of the character transformations in the Magical girls subgenre of Japanese anime series. Filmation used this strategy for much of its productions, and Hanna-Barbera often used it when necessary (most notably on Scooby-Doo, Where Are You?).

- Extensive recaps of previous episodes or segments, to cut down on the amount of new material necessary (used often in serial shows like Rocky and Bullwinkle or Underdog).

- Syncro-Vox, involves pasting a film of the moving lips of a real-life person over a still frame of an “animated” character to give the appearance that the character is doing the talking. Cambria Studios held a patent on the technology, and as such, it was primarily used on their productions, such as Clutch Cargo; it still has limited use today, the most widely known example being the online series The Annoying Orange.

- Chuckimation, another notoriously low-budget process, simply moves various “animated” figures by hand or by throwing them across a space. Most commonly used with stop-motion animation, it usually does not allow for characters’ mouths to move.
INTRODUCTION

Motion capture (Mo-cap for short) is the process of recording the movement of objects or people. It is used in military, entertainment, sports, medical applications, and for validation of computer vision and robotics. In filmmaking and video game development, it refers to recording actions of human actors, and using that information to animatedigital character models in 2D or 3D computer animation. When it includes face and fingers or captures subtle expressions, it is often referred to as performance capture. In many fields, motion capture is sometimes called motion tracking, but in filmmaking and games, motion tracking usually refers more to match moving.

In motion capture sessions, movements of one or more actors are sampled many times per second. Whereas early techniques used images from multiple cameras to calculate 3D positions, often the purpose of motion capture is to record only the movements of the actor, not his or her visual appearance. This animation data is mapped to a 3D model so that the model performs the same actions as the actor. This process may be contrasted with the older technique of rotoscoping, as seen in Ralph Bakshi’s The Lord of the Rings (1978) and American Pop (1981). The animated character movements were achieved in these films by tracing over a live-
action actor, capturing the actor’s motions and movements. To explain, an actor is filmed performing an action, and then the recorded film is projected onto an animation table frame-by-frame. Animators trace the live-action footage onto animation cels, capturing the actor’s outline and motions frame-by-frame, and then they fill in the traced outlines with the animated character. The completed animation cels are then photographed frame-by-frame, exactly matching the movements and actions of the live-action footage. The end result of which is that the animated character replicates exactly the live-action movements of the actor. However, this process takes a considerable amount of time and effort.

Camera movements can also be motion captured so that a virtual camera in the scene will pan, tilt, or dolly around the stage driven by a camera operator while the actor is performing, and the motion capture system can capture the camera and props as well as the actor’s performance. This allows the computer-generated characters, images and sets to have the same perspective as the video images from the camera. A computer processes the data and displays the movements of the actor, providing the desired camera positions in terms of objects in the set. Retroactively obtaining camera movement data from the captured footage is known as match moving or camera tracking.

ADVANTAGES

Motion capture offers several advantages over traditional computer animation of a 3D model:

- Low latency, close to real time, results can be obtained. In entertainment applications this can reduce the costs of keyframe-based animation. The Hand Over technique is an example of this.
- The amount of work does not vary with the complexity or length of the performance to the same degree as when using traditional techniques. This allows many tests to be done with different styles or deliveries, giving a different personality only limited by the talent of the actor.
• Complex movement and realistic physical interactions such as secondary motions, weight and exchange of forces can be easily recreated in a physically accurate manner.
• The amount of animation data that can be produced within a given time is extremely large when compared to traditional animation techniques. This contributes to both cost effectiveness and meeting production deadlines.
• Potential for free software and third party solutions reducing its costs.

DISADVANTAGES

• Specific hardware and special software programs are required to obtain and process the data.
• The cost of the software, equipment and personnel required can be prohibitive for small productions.
• The capture system may have specific requirements for the space it is operated in, depending on camera field of view or magnetic distortion.
• When problems occur, it is easier to reshoot the scene rather than trying to manipulate the data. Only a few systems allow real time viewing of the data to decide if the take needs to be redone.
• The initial results are limited to what can be performed within the capture volume without extra editing of the data.
• Movement that does not follow the laws of physics cannot be captured.
• Traditional animation techniques, such as added emphasis on anticipation and follow through, secondary motion or manipulating the shape of the character, as with squash and stretch animation techniques, must be added later.
• If the computer model has different proportions from the capture subject, artefacts may occur. For example, if a cartoon character has large, over-sized hands, these may intersect the character’s body if the human performer is not careful with their physical motion.
APPLICATIONS

Video games often use motion capture to animate athletes, martial artists, and other in-game characters. This has been done since the Sega Model 2 arcade game *Virtua Fighter 2* in 1994. By mid-1995 the use of motion capture in video game development had become commonplace, and developer/publisher Acclaim Entertainment had gone so far as to have its own in-house motion capture studio built into its headquarters. Namco’s 1995 arcade game *Soul Edge* used passive optical system markers for motion capture.

In film, *Snow White and the Seven Dwarfs* used an early form of motion capture technology. Actors and actresses would act out scenes and would be filmed. The animators would then use the individual frames as a guide to their drawings.

Movies use motion capture for CG effects, in some cases replacing traditional cel animation, and for completely computer-generated creatures, such as Gollum, The Mummy, King Kong, Davy Jones from *Pirates of the Caribbean*, the Na’vi from the film *Avatar*, and Clu from *Tron: Legacy*. The Great Goblin, the three Stone-trolls, many of the orcs and goblins in the 2012 film *The Hobbit: An Unexpected Journey*, and Smaug were created using motion capture.

*Sinbad: Beyond the Veil of Mists* was the first movie made primarily with motion capture, although many character animators also worked on the film, which had a very limited release. 2001’s *Final Fantasy: The Spirits Within* was the first widely released movie to be made primarily with motion capture technology. Despite its poor box-office intake, supporters of motion capture technology took notice.

*The Lord of the Rings: The Two Towers* was the first feature film to utilize a real-time motion capture system. This method streamed the actions of actor Andy Serkis into the computer generated skin of Gollum / Smeagol as it was being performed. Out of the three nominees for the 2006 Academy Award for Best Animated Feature,
two of the nominees (*Monster House* and the winner *Happy Feet*) used motion capture, and only Disney Pixar’s *Cars* was animated without motion capture. In the ending credits of Pixar’s film *Ratatouille*, a stamp appears labelling the film as “100% Pure Animation – No Motion Capture!”

Since 2001, motion capture is being used extensively to produce films which attempt to simulate or approximate the look of live-action cinema, with nearly photorealistic digital character models. *The Polar Express* used motion capture to allow Tom Hanks to perform as several distinct digital characters (in which he also provided the voices). The 2007 adaptation of the saga *Beowulf* animated digital characters whose appearances were based in part on the actors who provided their motions and voices. James Cameron’s highly popular *Avatar* used this technique to create the Na’vi that inhabit Pandora. The Walt Disney Company has produced Robert Zemeckis’ *A Christmas Carol* using this technique. In 2007, Disney acquired Zemeckis’ ImageMovers Digital (that produces motion capture films), but then closed it in 2011, after a string of failures.

Television series produced entirely with motion capture animation include *Laflaque* in Canada, *Sprookjesboom* and *Cafe de Wereld* in The Netherlands, and *Headcases* in the UK.

Virtual Reality and Augmented Reality allow users to interact with digital content in real-time. This can be useful for training simulations, visual perception tests, or performing a virtual walkthroughs in a 3D environment. Motion capture technology is frequently used in digital puppetry systems to drive computer generated characters in real-time.

Gait analysis is the major application of motion capture in clinical medicine. Techniques allow clinicians to evaluate human motion across several biometric factors, often while streaming this information live into analytical software.

During the filming of James Cameron’s *Avatar* all of the scenes involving this process were directed in realtime using Autodesk
Motion Builder software to render a screen image which allowed the director and the actor to see what they would look like in the movie, making it easier to direct the movie as it would be seen by the viewer. This method allowed views and angles not possible from a pre-rendered animation. Cameron was so proud of his results that he even invited Steven Spielberg and George Lucas on set to view the system in action.

In Marvel’s critically acclaimed *The Avengers*, Mark Ruffalo used motion capture so he could play his character the Hulk, rather than have him be only CGI like previous films, making Ruffalo the first actor to play both the human and the Hulk versions of Bruce Banner.

FaceRig software uses facial recognition technology from ULSee.Inc to map a player’s facial expressions to a 3D or 2D character’s motion onscreen.

**METHODS AND SYSTEMS**

Motion tracking or motion capture started as a photogrammetric analysis tool in biomechanics research in the 1970s and 1980s, and expanded into education, training, sports and recently computer animation for television, cinema, and video games as the technology matured.

*Reflective markers attached to skin to identify bony landmarks and the 3D motion of body segments*
Motion Capture

Since the 20th century the performer has to wear markers near each joint to identify the motion by the positions or angles between the markers. Acoustic, inertial, LED, magnetic or reflective markers, or combinations of any of these, are tracked, optimally at least two times the frequency rate of the desired motion.

The resolution of the system is important in both the spatial resolution and temporal resolution as motion blur causes almost the same problems as low resolution. Since the beginning of the 21st century and because of the rapidly growth of technology new methods were developed. Most modern systems can extract the silhouette of the performer from the background. Afterwards all joint angles are calculated by fitting in a mathematic model into the silhouette. For movements you can’t see a change of the silhouette, there are hybrid Systems available who can do both (marker and silhouette), but with less marker.

**OPTICAL SYSTEMS**

*Optical systems* utilize data captured from image sensors to triangulate the 3D position of a subject between two or more cameras calibrated to provide overlapping projections. Data acquisition is traditionally implemented using special markers attached to an actor; however, more recent systems are able to generate accurate data by tracking surface features identified dynamically for each particular subject. Tracking a large number of performers or expanding the capture area is accomplished by the addition of more cameras. These systems produce data with 3 degrees of freedom for each marker, and rotational information
must be inferred from the relative orientation of three or more markers; for instance shoulder, elbow and wrist markers providing the angle of the elbow. Newer hybrid systems are combining inertial sensors with optical sensors to reduce occlusion, increase the number of users and improve the ability to track without having to manually clean up data.

**Passive markers**

*A dancer wearing a suit used in an optical motion capture system*

*Several markers are placed at specific points on an actor’s face during facial optical motion capture*

Passive optical system use markers coated with a retroreflective material to reflect light that is generated near the cameras lens. The camera’s threshold can be adjusted so only the bright reflective markers will be sampled, ignoring skin and fabric.
The centroid of the marker is estimated as a position within the two-dimensional image that is captured. The grayscale value of each pixel can be used to provide sub-pixel accuracy by finding the centroid of the Gaussian.

An object with markers attached at known positions is used to calibrate the cameras and obtain their positions and the lens distortion of each camera is measured. If two calibrated cameras see a marker, a three-dimensional fix can be obtained. Typically a system will consist of around 2 to 48 cameras. Systems of over three hundred cameras exist to try to reduce marker swap. Extra cameras are required for full coverage around the capture subject and multiple subjects.

Vendors have constraint software to reduce the problem of marker swapping since all passive markers appear identical. Unlike active marker systems and magnetic systems, passive systems do not require the user to wear wires or electronic equipment. Instead, hundreds of rubber balls are attached with reflective tape, which needs to be replaced periodically. The markers are usually attached directly to the skin (as in biomechanics), or they are velcroed to a performer wearing a full body spandex/lycra suit designed specifically for motion capture. This type of system can capture large numbers of markers at frame rates usually around 120 to 160 fps although by lowering the resolution and tracking a smaller region of interest they can track as high as 10000 fps.

**Active marker**

Active optical systems triangulate positions by illuminating one LED at a time very quickly or multiple LEDs with software to identify them by their relative positions, somewhat akin to celestial navigation. Rather than reflecting light back that is generated externally, the markers themselves are powered to emit their own light. Since Inverse Square law provides 1/4 the power at 2 times the distance, this can increase the distances and volume for capture. This also enables high signal-to-noise ratio, resulting in very low marker jitter and a resulting high measurement
resolution (often down to 0.1 mm within the calibrated volume). The TV series (“Stargate SG1”) produced episodes using an active optical system for the VFX allowing the actor to walk around props that would make motion capture difficult for other non-active optical systems.

ILM used active Markers in Van Helsing to allow capture of Dracula’s flying brides on very large sets similar to Weta’s use of active markers in “Rise of the Planet of the Apes”. The power to each marker can be provided sequentially in phase with the capture system providing a unique identification of each marker for a given capture frame at a cost to the resultant frame rate. The ability to identify each marker in this manner is useful in realtime applications. The alternative method of identifying markers is to do it algorithmically requiring extra processing of the data.

There are also possibilities to find the position by using coloured LED-Markers. In these Systems, each colour is assigned to a specific point of the body. One of the earliest active marker systems in the 1980s was a hybrid passive-active mocap system with rotating mirrors and colored glass reflective markers and which used masked linear array detectors.

**Time modulated active marker**

A high-resolution uniquely identified active marker system with 3,600 × 3,600 resolution at 960 hertz providing real time submillimeter positions.

Active marker systems can further be refined by strobing one marker on at a time, or tracking multiple markers over time and modulating the amplitude or pulse width to provide marker ID. 12 megapixel spatial resolution modulated systems show more subtle movements than 4 megapixel optical systems by having both higher spatial and temporal resolution. Directors can see the actors performance in real time, and watch the results on the motion capture driven CG character. The unique marker IDs reduce the turnaround, by eliminating marker swapping and providing much cleaner data than other technologies. LEDs with onboard
processing and a radio synchronization allow motion capture outdoors in direct sunlight, while capturing at 120 to 960 frames per second due to a high speed electronic shutter. Computer processing of modulated IDs allows less hand cleanup or filtered results for lower operational costs. This higher accuracy and resolution requires more processing than passive technologies, but the additional processing is done at the camera to improve resolution via a subpixel or centroid processing, providing both high resolution and high speed. These motion capture systems are typically $20,000 for an eight camera, 12 megapixel spatial resolution 120 hertz system with one actor.

IR sensors can compute their location when lit by mobile multi-LED emitters, e.g. in a moving car. With 1d per marker, these sensor tags can be worn under clothing and tracked at 500 Hz in broad daylight.

Semi-passive imperceptible marker

One can reverse the traditional approach based on high speed cameras. Systems such as Prakash use inexpensive multi-LED high speed projectors. The specially built multi-LED IR projectors optically encode the space. Instead of retro-reflective or active light emitting diode (LED) markers, the system uses photosensitive marker tags to decode the optical signals. By attaching tags with photo sensors to scene points, the tags can compute not only their own locations of each point, but also their own orientation, incident illumination, and reflectance.

These tracking tags work in natural lighting conditions and can be imperceptibly embedded in attire or other objects. The system supports an unlimited number of tags in a scene, with each tag uniquely identified to eliminate marker reacquisition issues. Since the system eliminates a high speed camera and the corresponding high-speed image stream, it requires significantly lower data bandwidth. The tags also provide incident illumination data which can be used to match scene lighting when inserting synthetic elements. The technique appears ideal for on-set motion
capture or real-time broadcasting of virtual sets but has yet to be proven.

**Underwater motion capture system**

Motion capture technology has been available for researchers and scientists for a few decades, which has given new insight into many fields.

**Underwater cameras**

The vital part of the system, the Underwater camera, has a waterproof housing. The housing has a finish that withstands corrosion and chlorine which makes it perfect for use in basins and swimming pools. There are two types of cameras. Industrial high-speed-cameras can also be used as infrared cameras. The infrared underwater cameras come with a cyan light strobe instead of the typical IR light—for minimum falloff under water and the high-speed-cameras come with an LED-light or with the option of using image processing.

![Motion tracking in swimming by using image processing](image)

**Measurement volume**

A Underwater camera is typically able to measure 15–20 meters depending on the water quality, the camera and the type of marker used. Unsurprisingly, the best range is achieved when the water is clear, and like always, the measurement volume is also dependent on the number of cameras. A range of underwater markers are available for different circumstances.
**Motion Capture**

**Tailored**

Different pools require different mountings and fixtures. Therefore, all underwater motion capture systems are uniquely tailored to suit each specific pool installment. For cameras placed in the center of the pool, specially designed tripods, using suction cups, are provided.

**Markerless**

Emerging techniques and research in computer vision are leading to the rapid development of the markerless approach to motion capture. Markerless systems such as those developed at Stanford University, the University of Maryland, MIT, and the Max Planck Institute, do not require subjects to wear special equipment for tracking. Special computer algorithms are designed to allow the system to analyze multiple streams of optical input and identify human forms, breaking them down into constituent parts for tracking. ESC entertainment, a subsidiary of Warner Brothers Pictures created specially to enable virtual cinematography, including photorealistic digital look-alikes for filming theMatrix Reloaded and Matrix Revolutions movies, used a technique called Universal Capture that utilized 7 camera setup and the tracking the optical flow of all pixels over all the 2-D planes of the cameras for motion, gesture and facial expression capture leading to photorealistic results.

**Traditional systems**

Traditionally markerless optical motion tracking is used to keep track on various objects, including airplanes, launch vehicles, missiles and satellites. Many of such optical motion tracking applications occur outdoors, requiring differing lens and camera configurations. High resolution images of the target being tracked can thereby provide more information than just motion data. The image obtained from NASA’s long-range tracking system on space shuttle Challenger’s fatal launch provided crucial evidence about the cause of the accident. Optical tracking systems are also used
Aspects of Animation: Steps to Learn Animated Cartoons

to identify known spacecraft and space debris despite the fact that it has a disadvantage over radar in that the objects must be reflecting or emitting sufficient light.

An optical tracking system typically consists of 3 subsystems: the optical imaging system, the mechanical tracking platform and the tracking computer.

The optical imaging system is responsible for converting the light from the target area into digital image that the tracking computer can process. Depending on the design of the optical tracking system, the optical imaging system can vary from as simple as a standard digital camera to as specialized as an astronomical telescope on the top of a mountain. The specification of the optical imaging system determines the upper-limit of the effective range of the tracking system.

The mechanical tracking platform holds the optical imaging system and is responsible for manipulating the optical imaging system in such a way that it always points to the target being tracked. The dynamics of the mechanical tracking platform combined with the optical imaging system determines the tracking system’s ability to keep the lock on a target that changes speed rapidly.

The tracking computer is responsible for capturing the images from the optical imaging system, analyzing the image to extract target position and controlling the mechanical tracking platform to follow the target. There are several challenges. First the tracking computer has to be able to capture the image at a relatively high frame rate. This posts a requirement on the bandwidth of the image capturing hardware. The second challenge is that the image processing software has to be able to extract the target image from its background and calculate its position. Several textbook image processing algorithms are designed for this task. This problem can be simplified if the tracking system can expect certain characteristics that is common in all the targets it will track. The next problem down the line is to control the tracking platform to follow the
Motion Capture

This is a typical control system design problem rather than a challenge, which involves modeling the system dynamics and designing controllers to control it. This will however become a challenge if the tracking platform the system has to work with is not designed for real-time.

The software that runs such systems are also customized for the corresponding hardware components. One example of such software is OpticTracker, which controls computerized telescopes to track moving objects at great distances, such as planes and satellites. An other option is the software SimiShape, which can also be used hybrid in combination with markers.

NON-OPTICAL SYSTEMS

Inertial systems

Inertial Motion Capture technology is based on miniature inertial sensors, biomechanical models and sensor fusion algorithms. The motion data of the inertial sensors (inertial guidance system) is often transmitted wirelessly to a computer, where the motion is recorded or viewed. Most inertial systems use inertial measurement units (IMUs) containing a combination of gyroscope, magnetometer, and accelerometer, to measure rotational rates. These rotations are translated to a skeleton in the software. Much like optical markers, the more IMU sensors the more natural the data. No external cameras, emitters or markers are needed for relative motions, although they are required to give the absolute position of the user if desired. Inertial motion capture systems capture the full six degrees of freedom body motion of a human in real-time and can give limited direction information if they include a magnetic bearing sensor, although these are much lower resolution and susceptible to electromagnetic noise. Benefits of using Inertial systems include: capturing in a variety of environments including tight spaces, no solving, portability, and large capture areas. Disadvantages include lower positional accuracy and positional drift which can compound over time.
These systems are similar to the Wii controllers but are more sensitive and have greater resolution and update rates. They can accurately measure the direction to the ground to within a degree. The popularity of inertial systems is rising amongst independent game developers, mainly because of the quick and easy set up resulting in a fast pipeline. A range of suits are now available from various manufacturers and base prices range from $5,000 to $80,000 USD. Ironically the $5,000 systems use newer chips and sensors and are wireless taking advantage of the next generation of inertial sensors and wireless devices.

**Mechanical motion**

Mechanical motion capture systems directly track body joint angles and are often referred to as exoskeleton motion capture systems, due to the way the sensors are attached to the body. A performer attaches the skeletal-like structure to their body and as they move so do the articulated mechanical parts, measuring the performer’s relative motion. Mechanical motion capture systems are real-time, relatively low-cost, free-of-occlusion, and wireless (untethered) systems that have unlimited capture volume. Typically, they are rigid structures of jointed, straight metal or plastic rods linked together with potentiometers that articulate at the joints of the body. These suits tend to be in the $25,000 to $75,000 range plus an external absolute positioning system. Some suits provide limited force feedback or haptic input.

**Magnetic systems**

Magnetic systems calculate position and orientation by the relative magnetic flux of three orthogonal coils on both the transmitter and each receiver. The relative intensity of the voltage or current of the three coils allows these systems to calculate both range and orientation by meticulously mapping the tracking volume. The sensor output is 6DOF, which provides useful results obtained with two-thirds the number of markers required in optical systems; one on upper arm and one on lower arm for elbow position and angle. The markers are not occluded by nonmetallic
objects but are susceptible to magnetic and electrical interference from metal objects in the environment, like rebar (steel reinforcing bars in concrete) or wiring, which affect the magnetic field, and electrical sources such as monitors, lights, cables and computers. The sensor response is nonlinear, especially toward edges of the capture area. The wiring from the sensors tends to preclude extreme performance movements. The capture volumes for magnetic systems are dramatically smaller than they are for optical systems. With the magnetic systems, there is a distinction between “AC” and “DC” systems: one uses square pulses, the other uses sine wave pulse.

RELATED TECHNIQUES

Facial motion capture

Most traditional motion capture hardware vendors provide for some type of low resolution facial capture utilizing anywhere from 32 to 300 markers with either an active or passive marker system. All of these solutions are limited by the time it takes to apply the markers, calibrate the positions and process the data. Ultimately the technology also limits their resolution and raw output quality levels.

High fidelity facial motion capture, also known as performance capture, is the next generation of fidelity and is utilized to record the more complex movements in a human face in order to capture higher degrees of emotion. Facial capture is currently arranging itself in several distinct camps, including traditional motion capture data, blend shaped based solutions, capturing the actual topology of an actor’s face, and proprietary systems.

The two main techniques are stationary systems with an array of cameras capturing the facial expressions from multiple angles and using software such as the stereo mesh solver from OpenCV to create a 3D surface mesh, or to use light arrays as well to calculate the surface normals from the variance in brightness as the light source, camera position or both are changed. These
techniques tend to be only limited in feature resolution by the
camera resolution, apparent object size and number of cameras.
If the user’s face is 50 percent of the working area of the camera
and a camera has megapixel resolution, then sub millimeter facial
motions can be detected by comparing frames. Recent work is
focusing on increasing the frame rates and doing optical flow to
allow the motions to be retargeted to other computer generated
faces, rather than just making a 3D Mesh of the actor and their
expressions.

RF positioning

RF (radio frequency) positioning systems are becoming more
viable as higher frequency RF devices allow greater precision than
older RF technologies such as traditional radar. The speed of light
is 30 centimeters per nanosecond (billionth of a second), so a 10
gigahertz (billion cycles per second) RF signal enables an accuracy
of about 3 centimeters. By measuring amplitude to a quarter
wavelength, it is possible to improve the resolution down to about
8 mm. To achieve the resolution of optical systems, frequencies
of 50 gigahertz or higher are needed, which are almost as line of
sight and as easy to block as optical systems. Multipath and
reradiation of the signal are likely to cause additional problems,
but these technologies will be ideal for tracking larger volumes
with reasonable accuracy, since the required resolution at 100
meter distances is not likely to be as high. Many RF scientists
believe that radio frequency will never produce the accuracy
required for motion capture.

Non-traditional systems

An alternative approach was developed where the actor is
given an unlimited walking area through the use of a rotating
sphere, similar to a hamster ball, which contains internal sensors
recording the angular movements, removing the need for external
cameras and other equipment. Even though this technology could
potentially lead to much lower costs for motion capture, the basic
sphere is only capable of recording a single continuous direction.
Additional sensors worn on the person would be needed to record anything more.

Another alternative is using a 6DOF (Degrees of freedom) motion platform with an integrated omni-directional treadmill with high resolution optical motion capture to achieve the same effect. The captured person can walk in an unlimited area, negotiating different uneven terrains. Applications include medical rehabilitation for balance training, biomechanical research and virtual reality.

**FACIAL MOTION CAPTURE**

Facial Motion Capture is the process of electronically converting the movements of a person’s face into a digital database using cameras or laser scanners. This database may then be used to produce CG (computer graphics) computer animation for movies, games, or real-time avatars. Because the motion of CG characters is derived from the movements of real people, it results in more realistic and nuanced computer character animation than if the animation were created manually.

A facial motion capture database describes the coordinates or relative positions of reference points on the actor’s face. The capture may be in two dimensions, in which case the capture process is sometimes called “expression tracking”, or in three dimensions. Two dimensional capture can be achieved using a single camera and low cost capture software such as Zign Creations’ Zign Track. This produces less sophisticated tracking, and is unable to fully capture three-dimensional motions such as head rotation. Three-dimensional capture is accomplished using multi-camera rigs or laser marker system. Such systems are typically far more expensive, complicated, and time-consuming to use. Two predominate technologies exist; marker and markerless tracking systems.

Facial Motion Capture is related to body motion capture, but is more challenging due to the higher resolution requirements to detect and track subtle expressions possible from small movements of the eyes and lips. These movements are often less than a few
millimeters, requiring even greater resolution and fidelity and different filtering techniques than usually used in full body capture. The additional constraints of the face also allow more opportunities for using models and rules.

Facial expression capture is similar to Facial Motion Capture. It is a process of using visual or mechanical means to manipulate computer generated characters with input from human faces, or to recognize emotions from a user.

History

One of the first papers discussing performance-driven animation was published by Lance Williams in 1990. There, he describes ‘a means of acquiring the expressions of real faces, and applying them to computer-generated faces’.

Technologies

Marker-based

Traditional marker based systems apply up to 350 markers to the actors face and track the marker movement with high resolution cameras. This has been used on movies such as The Polar Express and Beowulf to allow an actor such as Tom Hanks to drive the facial expressions of several different characters. Unfortunately this is relatively cumbersome and makes the actors expressions overly driven once the smoothing and filtering have taken place. Next generation systems such as CaptiveMotion utilize offshoots of the traditional marker based system with higher levels of details.

Active LED Marker technology is currently being used to drive facial animation in real-time to provide user feedback.

Markerless

Markerless technologies use the features of the face such as nostrils, the corners of the lips and eyes, and wrinkles and then track them. This technology is discussed and demonstrated at CMU, IBM, University of Manchester (where much of this started with Tim Cootes, Gareth Edwards and Chris Taylor) and other
Motion Capture

locations, using active appearance models, principal component analysis, eigen tracking, deformable surface models and other techniques to track the desired facial features from frame to frame. This technology is much less cumbersome, and allows greater expression for the actor.

These vision based approaches also have the ability to track pupil movement, eyelids, teeth occlusion by the lips and tongue, which are obvious problems in most computer animated features. Typical limitations of vision based approaches are resolution and frame rate, both of which are decreasing as issues as high speed, high resolution CMOS cameras become available from multiple sources.

The technology for markerless face tracking is related to that in a Facial recognition system, since a facial recognition system can potentially be applied sequentially to each frame of video, resulting in face tracking. For example, the Neven Vision system (formerly Eyematics, now acquired by Google) allowed real-time 2D face tracking with no person-specific training; their system was also amongst the best-performing facial recognition systems in the U.S. Government’s 2002 Facial Recognition Vendor Test (FRVT). On the other hand some recognition systems do not explicitly track expressions or even fail on non-neutral expressions, and so are not suitable for tracking. Conversely, systems such as deformable surface models pool temporal information to disambiguate and obtain more robust results, and thus could not be applied from a single photograph.

Markerless face tracking has progressed to commercial systems such as Image Metrics, which has been applied in movies such as The Matrix sequels and The Curious Case of Benjamin Button. The latter used the Mova system to capture a deformable facial model, which was then animated with a combination of manual and vision tracking. Avatar was another prominent performance capture movie however it used painted markers rather than being markerless. Dynamixyz is another commercial system currently in use.
Markerless systems can be classified according to several distinguishing criteria:

- 2D versus 3D tracking
- whether person-specific training or other human assistance is required
- real-time performance (which is only possible if no training or supervision is required)
- whether they need an additional source of information such as projected patterns or invisible paint such as used in the Mova system.

To date, no system is ideal with respect to all these criteria. For example, the Neven Vision system was fully automatic and required no hidden patterns or per-person training, but was 2D. The Face/Off system is 3D, automatic, and real-time but requires projected patterns.

FACIAL EXPRESSION CAPTURE

Technology

Digital video-based methods are becoming increasingly preferred, as mechanical systems tend to be cumbersome and difficult to use.

Using digital cameras, the input user’s expressions are processed to provide the head pose, which allows the software to then find the eyes, nose, and mouth. The face is initially calibrated using a neutral expression. Then depending on the architecture, the eyebrows, eyelids, cheeks, and mouth can be processed as differences from the neutral expression. This is done by looking for the edges of the lips for instance and recognizing it as a unique object. Often contrast enhancing makeup or markers are worn, or some other method to make the processing faster. Like voice recognition, the best techniques are only good 90 percent of the time, requiring a great deal of tweaking by hand, or tolerance for errors. Since computer generated characters don’t actually have muscles, different techniques are used to achieve the same results.
Some animators create bones or objects that are controlled by the capture software, and move them accordingly, which when the character is rigged correctly gives a good approximation. Since faces are very elastic this technique is often mixed with others, adjusting the weights differently for the skin elasticity and other factors depending on the desired expressions.

**Usage**

Several commercial companies are developing products that have been used, but are rather expensive.

It is expected that this will become a major input device for computer games once the software is available in an affordable format, but the hardware and software do not yet exist, despite the research for the last 15 years producing results that are almost usable.

**FACIAL RECOGNITION SYSTEM**

A facial recognition system is a computer application capable of identifying or verifying a person from a digital image or a video frame from a video source. One of the ways to do this is by comparing selected facial features from the image and a facial database.

It is typically used in security systems and can be compared to other biometrics such as fingerprint or eye iris recognition systems. Recently, it has also become popular as a commercial identification and marketing tool.

**Techniques**

**Traditional**

Some facial recognition algorithms identify facial features by extracting landmarks, or features, from an image of the subject’s face. For example, an algorithm may analyze the relative position, size, and/or shape of the eyes, nose, cheekbones, and jaw. These features are then used to search for other images with matching features. Other algorithms normalize a gallery of face images and
then compress the face data, only saving the data in the image that is useful for face recognition. A probe image is then compared with the face data. One of the earliest successful systems is based on template matching techniques applied to a set of salient facial features, providing a sort of compressed face representation.

Recognition algorithms can be divided into two main approaches, geometric, which looks at distinguishing features, or photometric, which is a statistical approach that distills an image into values and compares the values with templates to eliminate variances.

Popular recognition algorithms include Principal Component Analysis using eigenfaces, Linear Discriminate Analysis, Elastic Bunch Graph Matching using the Fisherface algorithm, the Hidden Markov model, the Multilinear Subspace Learning using tensor representation, and the neuronal motivated dynamic link matching.

**3-dimensional recognition**

A newly emerging trend, claimed to achieve improved accuracies, is three-dimensional face recognition. This technique uses 3D sensors to capture information about the shape of a face. This information is then used to identify distinctive features on the surface of a face, such as the contour of the eye sockets, nose, and chin.

One advantage of 3D facial recognition is that it is not affected by changes in lighting like other techniques. It can also identify a face from a range of viewing angles, including a profile view. Three-dimensional data points from a face vastly improve the precision of facial recognition. 3D research is enhanced by the development of sophisticated sensors that do a better job of capturing 3D face imagery. The sensors work by projecting structured light onto the face. Up to a dozen or more of these image sensors can be placed on the same CMOS chip—each sensor captures a different part of the spectrum.

Even a perfect 3D matching technique could be sensitive to expressions. For that goal a group at the Technion applied tools
from metric geometry to treat expressions as isometries. A company called Vision Access created a firm solution for 3D facial recognition. The company was later acquired by the biometric access company Bioscrypt Inc., which developed a version known as 3D FastPass.

A new method is to introduce a way to capture a 3D picture by using three tracking cameras that point at different angles; one camera will be pointing at the front of the subject, second one to the side, and third one at an angle. All these cameras will work together so it can track a subject’s face in real time and be able to face detect and recognize.

**Skin texture analysis**

Another emerging trend uses the visual details of the skin, as captured in standard digital or scanned images. This technique, called skin texture analysis, turns the unique lines, patterns, and spots apparent in a person’s skin into a mathematical space.

Tests have shown that with the addition of skin texture analysis, performance in recognizing faces can increase 20 to 25 percent.

**Thermal cameras**

A different form of taking input data for face recognition is by using thermal cameras. By this procedure, the cameras will only detect the shape of the head and it will ignore the subject accessories such as glasses, hats, or makeup. A problem with using thermal pictures for face recognition is that the databases for face recognition is limited. Diego Socolinsky, and Andrea Selinger (2004) research the use of thermal face recognition in real life, and operation sceneries, and at the same time build a new database of thermal facial images. The research uses low-sensitive, low-resolution ferro-electric electrics sensors that are capable of acquire long wave thermal infrared (LWIR). The results show that a fusion of LWIR and regular visual cameras has the greater results in outdoor probes. Indoor results show that visual has a 97.05% accuracy, while LWIR has 93.93%, and the Fusion has 98.40%, however on
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the outdoor proves visual has 67.06%, LWIR 83.03%, and fusion has 89.02%. The study used 240 subjects over the period of 10 weeks to create the new database. The data was collected on sunny, rainy, and cloudy days.

Software

Notable software with face recognition ability include:

• digiKam (KDE)
• iPhoto (Apple)
• Lightroom (Adobe)
• OpenCV (Open Source)
• Photos (Apple)
• Photoshop Elements (Adobe Systems)
• Picasa (Google)
• Picture Motion Browser (Sony)
• Windows Live Photo Gallery (Microsoft)
• FotoBounce (Applied Recognition Inc)
• DeepFace (Facebook)

NOTABLE USERS AND DEPLOYMENTS

The Australian and New Zealand Customs Services have an automated border processing system called SmartGate that uses facial recognition. The system compares the face of the individual with the image in the e-passport microchip to verify that the holder of the passport is the rightful owner.

Law enforcement agencies in the United States, including the Los Angeles County Sheriff, use arrest mugshot databases in their forensic investigative work. As of 2013, there is no unified nationwide database of face pictures mapping to names, but there are some efforts to create one.

U.S. Department of State operates one of the largest face recognition systems in the world with over 75 million photographs that is actively used for visa processing. The FBI has also instituted its Next Generation Identification program to include facial
recognition, as well as more traditional biometrics like fingerprints and iris scans, which can pull from both criminal and civil databases.

The Tocumen International Airport in Panama operates an airport-wide surveillance system using hundreds of live facial recognition cameras to identify wanted individuals passing through the airport.

Additional uses

In addition to being used for security systems, authorities have found a number of other applications for facial recognition systems. While earlier post-9/11 deployments were well publicized trials, more recent deployments are rarely written about due to their covert nature.

At Super Bowl XXXV in January 2001, police in Tampa Bay, Florida used Viisage facial recognition software to search for potential criminals and terrorists in attendance at the event. 19 people with minor criminal records were potentially identified.

In the 2000 presidential election, the Mexican government employed facial recognition software to prevent voter fraud. Some individuals had been registering to vote under several different names, in an attempt to place multiple votes. By comparing new facial images to those already in the voter database, authorities were able to reduce duplicate registrations. Similar technologies are being used in the United States to prevent people from obtaining fake identification cards and driver’s licenses.

There are also a number of potential uses for facial recognition that are currently being developed. For example, the technology could be used as a security measure at ATMs. Instead of using a bank card or personal identification number, the ATM would capture an image of the customer’s face, and compare it to the account holder’s photo in the bank database to confirm the customer’s identity.

Facial recognition systems are used to unlock software on mobile devices. An independently developed Android Marketplace
app called Visidon Applock makes use of the phone’s built-in camera to take a picture of the user. Facial recognition is used to ensure only this person can use certain apps which they choose to secure. Face detection and facial recognition are integrated into the iPhoto application for Macintosh, to help users organize and caption their collections.

Also, in addition to biometric usages, modern digital cameras often incorporate a facial detection system that allows the camera to focus and measure exposure on the face of the subject, thus guaranteeing a focused portrait of the person being photographed. Some cameras, in addition, incorporate a smile shutter, or automatically take a second picture if someone blinks during exposure. Because of certain limitations of fingerprint recognition systems, facial recognition systems are used as an alternative way to confirm employee attendance at work for the claimed hours.

Another use could be a portable device to assist people with prosopagnosia in recognizing their acquaintances.

ADVANTAGES AND DISADVANTAGES

Compared to other technologies

Among the different biometric techniques, facial recognition may not be most reliable and efficient. However, one key advantage is that it does not require the cooperation of the test subject to work. Properly designed systems installed in airports, multiplexes, and other public places can identify individuals among the crowd, without passers-by even being aware of the system. Other biometrics like fingerprints, iris scans, and speech recognition cannot perform this kind of mass identification. However, questions have been raised on the effectiveness of facial recognition software in cases of railway and airport security.

Weaknesses

Face recognition is not perfect and struggles to perform under certain conditions. Ralph Gross, a researcher at the Carnegie Mellon
Robotics Institute, describes one obstacle related to the viewing angle of the face: “Face recognition has been getting pretty good at full frontal faces and 20 degrees off, but as soon as you go towards profile, there’ve been problems.”

Other conditions where face recognition does not work well include poor lighting, sunglasses, long hair, or other objects partially covering the subject’s face, and low resolution images.

Another serious disadvantage is that many systems are less effective if facial expressions vary. Even a big smile can render the system less effective. For instance: Canada now allows only neutral facial expressions in passport photos.

On several different occasions, firms like Google, Flickr and Nikon been criticized for their software’s lack of ability to recognize faces with darker toned skin colors. Link

There is also inconstancy in the datasets used by researchers. Researchers may use anywhere from several subjects to scores of subjects, and a few hundred images to thousands of images. It is important for researchers to make available the datasets they used to each other, or have at least a standard dataset.

On 18 January 2013 Japanese researchers created a privacy visor that uses nearly infrared light to make the face underneath it unrecognizable to facial recognition software.

**Effectiveness**

Critics of the technology complain that the London Borough of Newham scheme has, as of 2004, never recognized a single criminal, despite several criminals in the system’s database living in the Borough and the system having been running for several years. “Not once, as far as the police know, has Newham’s automatic facial recognition system spotted a live target.” This information seems to conflict with claims that the system was credited with a 34% reduction in crime (hence why it was rolled out to Birmingham also). However it can be explained by the notion that when the public is regularly told that they are under
constant video surveillance with advanced face recognition technology, this fear alone can reduce the crime rate, whether the face recognition system technically works or does not. This has been the basis for several other face recognition based security systems, where the technology itself does not work particularly well but the user’s perception of the technology does.

An experiment in 2002 by the local police department in Tampa, Florida, had similarly disappointing results.

A system at Boston’s Logan Airport was shut down in 2003 after failing to make any matches during a two-year test period.

**Privacy issues**

Civil rights right organizations and privacy campaigners such as the EFF and the ACLU express concern that privacy is being compromised by the use of surveillance technologies. Some fear that it could lead to a “total surveillance society,” with the government and other authorities having the ability to know the whereabouts and activities of all citizens around the clock. This knowledge has been, is being, and could continue to be deployed to prevent the lawful exercise of rights of citizens to criticize those in office, specific government policies or corporate practices. Many centralized power structures with such surveillance capabilities have abused their privileged access to maintain control of the political and economic apparatus, and to curtail populist reforms.

Facial recognition can be used not just to identify an individual, but also to unearth other personal data associated with an individual – such as other photos featuring the individual, blog posts, social networking profiles, Internet behavior, travel patterns, etc. – all through facial features alone. Moreover, individuals have limited ability to avoid or thwart facial recognition tracking unless they hide their faces. This fundamentally changes the dynamic of day-to-day privacy by enabling any marketer, government agency, or random stranger to secretly collect the identities and associated personal information of any individual captured by the facial recognition system.
Social media web sites such as Facebook have very large numbers of photographs of people, annotated with names. This represents a database which could potentially be used (or abused) by governments for facial recognition purposes.

In July 2012, a hearing was held before the Subcommittee on Privacy, Technology and the Law of the Committee on the Judiciary, United States Senate, to address issues surrounding what facial recognition technology means for privacy and civil liberties.

In 2014, the National Telecommunications and Information Association (NTIA) began a multi-stakeholder process to engage privacy advocates and industry representatives to establish guidelines regarding the use of facial recognition technology by private companies. In June 2015, privacy advocates left the bargaining table over what they felt was an impasse based on the industry representatives being unwilling to agree to consent requirements for the collection of facial recognition data. The NTIA and industry representatives continued without the privacy representatives, and draft rules are expected to be presented in the spring of 2016.

States have begun enacted legislation to protect citizen’s biometric data privacy. Illinois enacted the Biometric Information Privacy Act in 2008. Facebook’s DeepFace has become the subject of several class action lawsuits under the Biometric Information Privacy Act, with claims alleging that Facebook is collecting and storing facial recognition data of its users without obtaining informed consent, in direct violation of the Biometric Information Privacy Act. The most recent case was dismissed in January 2016 because the court lacked jurisdiction. Therefore, it is still unclear if the Biometric Information Privacy Act will be effective in protecting biometric data privacy rights.

**History**

Pioneers of automated facial recognition include Woody Bledsoe, Helen Chan Wolf, and Charles Bisson. During 1964 and 1965, Bledsoe, along with Helen Chan and Charles Bisson, worked
on using the computer to recognize human faces (Bledsoe 1966a, 1966b; Bledsoe and Chan 1965). He was proud of this work, but because the funding was provided by an unnamed intelligence agency that did not allow much publicity, little of the work was published. Given a large database of images (in effect, a book of mug shots) and a photograph, the problem was to select from the database a small set of records such that one of the image records matched the photograph. The success of the method could be measured in terms of the ratio of the answer list to the number of records in the database. Bledsoe (1966a) described the following difficulties:

“This recognition problem is made difficult by the great variability in head rotation and tilt, lighting intensity and angle, facial expression, aging, etc. Some other attempts at facial recognition by machine have allowed for little or no variability in these quantities. Yet the method of correlation (or pattern matching) of unprocessed optical data, which is often used by some researchers, is certain to fail in cases where the variability is great. In particular, the correlation is very low between two pictures of the same person with two different head rotations.” — Woody Bledsoe, 1966

This project was labeled man-machine because the human extracted the coordinates of a set of features from the photographs, which were then used by the computer for recognition. Using a graphics tablet (GRAFACON or RAND TABLET), the operator would extract the coordinates of features such as the center of pupils, the inside corner of eyes, the outside corner of eyes, point of widows peak, and so on. From these coordinates, a list of 20 distances, such as width of mouth and width of eyes, pupil to pupil, were computed. These operators could process about 40 pictures an hour. When building the database, the name of the person in the photograph was associated with the list of computed distances and stored in the computer. In the recognition phase, the set of distances was compared with the corresponding distance for each photograph, yielding a distance between the photograph
and the database record. The closest records are returned. Because it is unlikely that any two pictures would match in head rotation, lean, tilt, and scale (distance from the camera), each set of distances is normalized to represent the face in a frontal orientation. To accomplish this normalization, the program first tries to determine the tilt, the lean, and the rotation. Then, using these angles, the computer undoes the effect of these transformations on the computed distances. To compute these angles, the computer must know the three-dimensional geometry of the head. Because the actual heads were unavailable, Bledsoe (1964) used a standard head derived from measurements on seven heads.

After Bledsoe left PRI in 1966, this work was continued at the Stanford Research Institute, primarily by Peter Hart. In experiments performed on a database of over 2000 photographs, the computer consistently outperformed humans when presented with the same recognition tasks (Bledsoe 1968). Peter Hart (1996) enthusiastically recalled the project with the exclamation, “It really worked!”

By about 1997, the system developed by Christoph von der Malsburg and graduate students of the University of Bochum in Germany and the University of Southern California in the United States outperformed most systems with those of Massachusetts Institute of Technology and the University of Maryland rated next. The Bochum system was developed through funding by the United States Army Research Laboratory. The software was sold as ZN-Face and used by customers such as Deutsche Bank and operators of airports and other busy locations. The software was “robust enough to make identifications from less-than-perfect face views. It can also often see through such impediments to identification as mustaches, beards, changed hair styles and glasses—even sunglasses”.

In about January 2007, image searches were “based on the text surrounding a photo,” for example, if text nearby mentions the image content. Polar Rose technology can guess from a photograph, in about 1.5 seconds, what any individual may look like in three dimensions, and claimed they “will ask users to input the names
of people they recognize in photos online” to help build a database.
In 2006, the performance of the latest face recognition algorithms were evaluated in the Identix, a company out of Minnesota, has developed the software, FacelIt. FacelIt can pick out someone’s face in a crowd and compare it to databases worldwide to recognize and put a name to a face. The software is written to detect multiple features on the human face. It can detect the distance between the eyes, width of the nose, shape of cheekbones, length of jawlines and many more facial features. The software does this by putting the image of the face on a faceprint, a numerical code that represents the human face. Facial recognition software used to have to rely on a 2D image with the person almost directly facing the camera. Now, with FacelIt, a 3D image can be compared to a 2D image by choosing 3 specific points off of the 3D image and converting it into a 2D image using a special algorithm that can be scanned through almost all databases. Face Recognition Grand Challenge (FRGC). High-resolution face images, 3-D face scans, and iris images were used in the tests. The results indicated that the new algorithms are 10 times more accurate than the face recognition algorithms of 2002 and 100 times more accurate than those of 1995. Some of the algorithms were able to outperform human participants in recognizing faces and could uniquely identify identical twins.

U.S. Government-sponsored evaluations and challenge problems have helped spur over two orders-of-magnitude in face-recognition system performance. Since 1993, the error rate of automatic face-recognition systems has decreased by a factor of 272. The reduction applies to systems that match people with face images captured in studio or mugshot environments. In Moore’s law terms, the error rate decreased by one-half every two years.

Low-resolution images of faces can be enhanced using face hallucination. Further improvements in high resolution, megapixel cameras in the last few years have helped to resolve the issue of insufficient resolution.
Machinima

INTRODUCTION

Machinima is the use of real-time computer graphics engines to create a cinematic production. Most often video games are used to generate the computer animation. Machinima-based artists, sometimes called machinimists or machinimators, are often fan laborers, by virtue of their re-use of copyrighted materials.

Machinima filmed in Second Life

Machinima offers to provide an archive of gaming performance and access to the look and feel of software and hardware that may already have become unavailable or even obsolete; for game studies, “machinima’s gestures grant access to gaming’s historical
conditions of possibility and how machinima offers links to a comparative horizon that informs, changes, and fully participates in videogame culture.”

The practice of using graphics engines from video games arose from the animated software introductions of the 1980s demoscene, Disney Interactive Studios’ 1992 video game *Stunt Island*, and 1990s recordings of gameplay in first-person shooter (FPS) video games, such as id Software’s *Doom* and *Quake*. Originally, these recordings documented speedruns—attempts to complete a level as quickly as possible—and multiplayer matches. The addition of storylines to these films created “*Quake movies*”. The more general term *machinima*, a portmanteau of *machine cinema*, arose when the concept spread beyond the *Quake* series to other games and software. After this generalization, machinima appeared in mainstream media, including television series and advertisements.

Machinima has advantages and disadvantages when compared to other styles of filmmaking. Its relative simplicity over traditional frame-based animation limits control and range of expression. Its real-time nature favors speed, cost saving, and flexibility over the higher quality of pre-rendered computer animation. Virtual acting is less expensive, dangerous, and physically restricted than live action. Machinima can be filmed by relying on in-game artificial intelligence (AI) or by controlling characters and cameras through digital puppetry. Scenes can be precisely scripted, and can be manipulated during post-production using video editing techniques. Editing, custom software, and creative cinematography may address technical limitations. Game companies have provided software for and have encouraged machinima, but the widespread use of digital assets from copyrighted games has resulted in complex, unresolved legal issues.

Machinima productions can remain close to their gaming roots and feature stunts or other portrayals of gameplay. Popular genres include dance videos, comedy, and drama. Alternatively, some filmmakers attempt to stretch the boundaries of the rendering
engines or to mask the original 3-D context. The Academy of Machinima Arts & Sciences (AMAS), a non-profit organization dedicated to promoting machinima, recognizes exemplary productions through Mackie awards given at its annual Machinima Film Festival. Some general film festivals accept machinima, and game companies, such as Epic Games, Blizzard Entertainment and Jagex, have sponsored contests involving it.

**HISTORY**

**Precedent**

1980s software crackers added custom introductory credits sequences (intros) to programs whose copy protection they had removed. Increasing computing power allowed for more complex intros, and the demoscene formed when focus shifted to the intros instead of the cracks. The goal became to create the best 3-D demos in real-time with the least amount of software code. Disk storage was too slow for this; graphics had to be calculated on the fly and without a pre-existing game engine.

In Disney Interactive Studios’ 1992 computer game *Stunt Island*, users could stage, record, and play back stunts; as Nitsche stated, the game’s goal was “not... a high score but a spectacle.” Released the following year, id Software’s *Doom* included the ability to record gameplay as sequences of events that the game engine could later replay in real-time. Because events and not video frames were saved, the resulting game demo files were small and easily shared among players. A culture of recording gameplay developed, as Henry Lowood of Stanford University called it, “a context for spectatorship.... The result was nothing less than a metamorphosis of the player into a performer.” Another important feature of *Doom* was that it allowed players to create their own modifications, maps, and software for the game, thus expanding the concept of game authorship. In machinima, there is a dual register of gestures: the trained motions of the player determine the in-game images of expressive motion.
In parallel of the video game approach, in the media art field, Maurice Benayoun’s Virtual Reality artwork *The Tunnel under the Atlantic* (1995), often compared to video games, introduced a virtual film director, fully autonomous intelligent agent, to shoot and edit in real time a full video from the digging performance in the Pompidou Center in Paris and the Museum of Contemporary art in Montreal. The full movie, *Inside the Tunnel under the Atlantic*, 21h long, was followed in 1997 by *Inside the Paris New-Delhi Tunnel* (13h long). Only short excerpts where presented to the public. The complex behavior of the Tunnel’s virtual director makes it a significant precursor of later application to video games based machinimas.

*Doom*’s 1996 successor, *Quake*, offered new opportunities for both gameplay and customization, while retaining the ability to record demos. Multiplayer games became popular, almost a sport; demos of matches between teams of players (clans) were recorded and studied. Paul Marino, executive director of the AMAS, stated that deathmatches, a type of multiplayer game, became more “cinematic”. At this point, however, they still documented gameplay without a narrative.

**Quake movies**

On October 26, 1996, a well-known gaming clan, the Rangers, surprised the *Quake* community with *Diary of a Camper*, the first widely known machinima film. This short, 100-second demo file contained the action and gore of many others, but in the context of a brief story, rather than the usual deathmatch. An example of transformative or emergent gameplay, this shift from competition to theater required both expertise in and subversion of the game’s mechanics. The Ranger demo emphasized this transformation by retaining specific gameplay references in its story.

*Diary of a Camper* inspired many other “*Quake movies*,” as these films were then called. A community of game modifiers (modders), artists, expert players, and film fans began to form around them. The works were distributed and reviewed on
websites such as The Cineplex, Psyk’s Popcorn Jungle, and the Quake Movie Library (QML). Production was supported by dedicated demo-processing software, such as Uwe Girlich’s Little Movie Processing Center (LMPC) and David “crt” Wright’s non-linear editor Keygrip; the latter became known as “Adobe Premiere for Quake demo files”. Among the notable films were Clan Phantasm’s Devil’s Covenant, the first feature-length Quake movie; Avatar and Wendigo’s Blahbalicious, which the QML awarded seven Quake Movie Oscars; and Clan Undead’s Operation Bayshield, which introduced simulated lip synchronization and featured customized digital assets.

Released in December 1997, id Software’s Quake II improved support for user-created 3-D models. However, without compatible editing software, filmmakers continued to create works based on the original Quake; these included the ILL Clan’s Apartment Huntin’ and the Quake done Quick group’s Scourge Done Slick. Quake II demo editors became available in 1998; in particular, Keygrip 2.0 introduced “recamming”, the ability to adjust camera locations after recording. Paul Marino called the addition of this feature “a defining moment for [m]achinima”. With Quake II filming now feasible, Strange Company’s 1999 production Eschaton: Nightfall was the first work to feature entirely custom-made character models.

The December 1999 release of id’s Quake III Arena posed a problem to the Quake movie community. The game’s demo file included information needed for computer networking; however, to prevent cheating, id warned of legal action for dissemination of the file format. Thus, it was impractical to enhance software to work with Quake III. Concurrently, the novelty of Quake movies was waning. New productions appeared less frequently, and, according to Marino, the community needed to “reinvent itself” to offset this development.

Borg War, a 90-minute animated Star Trek fan film, was produced using Elite Force 2 (a Quake III variant) and Starfleet Command 3, repurposing the games’ voiceover clips to create a
new plot. Borg War was nominated for two “Mackie” awards by the Academy of Machinima Arts & Sciences. An August 2007 screening at a Star Trek convention in Las Vegas was the first time that CBS/Paramount had approved the screening of a non-parody fan film at a licensed convention.

Generalization

In January 2000, Hugh Hancock, the founder of Strange Company, launched a new website, machinima.com. The new name surprised the community; a misspelled contraction of machine cinema (machinema), the term machinima was intended to dissociate in-game filming from a specific engine. The misspelling stuck because it also referenced anime. The new site featured tutorials, interviews, articles, and the exclusive release of Tritin Films’ Quad God. The first film made with Quake III Arena, Quad God was also the first to be distributed as recorded video frames, not game-specific instructions. This change was initially controversial among machinima producers who preferred the smaller size of demo files. However, demo files required a copy of the game to view. The more accessible traditional video format broadened Quad God’s viewership, and the work was distributed on CDs bundled with magazines. Thus, id’s decision to protect Quake III’s code inadvertently caused machinima creators to use more general solutions and thus widen their audience. Within a few years, machinima films were almost exclusively distributed in common video file formats.

Machinima began to receive mainstream notice. Roger Ebert discussed it in a June 2000 article and praised Strange Company’s machinima setting of Percy Bysshe Shelley’s sonnet “Ozymandias”. At Showtime Network’s 2001 Alternative Media Festival, the ILL Clan’s 2000 machinima film Hardly Workin’ won the Best Experimental and Best in SHO awards. Steven Spielberg used Unreal Tournament to test special effects while working on his 2001 film Artificial Intelligence: A.I. Eventually, interest spread to game developers. In July 2001, Epic Games announced that its upcoming
Machinima

game *Unreal Tournament 2003* would include Matinee, a machinima production software utility. As involvement increased, filmmakers released fewer new productions to focus on quality.

At the March 2002 Game Developers Conference, five machinima makers—Anthony Bailey, Hugh Hancock, Katherine Anna Kang, Paul Marino, and Matthew Ross—founded the AMAS, a non-profit organization dedicated to promoting machinima. At QuakeCon in August, the new organization held the first Machinima Film Festival, which received mainstream media coverage. *Anachronox: The Movie*, by Jake Hughes and Tom Hall, won three awards, including Best Picture. The next year, “In the Waiting Line”, directed by Tommy Pallotta and animated by Randy Cole, utilizing Fountainhead Entertainment’s Machinimation tools, it became the first machinima music video to air on MTV. As graphics technology improved, machinima filmmakers used other video games and consumer-grade video editing software. Using Bungie’s 2001 game *Halo: Combat Evolved*, Rooster Teeth Productions created a popular comedy series *Red vs. Blue: The Blood Gulch Chronicles*. The series’ second season premiered at the Lincoln Center for the Performing Arts in 2004.

Mainstream appearances

A scene from a machinima portion of “Make Love, Not Warcraft”

Machinima has appeared on television, starting with G4’s series *Portal*. In the BBC series *Time Commanders*, players re-enacted
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historic battles using Creative Assembly’s real-time game Rome: Total War. MTV2’s Video Mods re-creates music videos using characters from video games such as The Sims 2, BloodRayne, and Tribes. Blizzard Entertainment helped to set part of “Make Love, Not Warcraft”, an Emmy Award-winning 2006 episode of the comedy series South Park, in its massively multiplayer online role-playing game (MMORPG) World of Warcraft. By purchasing broadcast rights to Douglas Gayeton’s machinima documentary Molotov Alva and His Search for the Creator in September 2007, HBO became the first television network to buy a work created completely in a virtual world. In December 2008, machinima.com signed fifteen experienced television comedy writers—including Patric Verrone, Bill Oakley, and Mike Rowe—to produce episodes for the site. Commercial use of machinima has increased.

Rooster Teeth sells DVDs of their Red vs. Blue series and, under sponsorship from Electronic Arts, helped to promote The Sims 2 by using the game to make a machinima series, The Strangerhood. Volvo Carssponsored the creation of a 2004 advertisement, Game: On, the first film to combine machinima and live action. Later, Electronic Arts commissioned Rooster Teeth to promote their Madden NFL 07 video game. Blockhouse TV uses Moviestorm’s machinima software to produce its pre-school educational DVD series Jack and Holly.

Game developers have continued to increase support for machinima. Products such as Lionhead Studios’ 2005 business simulation game The Movies, Linden Research’s virtual world Second Life, and Bungie’s 2007 first-person shooter Halo 3 encourage the creation of user content by including machinima software tools. Using The Movies, Alex Chan, a French resident with no previous filmmaking experience, took four days to create The French Democracy, a short political film about the 2005 civil unrest in France. Third-party mods like Garry’s Mod usually offer the ability to manipulate characters and take advantage of custom or migrated content, allowing for the creation of works like Counter-Strike For Kids that can be filmed using multiple games.
In a 2010 interview with PC Magazine, Valve CEO and co-founder Gabe Newell said that they wanted to make a *Half-Life* feature film themselves, rather than hand it off to a big-name director like Sam Raimi, and that their recent *Team Fortress 2* “Meet The Team” machinima shorts were experiments in doing just that. Two years later, Valve released their proprietary non-linear machinima software, Source Filmmaker.

**PRODUCTION**

**Comparison to film techniques**

The AMAS defines machinima as “animated filmmaking within a real-time virtual 3-D environment”. In other 3-D animation methods, creators can control every frame and nuance of their characters but, in turn, must consider issues such as key frames and inbetweening. Machinima creators leave many rendering details to their host environments, but may thus inherit those environments’ limitations. Second Life Machinima film maker, Ozymandius King, provided a detailed account of the process by which the artists at MAGE Magazine produce their videos. “Organizing for a photo shoot is similar to organizing for a film production. Once you find the actors / models, you have to scout locations, find clothes and props for the models and type up a shooting script. The more organized you are the less time it takes to shoot the scene.” Because game animations focus on dramatic rather than casual actions, the range of character emotions is often limited. However, Kelland, Morris, and Lloyd state that a small range of emotions is often sufficient, as in successful Japanese anime television series.

Another difference is that machinima is created in real time, but other animation is pre-rendered. Real-time engines need to trade quality for speed and use simpler algorithms and models. In the 2001 animated film *Final Fantasy: The Spirits Within*, every strand of hair on a character’s head was independent; real-time needs would likely force them to be treated as a single unit.
Kelland, Morris, and Lloyd argue that improvement in consumer-grade graphics technology will allow more realism; similarly, Paul Marino connects machinima to the increasing computing power predicted by Moore’s Law. For cut scenes in video games, issues other than visual fidelity arise. Pre-rendered scenes can require more digital storage space, weaken suspension of disbelief through contrast with real-time animation of normal gameplay, and limit interaction.

Like live action, machinima is recorded in real-time, and real people can act and control the camera. Filmmakers are often encouraged to follow traditional cinematic conventions, such as avoiding wide fields of view, the overuse of slow motion, and errors in visual continuity. Unlike live action, machinima involves less expensive, digital special effects and sets, possibly with a science-fiction or historical theme. Explosions and stunts can be tried and repeated without monetary cost and risk of injury, and the host environment may allow unrealistic physical constraints. University of Cambridge experiments in 2002 and 2003 attempted to use machinima to re-create a scene from the 1942 live-action film *Casablanca*. Machinima filming differed from traditional cinematography in that character expression was limited, but camera movements were more flexible and improvised. Nitsche compared this experiment to an unpredictable Dogme 95 production.

Berkeley sees machinima as “a strangely hybrid form, looking forwards and backwards, cutting edge and conservative at the same time”. Machinima is a digital medium based on 3-D computer games, but most works have a linear narrative structure. Some, such as *Red vs. Blue* and *The Strangerhood*, follow narrative conventions of television situational comedy. Nitsche agrees that pre-recorded (“reel”) machinima tends to be linear and offers limited interactive storytelling; he sees more opportunities in machinima performed live and with audience interaction. In creating their improvisational comedy series *On the Campaign Trail with Larry & Lenny Lumberjack* and talk show *Tra5hTa1k with
Machinima

ILL Will, the ILL Clan blended real and virtual performance by creating the works on-stage and interacting with a live audience. In another combination of real and virtual worlds, Chris Burke’s talk show This Spartan Life takes place in Halo 2’s open multiplayer environment.

There, others playing in earnest may attack the host or his interviewee. Although other virtual theatrical performances have taken place in chat rooms and multi-user dungeons, machinima adds “cinematic camera work”. Previously, such virtual cinematic performances with live audience interaction were confined to research labs equipped with powerful computers.

Machinima can be less expensive than other forms of filmmaking. Strange Company produced its feature-length machinima film BloodSpell for less than £10,000. Before using machinima, Burnie Burns and Matt Hullum of Rooster Teeth Productions spent US$9,000 to produce a live-action independent film; in contrast, the four Xbox game consoles used to make Red vs. Blue in 2005 cost $600.

The low cost caused a product manager for Electronic Arts to compare machinima to the low-budget independent film The Blair Witch Project, without the need for cameras and actors. Because these are seen as low barriers to entry, machinima has been called a “democratization of filmmaking”. Berkeley weighs increased participation and a blurred line between producer and consumer against concerns that game copyrights limit commercialization and growth of machinima.

Comparatively, machinimists using pre-made virtual platforms like Second Life have indicated that their productions can be made quite successfully with no cost at all. Creators like Dutch director Chantal Harvey, producer of the 48 Hour Film Project Machinima sector, have created upwards of 200 films using the platform. Harvey’s advocacy of the genre has resulted in the involvement of film director Peter Greenaway who served as a juror for the Machinima category and gave a keynote speech during the event.
Character and camera control

Kelland, Morris, and Lloyd list four main methods of creating machinima. From simple to advanced, these are: relying on the game’s AI to control most actions, digital puppetry, recamming, and precise scripting of actions. Although simple to produce, AI-dependent results are unpredictable, thus complicating the realization of a preconceived film script. For example, when Rooster Teeth produced *The Strangerhood* using *The Sims 2*, a game that encourages the use of its AI, the group had to create multiple instances of each character to accommodate different moods. Individual instances were selected at different times to produce appropriate actions.

In digital puppetry, machinima creators become virtual actors; each crew member controls a character in real-time, as in a multiplayer game. The director can use built-in camera controls, if available. Otherwise, video is captured from the perspectives of one or more puppeteers who serve as camera operators. Puppetry allows for improvisation and offers controls familiar to gamers, but requires more personnel than the other methods and is less precise than scripted recordings. However, some games, such as the *Halo* series, (except for Halo PC and Custom Edition, which allow AI and custom objects and characters), allow filming only through puppetry. According to Marino, other disadvantages are the possibility of disruption when filming in an open multi-user environment and the temptation for puppeteers to play the game in earnest, littering the set with blood and dead bodies. However, Chris Burke intentionally hosts *This Spartan Life* in these unpredictable conditions, which are fundamental to the show. Other works filmed using puppetry are the ILL Clan’s improvisational comedy series *On the Campaign Trail with Larry & Lenny Lumberjack* and Rooster Teeth Productions’ *Red vs. Blue*. In recamming, which builds on puppetry, actions are first recorded to a game engine’s demo file format, not directly as video frames. Without re-enacting scenes, artists can then manipulate the demo files to add cameras, tweak timing and lighting, and
Machinima
c

change the surroundings. This technique is limited to the few engines and software tools that support it.

A technique common in cut scenes of video games, scripting consists of giving precise directions to the game engine. A filmmaker can work alone this way, as J. Thaddeus “Mindcrime” Skubis did in creating the nearly four-hour *The Seal of Nehahra* (2000), the longest work of machinima at the time. However, perfecting scripts can be time-consuming. Unless what-you-see-is-what-you-get (WYSIWYG) editing is available, as in *Vampire: The Masquerade – Redemption*, changes may need to be verified in additional runs, and non-linear editing may be difficult. In this respect, Kelland, Morris, and Lloyd compare scripting to stop-motion animation. Another disadvantage is that, depending on the game, scripting capabilities may be limited or unavailable. Matinee, a machinima software tool included with *Unreal Tournament 2004*, popularized scripting in machinima.

Limitations and solutions

When *Diary of a Camper* was created, no software tools existed to edit demo files into films. Rangers clan member Eric “ArchV” Fowler wrote his own programs to reposition the camera and to splice footage from the *Quake* demo file. *Quake* movie editing software later appeared, but the use of conventional non-linear video editing software is now common. For example, Phil South inserted single, completely white frames into his work *No Licence* to enhance the visual impact of explosions. In the post-production of *Red vs. Blue: The Blood Gulch Chronicles*, Rooster Teeth Productions added letterboxing with Adobe Premiere Pro to hide the camera player’s head-up display.

Machinima creators have used different methods to handle limited character expression. The most typical ways that amateur-style machinima gets around limitations of expression include taking advantage of speech bubbles seen above players’ heads when speaking, relying on the visual matching between a character’s voice and appearance, and finding methods available
within the game itself. *Garry’s Mod* and Source Filmmaker include the ability to manipulate characters and objects in real-time, though the former relies on community addons to take advantage of certain engine features, and the latter renders scenes using non-real-time effects. In the *Halo* video game series, helmets completely cover the characters’ faces. To prevent confusion, Rooster Teeth’s characters move slightly when speaking, a convention shared with anime. Some machinima creators use custom software. For example, Strange Company uses Take Over GL Face Skins to add more facial expressions to their characters filmed in BioWare’s 2002 role-playing video game *Neverwinter Nights*. Similarly, Atussa Simon used a “library of faces” for characters in *The Battle of Xerxes*. In some cases, some game companies may provide such software; examples include Epic Games’ Impersonator for *Unreal Tournament 2004* and Valve Corporation’s Faceposer for Source games. Another solution is to blend in non-machinima elements, as nGame did by inserting painted characters with more expressive faces into its 1999 film *Berlin Assassins*. It may be possible to point the camera elsewhere or employ other creative cinematography or acting. For example, Tristan Pope combined creative character and camera positioning with video editing to suggest sexual actions in his controversial film *Not Just Another Love Story*.

**LEGAL ISSUES**

New machinima filmmakers often want to use game-provided digital assets, but doing so raises legal issues. As derivative works, their films could violate copyright or be controlled by the assets’ copyright holder, an arrangement that can be complicated by separate publishing and licensing rights. The software license agreement for *The Movies* stipulates that Activision, the game’s publisher, owns “any and all content within... Game Movies that was either supplied with the Program or otherwise made available... by Activision or its licensors...” Some game companies provide software to modify their own games, and machinima makers often cite fair use as a defense, but the issue has never been tested in
court. A potential problem with this defense is that many works, such as *Red vs. Blue*, focus more on satire, which is not as explicitly protected by fair use as parody. Berkeley adds that, even if machinima artists use their own assets, their works could be ruled derivative if filmed in a proprietary engine. The risk inherent in a fair-use defense would cause most machinima artists simply to yield to a cease-and-desist order. The AMAS has attempted to negotiate solutions with video game companies, arguing that an open-source or reasonably priced alternative would emerge from an unfavorable situation. Unlike *The Movies*, some dedicated machinima software programs, such as Reallusion’s iClone, have licenses that avoid claiming ownership of users’ films featuring bundled assets.

Generally, companies want to retain creative control over their intellectual properties and are wary of fan-created works, like fan fiction. However, because machinima provides free marketing, they have avoided a response demanding strict copyright enforcement. In 2003, Linden Lab was praised for changing license terms to allow users to retain ownership of works created in its virtual world *Second Life*. Rooster Teeth initially tried to release *Red vs. Blue* unnoticed by *Halo*’s owners because they feared that any communication would force them to end the project. However, Microsoft, Bungie’s parent company at the time, contacted the group shortly after episode 2, and allowed them to continue without paying licensing fees.

A case in which developer control was asserted involved Blizzard Entertainment’s action against Tristan Pope’s *Not Just Another Love Story*. Blizzard’s community managers encouraged users to post game movies and screenshots, but viewers complained that Pope’s suggestion of sexual actions through creative camera and character positioning was pornographic. Citing the user license agreement, Blizzard closed discussion threads about the film and prohibited links to it. Although Pope accepted Blizzard’s right to some control, he remained concerned about censorship of material that already existed in-game in some form. Discussion ensued
about boundaries between MMORPG player and developer control. Lowood asserted that this controversy demonstrated that machinima could be a medium of negotiation for players.

**Microsoft and Blizzard**

In August 2007, Microsoft issued its Game Content Usage Rules, a license intended to address the legal status of machinima based on its games, including the *Halo* series. Microsoft intended the rules to be “flexible”, and, because it was unilateral, the license was legally unable to reduce rights. However, machinima artists, such as Edgeworks Entertainment, protested the prohibitions on extending Microsoft’s fictional universes (a common component of fan fiction) and on selling anything from sites hosting derivative works. Compounding the reaction was the license’s statement, “If you do any of these things, you can expect to hear from Microsoft’s lawyers who will tell you that you have to stop distributing your items right away.”

Surprised by the negative feedback, Microsoft revised and reissued the license after discussion with Hugh Hancock and an attorney for the Electronic Frontier Foundation. The rules allow noncommercial use and distribution of works derived from Microsoft-owned game content, except audio effects and soundtracks. The license prohibits reverse engineering and material that is pornographic or otherwise “objectionable”. On distribution, derivative works that elaborate on a game’s fictional universe or story are automatically licensed to Microsoft and its business partners. This prevents legal problems if a fan and Microsoft independently conceive similar plots.

A few weeks later, Blizzard Entertainment posted on WorldofWarcraft.com their “Letter to the Machinimators of the World”, a license for noncommercial use of game content. It differs from Microsoft’s declaration in that it addresses machinima specifically instead of general game-derived content, allows use of game audio if Blizzard can legally license it, requires derivative material to meet the Entertainment Software Rating Board’s Teen
content rating guideline, defines noncommercial use differently, and does not address extensions of fictional universes.

Hayes states that, although licensees’ benefits are limited, the licenses reduce reliance on fair use regarding machinima. In turn, this recognition may reduce film festivals’ concerns about copyright clearance; in an earlier analogous situation, festivals were concerned about documentary films until best practices for them were developed. According to Hayes, Microsoft and Blizzard helped themselves through their licenses because fan creations provide free publicity and are unlikely to harm sales. If the companies had instead sued for copyright infringement, defendants could have claimed estoppel or implied license because machinima had been unaddressed for a long time. Thus, these licenses secured their issuers’ legal rights. Even though other companies, such as Electronic Arts, have encouraged machinima, they have avoided licensing it. Because of the involved legal complexity, they may prefer to under-enforce copyrights. Hayes believes that this legal uncertainty is a suboptimal solution and that, though limited and “idiosyncratic”, the Microsoft and Blizzard licenses move towards an ideal video gaming industry standard for handling derivative works.

Semiotic mode

Just as machinima can be the cause of legal dispute in copyright ownership and illegal use, it makes heavy use of intertextuality and raises the question of authorship. Machinima takes copyrighted property (such as characters in a game engine) and repurposes it to tell a story, but another common practice in machinima-making is to retell an existing story from a different medium in that engine.

This re-appropriation of established texts, resources, and artistic properties to tell a story or make a statement is an example of a semiotic phenomenon known as intertextuality or resemiosis. A more common term for this phenomenon is “parody”, but not all of these intertextual productions are intended for humor or satire,
as demonstrated by the *Few Good G-Men* video. Furthermore, the argument of how well-protected machinima is under the guise of parody or satire is still highly debated; a piece of machinima may be reliant upon a protected property, but may not necessarily be making a statement about that property. Therefore, it is more accurate to refer to it simply as resemiosis, because it takes an artistic work and presents it in a new way, form, or medium. This resemiosis can be manifested in a number of ways. The machinima-maker can be considered an author who restructures the story and/or the world that the chosen game engine is built around. In the popular web series *Red vs. Blue*, most of the storyline takes place within the game engine of *Halo: Combat Evolved* and its subsequent sequels. *Halo: Combat Evolved* has an extensive storyline already, but *Red vs. Blue* only ever makes mention of this storyline once in the first episode. Even after over 200 episodes of the show being broadcast onto the Internet since 2003, the only real similarities that can be drawn between *Red vs. Blue* and the game-world it takes place in are the character models, props, vehicles, and settings. Yet Burnie Burns and the machinima team at Rooster Teeth created an extensive storyline of their own using these game resources.

The ability to re-appropriate a game engine to film a video demonstrates intertextuality because it is an obvious example of art being a product of creation-through-manipulation rather than creation per se. The art historian Ernst Gombrich likened art to the “manipulation of a vocabulary” and this can be demonstrated in the creation of machinima. When using a game world to create a story, the author is influenced by the engine. For example, since so many video games are built around the concept of war, a significant portion of machinima films also take place in war-like environments.

Intertextuality is further demonstrated in machinima not only in the re-appropriation of content but in artistic and communicatory techniques. Machinima by definition is a form of puppetry, and thus this new form of digital puppetry employs age-old techniques
Machinima from the traditional artform. It is also, however, a form of filmmaking, and must employ filmmaking techniques such as camera angles and proper lighting. Some machinima takes place in online environments with participants, actors, and “puppeteers” working together from thousands of miles apart. This means other techniques born from long-distance communication must also be employed. Thus, techniques and practices that would normally never be used in conjunction with one another in the creation of an artistic work end up being used intertextually in the creation of machinima.

Another way that machinima demonstrates intertextuality is in its tendency to make frequent references to texts, works, and other media just like TV ads or humorous cartoons such as The Simpsons might do. For example, the machinima series Freeman’s Mind, created by Ross Scott is filmed by taking a recording of Scott playing through the game Half Life as a player normally would and combining it with a voiceover (also recorded by Scott) to emulate an inner monologue of the normally voiceless protagonist Gordon Freeman. Scott portrays Freeman as a snarky, sociopathic character who makes frequent references to works and texts including science fiction, horror films, action movies, American history, and renowned novels such as Moby Dick. These references to works outside the game, often triggered by events within the game, are prime examples of the densely intertextual nature of machinima.

COMMON GENRES

Nitsche and Lowood describe two methods of approaching machinima: starting from a video game and seeking a medium for expression or for documenting gameplay (“inside-out”), and starting outside a game and using it merely as animation tool (“outside-in”). Kelland, Morris, and Lloyd similarly distinguish between works that retain noticeable connections to games, and those closer to traditional animation. Belonging to the former category, gameplay and stunt machinima began in 1997 with
Quake done Quick. Although not the first speedrunners, its creators used external software to manipulate camera positions after recording, which, according to Lowood, elevated speedrunning “from cyberathleticism to making movies”. Stunt machinima remains popular. Kelland, Morris, and Lloyd state that Halo: Combat Evolved stunt videos offer a new way to look at the game, and compare Battlefield 1942 machinima creators to the Harlem Globetrotters. Built-in features for video editing and post-recording camera positioning in Halo 3 were expected to facilitate gameplay-based machinima. MMORPGs and other virtual worlds have been captured in documentary films, such as Miss Galaxies 2004, a beauty pageant that took place in the virtual world of Star Wars Galaxies. Footage was distributed in the cover disc of the August 2004 issue of PC Gamer. Douglas Gayeton’s Molotov Alva and His Search for the Creator documents the title character’s interactions in Second Life.

Gaming-related comedy offers another possible entry point for new machinima producers. Presented as five-minute sketches, many machinima comedies are analogous to Internet Flash animations. After Clan Undead’s 1997 work Operation Bayshield built on the earliest Quake movies by introducing narrative conventions of linear media and sketch comedy reminiscent of the television show Saturday Night Live, the New-York-based ILL Clan further developed the genre in machinima through works including Apartment Huntin’ and Hardly Workin’. Red vs. Blue: The Blood Gulch Chronicles chronicles a futile civil war over five seasons and 100 episodes. Marino wrote that although the series’ humor was rooted in video games, strong writing and characters caused the series to “transcend the typical gamer”. An example of a comedy film that targets a more general audience is Strange Company’s Tum Raider, produced for the BBC in 2004.

Machinima has been used in music videos, of which the first documented example is Ken Thain’s 2002 “Rebel vs. Thug”, made in collaboration with Chuck D. For this, Thain used Quake2Max, a modification of Quake II that provided cel-shaded animation.
The following year, Tommy Pallotta directed “In the Waiting Line” for the British group Zero 7. He told *Computer Graphics World*, “It probably would have been quicker to do the film in a 3D animated program. But now, we can reuse the assets in an improvisational way.” Scenes of the game *Postal 2* can be seen in the music video of the Black Eyed Peas single “Where Is the Love?” In television, MTV features video game characters on its show *Video Mods*. Among *World of Warcraft* players, dance and music videos became popular after dancing animations were discovered in the game.

Others use machinima in drama; these works may or may not retain signs of their video game provenance. *Unreal Tournament* is often used for science fiction and *Battlefield 1942* for war, but some artists subvert their chosen game’s setting or completely detach their work from it. In 1999, Strange Company used *Quake II* in *Eschaton: Nightfall*, a horror film based on the work of H. P. Lovecraft. A later example is Damien Valentine’s series *Consanguinity*, made using BioWare’s 2002 computer game *Neverwinter Nights* and based on the television series *Buffy the Vampire Slayer*. Another genre consists of experimental works that attempt to push the boundaries of game engines. One example, Fountainhead’s *Anna*, is a short film that focuses on the cycle of life and is reminiscent of *Fantasia*. Other productions go farther and completely eschew a 3-D appearance. Friedrich Kirschner’s *The Tournament* and *The Journey* deliberately appear hand-drawn, and *Dead on Que’s Fake Science* resembles two-dimensional Eastern European modernist animation from the 1970s.

Another derivative genre termed macinima verite, from cinéma vérité, seeks to add a documentary and additional realism to the machinima piece. L.M. Sabo’s *CATACLYSM* achieves a machinima verite style through displaying and recapturing the machinima video with a low resolution black and white hand-held video camera to produce a shaky camera effect. Other element of cinéma vérité, such as longer takes, sweeping camera transitions, and jump cuts may be included to complete the effect.
Some have used machinima to make political statements, often from left-wing perspectives. Alex Chan’s take on the 2005 civil unrest in France, *The French Democracy*, attained mainstream attention and inspired other machinima commentaries on American and British society. Horwatt deemed Thuyen Nguyen’s 2006 *An Unfair War*, a criticism of the Iraq war, similar in its attempt “to speak for those who cannot”. Joshua Garrison mimicked Chan’s “political pseudo-documentary style” in his *Virginia Tech Massacre*, a controversial *Halo 3*-based re-enactment and explanation of the eponymous real-life events. More recently, *War of Internet Addiction* addressed internet censorship in China using *World of Warcraft*.

**Competitions**

After the QML’s Quake Movie Oscars, dedicated machinima awards did not reappear until the AMAS created the Mackies for its first Machinima Film Festival in 2002. The annual festival has become an important one for machinima creators. Ho Chee Yue, a founder of the marketing company AKQA, helped to organize the first festival for the Asia chapter of the AMAS in 2006. In 2007, the AMAS supported the first machinima festival held in Europe. In addition to these smaller ceremonies, Hugh Hancock of Strange Company worked to add an award for machinima to the more general Bitfilm Festival in 2003. Other general festivals that allow machinima include the Sundance Film Festival, the Florida Film Festival, and the New Media Film Festival. The Ottawa International Animation Festival opened a machinima category in 2004, but, citing the need for “a certain level of excellence”, declined to award anything to the category’s four entries that year.

Machinima has been showcased in contests sponsored by game companies. Epic Games’ popular Make Something Unreal contest included machinima that impressed event organizer Jeff Morris because of “the quality of entries that really push the technology, that accomplish things that Epic never envisioned”. In December 2005, Blizzard Entertainment and Xfire, a gaming-focused instant messaging service, jointly sponsored a *World of Warcraft* machinima contest.
INTRODUCTION

Animatronics refers to the use of robotic devices to emulate a human or an animal, or bring lifelike characteristics to an otherwise inanimate object. Animatronic creations include animals (including dinosaurs), plants and even mythical creatures. A robot designed to be a convincing imitation of a human is more specifically labeled as an android.

Modern animatronics have found widespread applications in movie special effects and theme parks and have, since their inception, been primarily used as a spectacle of amusement.

Lucky the Dinosaur, a free roaming audio animatronics at Walt Disney World in 2005 was the first one to walk on land.
Animatronics is a multi-disciplinary field which integrates anatomy, robots, mechatronics, and puppetry resulting in lifelike animation. Animatronic figures are often powered by pneumatics, hydraulics, or by electrical means, and can be implemented using both computer control and human control, including teleoperation. Motion actuators are often used to imitate muscle movements and create realistic motions in limbs. Figures are covered with body shells and flexible skins made of hard and soft plastic materials, and finished with details like colors, hair and feathers and other components to make the figure more realistic.

**Etymology**

The term *audio-animatronics* was coined by Walt Disney when he started developing animatronics for entertainment and film. Audio-Animatronics does not differentiate between animatronics and androids. *Autonomatronics*, was also defined by Walt Disney Imagineers, to describe a more advanced audio-animatronic technology featuring cameras and complex sensors to process information around the character’s environment and respond to that stimulus.

**Timeline**

- 1220–1240: The Portfolio of Villard de Honnecourt depicts an early escapement mechanism in a drawing titled *How to make an angel keep pointing his finger toward the Sun* and an automaton of a bird, with jointed wings.
- 1550: Leonardo da Vinci designed and built the Automata Lion.

*All three of Vaucanson’s Automata: The Flute Player, The Tambourine Player, and Digesting Duck*
**The Enchanted Tiki Room**

**Tyrannosaurus animatronic, the largest animatronic, used for Jurassic Park**

- 1738: The construction of automata begins in Grenoble, France by Jacques de Vaucanson. First a flute player that could play twelve songs - *The Flute Player*, followed by a character playing a flute and drum or tambourine - *The Tambourine Player*, and concluding with a moving / quacking / flapping / eating duck - *The Digesting Duck*.
• 1770: Pierre Jaquet-Droz and his son Henri-Louis Jaquet-Droz, both Swiss watchmakers, start making automata for European royalty. Once completed, they had created three dolls. One doll was able to write, the other play music and the third doll could draw pictures.
• 1801: Joseph Jacquard builds a loom that is controlled autonomously with punched cards.
• 1939: Sparko, The Robot Dog, pet of Elektro, performs in front of the public but Sparko, unlike many depictions of robots in that time, represented a living animal, thus becoming the very first modern day animatronic character, along with an unnamed horse which was reported to gallop realistically. The animatronic galloping horse was also on display at the 1939 World’s Fair, in a different exhibit than Sparko’s., 1939 New York World’s Fair
• 1961: Heinrich Ernst develops the MH-1, a computer operated mechanical hand., MIT
• 1961: Walt Disney coins the term audio-animatronics and begins developing modern animatronic technology.
• 1963: The first animatronics, called Audio-Animatronics, created by Disney were the Enchanted Tiki Birds., Disneyland
• 1964: In the film Mary Poppins, animatronic birds are the first animatronics to be featured in a motion picture.
• 1965: The first animatronics figure of a person is created by Disney and is Abraham Lincoln.
• 1977: Chuck E. Cheese’s (then known as Pizza Time Theatre) opens its doors, as the first restaurant with animatronics as an attraction.
• 1980-ShowBiz Pizza Place opens with the Rock-afire Explosion
• 1982: Ben Franklin is the first animatronic figure to walk up a set of stairs.
• 1989: The first A-100 animatronic is developed for the film The Wizard of Oz to represent The Wicked Witch of the West.
Animatronics

1993: The largest animatronic figure ever built is the T. rex for the movie, Jurassic Park.

1998: Tiger Electronics begins selling Furby, an animatronic pet with over 800 English phrases or Furbish and the ability to react to its environment, Vernon Hills, Illinois.

May 11, 1999: Sony releases the AIBO animatronics pet, Tokyo, Japan.

2008: Mr. Potato Head at the Toy Story exhibit features lips with superior range of movement to any other animatronic figure previously, Disney's Hollywood Studios.

October 31, 2008–July 1, 2009: The Abraham Lincoln animatronic character is upgraded to incorporate autonomatronic technology, The Hall of Presidents.

September 28, 2009: Disney develops Otto, the first interactive figure that can hear, see and sense actions in the room, D23 Expo.

HISTORY

Origins

The 3rd-century BC text of the Liezi describes an encounter between King Mu of Zhou and an ‘artificer’ known as Yan Shi, who presented the king with a life-size automaton. The ‘figure’ was described as able to walk, pose and sing, and when dismantled was observed to consist of anatomically accurate organs.

The 5th-century BC Mohist philosopher Mozi and his contemporary Lu Ban are attributed with the invention of artificial wooden birds (ma yuan) that could successfully fly in the Han Fei Zi and in 1066, the Chinese inventor Su Song built a water clock in the form of a tower which featured mechanical figurines which chimed the hours.

In 1515, Leonardo da Vinci designed and built the Automata Lion, one of the earliest described animatrons. The mechanical lion was presented by Giuliano de’ Medici of Florence to Francois I, King of France as a symbol of an alliance between France and Florence. The Automata Lion was rebuilt in 2009 according to
contemporary descriptions and da Vinci’s own drawings of the mechanism. Prior to this, da Vinci had designed and exhibited a mechanical knight at a celebration hosted by Ludovico Sforza at the court of Milan in 1495. The ‘robot’ was capable of standing, sitting, opening its visor and moving its arms. The drawings were rediscovered in the 1950s and a functional replica was later built.

**Early implementations**

**Clocks**

![Greek washstand automaton of the 3rd century BC](image)

While functional, early clocks were also designed as novelties and spectacles which integrated features of early animatronics.

Approximately 1220–1230, Villard de Honnecourt wrote *The Portfolio of Villard de Honnecourt* which depicts an early escapement mechanism in a drawing titled *How to make an angel keep pointing his finger toward the Sun* and an automaton of a bird, with jointed wings which led to their design implementation in clocks. Because of their size and complexity, the majority of these clocks were built as public spectacles in the town centre. One of the earliest of these
large clocks was the Strasbourg Clock, built in the fourteenth century which takes up the entire side of a cathedral wall. It contained an astronomical calendar, automata depicting animals, saints and the life of Christ. The clock still functions to this day, but has undergone several restorations since its initial construction. The Prague astronomical clock was built in 1410, animated figures were added from the 17th century onwards.

Face of the Astronomical Clock, in Old Town Square, Prague

The first description of a modern cuckoo clock was by the Augsburg nobleman Philipp Hainhofer in 1629. The clock belonged to Prince Elector August von Sachsen. By 1650, the workings of mechanical cuckoos were understood and were widely disseminated in Athanasius Kircher’s handbook on music, *Musurgia Universalis*. In what is the first documented description of how a mechanical cuckoo works, a mechanical organ with several automated figures is described.

In 18th-century Germany, clock makers began making cuckoo clocks for sale. Clock shops selling cuckoo clocks became commonplace in the Black Forest region by the middle of the 18th century.

Attractions

A banquet in Camilla of Aragon’s honor in Italy, 1475, featured a lifelike automated camel. The spectacle was a part of a larger parade which continued over days.
In 1454, Duke Philip, created an entertainment show named The extravagant Feast of the Pheasant, which was intended to influence the Duke’s peers to participate in a crusade against the Ottomans, but ended up being a grand display of automata, giants, and dwarves.

Giovanni Fontana, a Paduan engineer in 1420, developed Bellicorum instrumentorum liber which includes a puppet of a camelid driven by a clothed primate twice the height of a human being and an automaton of Mary Magdalene.

IMPLEMENTATIONS

Modern attractions

The earliest modern animatronics can actually be found in old robots. While some of these robots were in fact animatronics, at the time they were thought of simply as robots because the term animatronics had yet to become popularized.

The first animatronics characters to be displayed to the public were a dog and a horse. Each were the attraction at two separate spectacles during the 1939 New York World’s Fair. Sparko, The Robot Dog, pet of Elektro the Robot, performs in front of the public at the 1939 New York World’s Fair but Sparko is not like normal robots. Sparko represents a living animal, thus becoming the very first modern day animatronics character, along with an unnamed
Animatronics

horse which was reported to gallop realistically. The animatronics galloping horse was also on display at the 1939 World’s Fair, in a different exhibit than Sparko’s.

Walt Disney is often credited for popularizing animatronics for entertainment after he bought an animatronic bird while he was vacationing, although it is disputed whether it was in New Orleans or Europe. Disney’s vision for audio-animatronics was primarily focused on patriotic displays rather than amusements.

In 1951, two years after Walt Disney discovered animatronics, he commissioned machinist Roger Broggie and sculptor Wathel Rogers to lead a team tasked with creating a 9” tall figure that could move and talk simulating dance routines performed by actor Buddy Ebsen. The project was titled ‘Project Little Man’ but was never finished. A year later, Walt Disney Imagineering was created.

After “Project Little Man”, the Imagineering team at Disney’s first project was a “Chinese Head” which was on display in the lobby of their office. Customers could ask the head questions and it would reply with words of wisdom. The eyes blinked and its mouth opened and closed.

The Walt Disney Production company started using animatronics in 1955 for Disneyland’s ride, the Jungle Cruise, and later for its attraction Walt Disney’s Enchanted Tiki Room which featured animatronics Enchanted Tiki Birds.

The first fully completed human audio-animatronic figure was Abraham Lincoln, created by Walt Disney in 1964 for the 1964 World’s Fair in the New York. In 1965, Disney upgraded the figure and coined it as the Lincoln Mark II, which appeared at the Opera House at Disneyland Resort in California. For three months, the original Lincoln performed in New York, while the Lincoln Mark II played 5 performances per hour at Disneyland. Body language and facial motions were matched to perfection with the recorded speech. Actor Royal Dano voiced the animatronics version of Abraham Lincoln.
Lucky the Dinosaur is an approximately 8-foot-tall (2.4 m) green Segnosaurus which pulls a flower-covered cart and is led by “Chandler the Dinosaur Handler”. Lucky is notable in that he was the first free-roving audio-animatronic figure ever created by Disney’s Imagineers. The flower cart he pulls conceals the computer and power source.

The Muppet Mobile Lab is a free-roving, audio-animatronic entertainment attraction designed by Walt Disney Imagineering. Two Muppet characters, Dr. Bunsen Honeydew and his assistant, Beaker, pilot the vehicle through the park, interacting with guests and deploying special effects such as foggers, flashing lights, moving signs, confetti cannons and spray jets. It is currently deployed at Hong Kong Disneyland in Hong Kong.

A Laffing Sal is one of several automated characters that were used to attract carnival and amusement park patrons to funhouses and dark rides throughout the United States. Its movements were accompanied by a raucous laugh that sometimes frightened small children and annoyed adults. The Rock-afire Explosion in an animatronic robot band that played in Showbiz Pizza Place from 1980 to 1990.

**Film and television**

The film industry has been a driving force revolutionizing the technology used to develop animatronics.

Animatronics are used in situations where a creature does not exist, the action is too risky or costly to use real actors or animals, or the action could never be obtained with a living person or animal. Its main advantage over CGI and stop motion is that the simulated creature has a physical presence moving in front of the camera in real time. The technology behind animatronics has become more advance and sophisticated over the years, making the puppets even more realistic and lifelike.

Animatronics were first introduced by Disney in the 1964 film *Mary Poppins* which featured an animatronics bird. Since then, animatronics have been used extensively in such movies as *Jaws*,...
Animatronics

and *E.T. the Extra-Terrestrial*, which relied heavily on animatronics. Directors such as Steven Spielberg and Jim Henson have been pioneers in using animatronics in the film industry.

The 1993 film *Jurassic Park* used a combination of computer-generated imagery in conjunction with life-sized animatronic dinosaurs built by Stan Winston and his team. Winston’s animatronic “T. rex” stood almost 20 feet (6.1 m), 40 feet (12 m) in length and even the largest animatronics weighing 9,000 pounds (4,100 kg) were able to perfectly recreate the appearance and natural movement on screen of a full-sized tyrannosaurus rex.

Jack Horner called it “the closest I’ve ever been to a live dinosaur”. Critics referred to Spielberg’s dinosaurs as breathtakingly — and terrifyingly — realistic.

The 1999 BBC miniseries *Walking with Dinosaurs* was produced using a combination of about 80% CGI and 20% animatronic models. The quality of computer imagery of the day were good, but animatronics were still better at distance shots, as well as closeups of the dinosaurs. Animatronics for the series were designed by British animatronics firm Crawley Creatures. The show was followed up in 2007 with a live adaptation of the series, *Walking with Dinosaurs: The Arena Spectacular*.

Geoff Peterson is an animatronic human skeleton that serves as the sidekick on the late-night talk show *The Late Late Show with Craig Ferguson*. Often referred to as a “robot skeleton”, Peterson is a radio-controlled animatronic robot puppet designed and built by Grant Imahara of *MythBusters*.

**Advertising**

The British advertisement campaign for Cadbury Schweppes titled *Gorilla* featured an actor inside a gorilla suit with an animatronically animated face.

The Slowskys was an advertising campaign for Comcast Cable’s Xfinity broadband Internet service. The ad features two animatronic turtles, and it won the gold Effie Award in 2007.
Toys

Some examples of animatronic toys include Teddy Ruxpin, Big Mouth Billy Bass, Kota the triceratops, Pleo, WowWee Alive Chimpanzee, and Furby.

DESIGN

An animatronic character is built around an internal supporting frame, usually made of steel. Attached to these “bones” are the “muscles” which can be manufactured using elastic netting composed of styrene beads. The frame provides the support for the electronics and mechanical components, as well as providing the shape for the outer skin.

The “skin” of the figure is most often made of foam rubber, silicone or urethane poured into moulds and allowed to cure. To provide further strength a piece of fabric is cut to size and embedded in the foam rubber after it is poured into the mould. Once the mould has fully cured, each piece is separated and attached to the exterior of the figure providing the appearance and texture similar to that of “skin”.

An animatronic
**Structure**

An animatronics character is typically designed to be as realistic as possible and thus, is built similarly to how it would be in real life. The framework of the figure is like the “skeleton”. Joints, motors, and actuators act as the “muscles”. Connecting all the electrical components together are wires, such as the “nervous system” of a real animal or person.

**Frame or skeleton**

Steel, aluminum, plastic, and wood are all commonly used in building animatronics but each has its best purpose. The relative strength as well as the weight of the material itself should be considered when determining the most appropriate material to use. The cost of the material may also be a concern.

**Exterior or skin**

Several materials are commonly used in the fabrication of an animatronics figure’s exterior. Dependent on the particular circumstances, the best material will be used to produce the most lifelike form.

For example, “eyes” and “teeth” are commonly made completely out of acrylic.

**Latex**

White latex is commonly used as a general material because it has a high level of elasticity. It is also pre-vulcanized, making it easy and fast to apply. Latex is produced in several grades. Grade 74 is a popular form of latex that dries rapidly and can be applied very thick, making it ideal for developing molds.

Foam latex is a lightweight, soft form of latex which is used in masks and facial prosthetics to change a person’s outward appearance, and in animatronics to create a realistic “skin”. *The Wizard of Oz* was one of the first films to make extensive use of foam latex prosthetics in the 1930s.
Silicone

Disney has a research team devoted to improving and developing better methods of creating more lifelike animatronics exteriors with silicone.

RTV silicone (room temperature vulcanization silicone) is used primarily as a molding material as it is very easy to use but is relatively expensive. Few other materials stick to it, making molds easy to separate.

Bubbles are removed from silicone by pouring the liquid material in a thin stream or processing in a vacuum chamber prior to use. Fumed silica is used as a bulking agent for thicker coatings of the material.

Polyurethane

Polyurethane rubber is a more cost effective material to use in place of silicone. Polyurethane comes in various levels of hardness which are measured on the Shore scale. Rigid polyurethane foam is used in prototyping because it can be milled and shaped in high density.

Flexible polyurethane foam is often used in the actual building of the final animatronic figure because it is flexible and bonds well with latex.

Plaster

As a commonplace construction and home decorating material, plaster is widely available. Its rigidity limits its use in moulds, and plaster moulds are unsuitable when undercuts are present. This may make plaster far more difficult to use than softer materials like latex or silicone.

Movement

Pneumatic actuators can be used for small animatronics but are not powerful enough for large designs and must be supplemented with hydraulics. To create more realistic movement in large figures, an analog system is generally used to give the
figures a full range of fluid motion rather than simple two position movements.

A postulated interior of the Duck of Vaucanson (1738-1739)

Emotion modeling

Mimicking the often subtle displays of humans and other living creatures, and the associated movement is a challenging task when developing animatronics. One of the most common emotional models is the Facial Action Coding System (FACS) developed by Ekman and Friesen. FACS defines that through facial expression, humans can recognize 6 basic emotions: anger, disgust, fear, joy, sadness, and surprise. Another theory is that of Ortony, Clore and Collins, or the OCC model which defines 22 different emotional categories.

TRAINING AND EDUCATION

Animatronics has been developed as a career which combines areas of mechanical engineering, casting/sculpting, control technologies, electrical/electronic, radio control and airbrushing.

Colleges and universities do not offer degree programs in animatronics. Individuals interested in animatronics typically earn a degree in robotics which closely relate to the specializations needed in animatronics engineering.
Students achieving a bachelor’s degree in robotics commonly complete courses in:

- Mechanical engineering
- Industrial robotics
- Mechatronics systems
- Modeling of robotics systems
- Robotics engineering
- Foundational theory of robotics
- Introduction to robotics

**AUDIO-ANIMATRONICS**

Audio-Animatronics (Animatronics, AA) is the registered trademark for a form of robotics animation created by Walt Disney Imagineering for shows and attractions at Disney theme parks, and subsequently expanded on and used by other companies. The robots move and make noise (generally a recorded speech or song), but are usually fixed to whatever supports them. They can sit and stand but usually cannot walk. An Audio-Animatron is different from an android-type robot in that it uses prerecorded movements and sounds, rather than responding to external stimuli. In 2009, Disney created an interactive version of the technology called Autonomatronics.

“Animatronics” has become a generic name for similar robots created by firms other than Disney.

**History**

Audio-Animatronics were originally a creation of Walt Disney employee Lee Adams, who worked as an electrician at the Burbank studio and was one of Disney’s original Imagineers. One of the first Disney Audio-Animatrons was a toy bird Walt Disney got in New Orleans. It was a simple mechanical bird, and Walt decided to improve the device that moved it. Another was a “dancing man”, created by Roger Broggie and Wathel Rogers. The dancing man was modeled after a tap dancing routine by actor Buddy Ebsen.
The term “Audio-Animatronics” was first used commercially by Disney in 1961, was filed as a trademark in 1964, and was registered in 1967.

Perhaps the most impressive of the early Audio-Animatronics efforts was The Enchanted Tiki Room, which opened in 1963 at Disneyland. It was (and still is) a room full of tropical creatures with eye and facial actions synchronized to a musical score entirely by electromechanical means. The “cast” of the musical revue uses tones recorded on tape to vibrate a metal reed that closes a circuit to trigger a relay, which sends a pulse of electricity to a mechanism that causes a pneumatic valve to move part of the figure.

The movements of the attraction’s birds, flowers, and tiki idols are triggered by sound. Figures’ movements have a neutral “natural resting position” that the limb or part returns to when there is no electric pulse present. Other than this, the animation is a digital system, with only on/off moves, such as an open or closed eye.

Other early Audio-Animatrons were at the 1964 New York World’s Fair. They were used in the Great Moments with Mr. Lincoln exhibit at the State of Illinois Pavilion, Pepsi/UNICEF’s “it’s a small world” exhibit, General Electric’s Carousel of Progress, and Ford Motor Company’s “Magic Skyway.”

TECHNOLOGY

Pneumatic actuators were not powerful enough to move heavier objects like simulated limbs, so hydraulics were used for large figures. On/off type movement would cause an arm to be lifted (for example) either up over an animatron’s head or down next to its body, but with no halting or change of speed in between. To create more realistic movement in large figures, an analog system was used. This gave the figures’ body parts a full range of fluid motion, rather than only two positions. The digital system was used with small pneumatic moving limbs (eyelids, beaks, fingers), and the analog system was used for large hydraulic human or animal moving limbs (arms, heads).
To permit a high degree of freedom, the control cylinders resemble typical miniature pneumatic or hydraulic cylinders, but mount the back of the cylinder on a ball joint and threaded rod. This ball joint permits the cylinders to float freely inside the frame, such as when the wrist joint rotates and flexes.

Disney’s technology is not infallible however; the oil-filled cylinders do occasionally drip or leak. It is sometimes necessary to do makeup touch-up work, or to strip the clothing off a figure due to leaking fluids inside. The Tiki Room remains a pneumatic theatrical set, primarily due to the leakage concerns; Disney does not want hydraulic fluids dripping down onto the audience during a show.

Because each individual cylinder requires its own control channel, the original Audio-Animatronic figures were relatively simple in design, to reduce the number of channels required. For example, the first human designs (referred to internally by Disney as series A-1) included all four fingers of the hand as one actuator. It could wave its hand but it could not grasp or point at something. With modern digital computers controlling the device, the number of channels is virtually unlimited, allowing more complex, realistic motion. The current versions (series A-100) now have individual actuators for each finger.

**Compliance**

Compliance is a new technology that allows faster, more realistic movements without sacrificing control. In the older figures, a fast limb movement would cause the entire figure to shake in an unnatural way. The Imagineers thus had to program slower movements, sacrificing speed in order to gain control. This was frustrating for the animators, who, in many cases, wanted faster movements. Compliance improves this situation by allowing limbs to continue past the points where they are programmed to stop; they then return quickly to the “intended” position, much as real organic body parts do. The various elements also slow to a stop at their various positions, instead of using the immediate stops
that caused the unwanted shaking. This absorbs shock, much like the shock absorbers on a car or the natural shock absorption in a living body.

**Cosmetics**

The skin of an Audio-Animatronic is made from silicone rubber. Because the neck is so much narrower than the rest of the skull, the skull skin cover has a zipper up the back to permit easy removal. The facial appearance is painted onto the rubber, and standard cosmetic makeup is also used. Over time, the flexing causes the paint to loosen and fall off, so occasional makeup work and repainting is required.

Generally as the rubber skin flexes, the stress causes it to dry and begin to crack. Figures that do not have a high degree of motion flexibility (such as the older A-1 series Lincoln) may only need the skin to be replaced every ten years. The most recent A-100 series human AAs (such as for Barack Obama) also include flexion actuators that move the cheeks and eyebrows to permit more realistic expressions, but the skin wears out more quickly and needs replacement at least every five years.

The wig on each human AA is made from natural human hair for the highest degree of realism, but using real hair creates its own problems, since the changing humidity and constant rapid motions of the moving AA carriage hardware throughout the day cause the hair to slowly lose its styling, requiring touch-ups before each day’s showing.

**Autonomatronics**

Autonomatronics is a registered trademark for a more advanced Audio-Animatronic technology, also created by Walt Disney Imagineers.

The original Audio-Animatrons used hydraulics to operate robotic figures to present a pre-programmed show. This more sophisticated technology can include cameras and other sensors feeding signals to a high-speed computer which processes the
information and makes choices about what to say and do. Disney created “Otto”, the first interactive figure that can hear, see and sense actions in the room. Otto can hold conversations and react to the audience.

In December 2009, Great Moments with Mr. Lincoln returned to Disneyland using the new Autonomatronics technology.

Variations

The technology of the AAs at Disney’s theme parks around the world vary in their sophistication. They range from the blinking and mouth movements at Walt Disney’s Enchanted Tiki Room to full body movement, from the mouth to the tip of the fingers at Stitch’s Great Escape! at the Magic Kingdom.

Current technologies have paved the way for more elaborate AA figures, such as the “Ursula head” inside the Mermaid Lagoon Theater at Tokyo DisneySea, the Indiana Jones figures inside the Indiana Jones attractions at both Disneyland and Tokyo DisneySea, the “swordfighting” pirates inside Pirates of the Caribbean at Disneyland Park (Paris), the “lava/rock monster” inside Journey to the Center of the Earth at Tokyo DisneySea, the dinosaurs inside DINOSAUR and the “Yeti” inside Expedition Everest at Disney’s Animal Kingdom (though the latter has been non-functional since 2008, using a strobe light to simulate movement of the still figure, referred to by fans as “Disco Yeti”), or the Roz figure inside Monsters, Inc. Mike & Sulley to the Rescue! at Disney California Adventure Park.

The Roz figure is able to “interact” with guests with help from an unseen ride operator who chooses pre-recorded messages for Roz to “speak”, thereby seeming to “react” to individual guests’ unique appearances and clothing.

Mr. Potato Head outside of the Toy Story Mania! attractions at the Disney California Adventure and Disney’s Hollywood Studios parks does the same as Roz does. One of the newest figures comes with changes to the classic Pirates of the Caribbean attraction at Disneyland and the Magic Kingdom, both now
Animatronics

featuring characters from the Pirates of the Caribbean film series. The Jack Sparrow figure is based on the actor that portrays him, Johnny Depp, even featuring his voice and facial mold. So far, the newest and most advanced Audio-Animatronic figure is Abraham Lincoln at The Disneyland Story: Featuring Great Moments With Mr. Lincoln at Disneyland. Lincoln can move his lips to form words, can make very dramatic movements, and can portray emotions to match the words he’s saying.

The Audio-Animatronic Indiana Jones figures inside Indiana Jones Adventure: Temple of the Crystal Skull at Tokyo DisneySea resemble actor Harrison Ford, unlike the original figures found at the Disneyland version, Temple of the Forbidden Eye. In 2010, some of the Audio-Animatronic figures at the Disneyland version were replaced with more technically advanced figures that also look more like Ford. However, neither version features Harrison Ford’s actual voice.

Audio-Animatronics found in Magic Kingdom’s Seven Dwarfs Mine Train are Disney’s latest animatronic technology and use screens as faces to make the dwarfs’ mouths move and their eyes blink.

In popular culture

- Less-sophisticated forms of animatronics also gained popularity in the 1980s through use at family entertainment centers such as Showbiz Pizza Place and Chuck E. Cheese’s Pizza Time Theatre. They are also used in film and television special effects.
- Several passengers and the crew of a Pioneer Zephyr are represented in a display of this historic train at Chicago’s Museum of Science and Industry. Neatly dressed in the proper style of first class passengers of their era, one remarks upon the casual dress of the visitors.
- John Wardley is often said to have brought animatronics to the United Kingdom, utilizing a concept called Ramped
Movement, which allowed for smoother movements of the figures. John appeared on *Tomorrow's World* in the 1970s showing a guitar playing animatronic programmed to music. His first project was the creation of the animated show “50 Glorious Years” for Tussaud’s “Royalty and Empire Exhibition” at Windsor.

- Scissor Sisters member Ana Matronic named herself after animatronics, as an homage to her love of *The Bionic Woman*.
- The Pennsylvania Lottery uses an animatronic groundhog named Gus (who refers to himself as the “second-most-famous groundhog in Pennsylvania”, after Punxsutawney Phil) as the mascot for television commercials for their instant scratch-off games.
- The Disney film *Tomorrowland* uses the Audio-Animatronics word as a term for their sophisticated android characters.
COMPUTER GRAPHICS

Although computer graphics is a vast field that encompasses almost any graphical aspect, we are mainly interested in the generation of images of 3-dimensional scenes. Computer imagery has applications for filmspecial effects, simulation and training, games, medical imagery, flying logos, etc. Computer graphics relies on an internal model of the scene, that is, a mathematical representation suitable for graphical computations. The model describes the 3D shapes, layout and materials of the scene.

This 3D representation then has to be projected to compute a 2D image from a given viewpoint, this is the rendering step. Rendering involves projecting the objects (perspective), handling visibility (which parts of objects are hidden) and computing their appearance and lighting interactions. Finally, for animated sequence, the motion of objects has to be specified.

Why Computer Graphics?
- Movies
- Games
- CAD-CAM
- Simulation
- Virtual reality
- Visualization
- Medical imaging.

The term computer graphics includes almost everything on computers that is not text or sound. Today almost every computer can do some graphics, and people have even come to expect to control their computer through icons and pictures rather than just by typing. The development of computer graphics has made computers easier to interact with, and better for understanding and interpreting many types of data. Developments in computer graphics have had a profound impact on many types of media and have revolutionized animation, movies and the video game industry.

Typically, the term computer graphics refers to several different things:

- The representation and manipulation of image data by a computer
- The various technologies used to create and manipulate images
- The sub-field of computer science which studies methods for digitally synthesizing and manipulating visual content.

Computer graphics is widespread today. Computer imagery is found on television, in newspapers, for example in weather reports, or for example in all kinds of medical investigation and surgical procedures.

A well-constructed graph can present complex statistics in a form that is easier to understand and interpret. In the media “such graphs are used to illustrate papers, reports, thesis”, and other presentation material. The development of computer graphics has made computers easier to interact with, and better for understanding and interpreting many types of data. Developments in computer graphics have had a profound impact on many types of media and have revolutionized animation, movies and the video game industry.
Many powerful tools have been developed to visualize data. Computer generated imagery can be categorized into several different types: 2D, 3D, and animated graphics. As technology has improved, 3D computer graphics have become more common, but 2D computer graphics are still widely used. Computer graphics has emerged as a sub-field of computer science which studies methods for digitally synthesizing and manipulating visual content.

Over the past decade, other specialized fields have been developed like information visualization, and scientific visualization more concerned with “the visualization of three dimensional phenomena (architectural, meteorological, medical, biological, etc.), where the emphasis is on realistic renderings of volumes, surfaces, illumination sources, and so forth, perhaps with a dynamic (time) component”.

History

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The phrase “Computer Graphics” was coined in 1960 by William Fetter, a graphic designer for Boeing. The field of computer graphics developed with the emergence of computer graphics hardware. Early projects like the Whirlwind and SAGE Projects introduced the CRT as a viable display and interaction interface.
and introduced the light pen as an input device. Initial 1960s developments

Further advances in computing led to greater advancements in interactive computer graphics. In 1959, the TX-2 computer was developed at MIT’s Lincoln Laboratory. The TX-2 integrated a number of new man-machine interfaces. A light pen could be used to draw sketches on the computer using Ivan Sutherland’s revolutionary Sketchpad software. Using a light pen, Sketchpad allowed one to draw simple shapes on the computer screen, save them and even recall them later. The light pen itself had a small photoelectric cell in its tip. This cell emitted an electronic pulse whenever it was placed in front of a computer screen and the screen’s electron gun fired directly at it. By simply timing the electronic pulse with the current location of the electron gun, it was easy to pinpoint exactly where the pen was on the screen at any given moment. Once that was determined, the computer could then draw a cursor at that location.

Sutherland seemed to find the perfect solution for many of the graphics problems he faced. Even today, many standards of computer graphics interfaces got their start with this early Sketchpad Programme. One example of this is in drawing constraints. If one wants to draw a square for example, they do not have to worry about drawing four lines perfectly to form the edges of the box. One can simply specify that they want to draw a box, and then specify the location and size of the box. The software will then construct a perfect box, with the right dimensions and at the right location. Another example is that Sutherland’s software modelled objects - not just a picture of objects. In other words, with a model of a car, one could change the size of the tires without affecting the rest of the car. It could stretch the body of the car without deforming the tires.

Further 1961 Developments

Also in 1961 another student at MIT, Steve Russell, created the first video game, Spacewar. Written for the DEC PDP-1,
Spacewar was an instant success and copies started flowing to other PDP-1 owners and eventually even DEC got a copy. The engineers at DEC used it as a diagnostic Programme on every new PDP-1 before shipping it. The sales force picked up on this quickly enough and when installing new units, would run the world’s first video game for their new customers.

E. E. Zajac, a scientist at Bell Telephone Laboratory (BTL), created a film called “Simulation of a two-gyro gravity attitude control system” in 1963. In this computer generated film, Zajac showed how the attitude of a satellite could be altered as it orbits the Earth. He created the animation on an IBM 7090 mainframe computer. Also at BTL, Ken Knowlton, Frank Sindon and Michael Noll started working in the computer graphics field. Sindon created a film called Force, Mass and Motion illustrating Newton’s laws of motion in operation. Around the same time, other scientists were creating computer graphics to illustrate their research. At Lawrence Radiation Laboratory, Nelson Max created the films, “Flow of a Viscous Fluid” and “Propagation of Shock Waves in a Solid Form.” Boeing Aircraft created a film called “Vibration of an Aircraft.”

It was not long before major corporations started taking an interest in computer graphics. TRW, Lockheed-Georgia, General Electric and Sperry Rand are among the many companies that were getting started in computer graphics by the mid-1960s. IBM was quick to respond to this interest by releasing the IBM 2250 graphics terminal, the first commercially available graphics computer.

Ralph Baer, a supervising engineer at Sanders Associates, came up with a home video game in 1966 that was later licensed to Magnavox and called the Odyssey. While very simplistic, and requiring fairly inexpensive electronic parts, it allowed the player to move points of light around on a screen. It was the first consumer computer graphics product.

David C. Evans was director of engineering at Bendix Corporation’s computer division from 1953 to 1962, after which
he worked for the next five years as a visiting professor at Berkeley. There he continued his interest in computers and how they interfaced with people. In 1966, the University of Utah recruited Evans to form a computer science programme, and computer graphics quickly became his primary interest. This new department would become the world’s primary research centre for computer graphics.

Also in 1966, Sutherland at MIT invented the first computer controlled head-mounted display (HMD). Called the Sword of Damocles because of the hardware required for support, it displayed two separate wireframe images, one for each eye. This allowed the viewer to see the computer scene in stereoscopic 3D. After receiving his Ph.D. from MIT, Sutherland became Director of Information Processing at ARPA (Advanced Research Projects Agency), and later became a professor at Harvard. In 1967 Sutherland was recruited by Evans to join the computer science programme at the University of Utah. There he perfected his HMD. Twenty years later, NASA would re-discover his techniques in their virtual reality research. At Utah, Sutherland and Evans were highly sought after consultants by large companies but they were frustrated at the lack of graphics hardware available at the time so they started formulating a plan to start their own company.

In 1969, the ACM initiated A Special Interest Group in Graphics (SIGGRAPH) which organizes conferences, graphics standards, and publications within the field of computer graphics. In 1973, the first annual SIGGRAPH conference was held, which has become one of the focuses of the organization. SIGGRAPH has grown in size and importance as the field of computer graphics has expanded over time.

1970s

Many of the most important early breakthroughs in computer graphics research occurred at the University of Utah in the 1970s. A student by the name of Edwin Catmull started at the University of Utah in 1970 and signed up for Sutherland’s computer graphics
class. Catmull had just come from The Boeing Company and had been working on his degree in physics. Growing up on Disney, Catmull loved animation yet quickly discovered that he did not have the talent for drawing. Now Catmull (along with many others) saw computers as the natural progression of animation and they wanted to be part of the revolution. The first animation that Catmull saw was his own. He created an animation of his hand opening and closing. It became one of his goals to produce a feature length motion picture using computer graphics. In the same class, Fred Parke created an animation of his wife’s face. Because of Evan’s and Sutherland’s presence, UU was gaining quite a reputation as the place to be for computer graphics research so Catmull went there to learn 3D animation.

As the UU computer graphics laboratory was attracting people from all over, John Warnock was one of those early pioneers; he would later found Adobe Systems and create a revolution in the publishing world with his PostScript page description language. Tom Stockham led the image processing group at UU which worked closely with the computer graphics lab. Jim Clark was also there; he would later found Silicon Graphics, Inc.

The first major advance in 3D computer graphics was created at UU by these early pioneers, the hidden-surface algorithm. In order to draw a representation of a 3D object on the screen, the computer must determine which surfaces are “behind” the object from the viewer’s perspective, and thus should be “hidden” when the computer creates (or renders) the image.

The 3D Core Graphics System (or Core) was the first graphical standard to be developed. A group of 25 experts of the ACM Special Interest Group SIGGRAPH developed this “conceptual framework”. The specifications were published in 1977, and it became a foundation for many future development in the field.

1980s

In the early 1980s, the availability of bit-slice and 16-bit microprocessors started to revolutionise high resolution computer
graphics terminals which now increasingly became intelligent, semi-standalone and standalone workstations. Graphics and application processing were increasingly migrated to the intelligence in the workstation, rather than continuing to rely on central mainframe and mini-computers.

Typical of the early move to high resolution computer graphics intelligent workstations for the computer-aided engineering market were the Orca 1000, 2000 and 3000 workstations, developed by Orcatech of Ottawa, a spin-off from Bell-Northern Research, and led by an early workstation pioneer David John Pearson. The Orca 3000 was based on Motorola 68000 and AMD bit-slice processors and had Unix as its operating system. It was targeted squarely at the sophisticated end of the design engineering sector. Artists and graphic designers began to see the personal computer, particularly the Commodore Amiga and Macintosh, as a serious design tool, one that could save time and draw more accurately than other methods. In the late 1980s, SGI computers were used to create some of the first fully computer-generated short films at Pixar. The Macintosh remains a highly popular tool for computer graphics among graphic design studios and businesses. Modern computers, dating from the 1980s often use graphical user interfaces (GUI) to present data and information with symbols, icons and pictures, rather than text. Graphics are one of the five key elements of multimedia technology.

1990s

3D graphics became more popular in the 1990s in gaming, multimedia and animation. At the end of the 80s and beginning of the nineties were created, in France, the very first computer graphics TV series: “La Vie des bêtes” by studio Mac Guff Ligne, Les Fables Géométriques J.-Y. Grall, Georges Lacroix and Renato and Quarxs, the first HDTV computer graphics series by Maurice Benayoun and François Schuiten. In 1995, Toy Story, the first full-length computer-generated animation film, was released in cinemas worldwide. In 1996, Quake, one of the first fully 3D games, was
released. Since, then, computer graphics have only become more detailed and realistic, due to more powerful graphics hardware and 3D modelling software.

IMAGE TYPES

Two-dimensional

2D computer graphics are the computer-based generation of digital images—mostly from two-dimensional models, such as 2D geometric models, text, and digital images, and by techniques specific to them.

2D computer graphics are mainly used in applications that were originally developed upon traditional printing and drawing technologies, such as typography, cartography, technical drawing, advertising, etc.. In those applications, the two-dimensional image is not just a representation of a real-world object, but an independent artifact with added semantic value; two-dimensional models are therefore preferred, because they give more direct control of the image than 3D computer graphics, whose approach is more akin to photography than to typography.

Pixel Art

Pixel art is a form of digital art, created through the use of raster graphics software, where images are edited on the pixel level. Graphics in most old (or relatively limited) computer and video games, graphing calculator games, and many mobile phone games are mostly pixel art.

Vector Graphics

Vector graphics formats are complementary to raster graphics. Raster graphics is the representation of images as an array of pixels and is typically used for the representation of photographic images. Vector graphics consists in encoding information about shapes and colours that comprise the image, which can allow for more flexibility in rendering. There are instances when working with vector tools and formats is best practice, and instances when
working with raster tools and formats is best practice. There are times when both formats come together. An understanding of the advantages and limitations of each technology and the relationship between them is most likely to result in efficient and effective use of tools.

Three-dimensional

3D computer graphics in contrast to 2D computer graphics are graphics that use a three-dimensional representation of geometric data that is stored in the computer for the purposes of performing calculations and rendering 2D images. Such images may be for later display or for real-time viewing.

Despite these differences, 3D computer graphics rely on many of the same algorithms as 2D computer vector graphics in the wire frame model and 2D computer raster graphics in the final rendered display. In computer graphics software, the distinction between 2D and 3D is occasionally blurred; 2D applications may use 3D techniques to achieve effects such as lighting, and primarily 3D may use 2D rendering techniques.

3D computer graphics are often referred to as 3D models. Apart from the rendered graphic, the model is contained within the graphical data file. However, there are differences. A 3D model is the mathematical representation of any three-dimensional object. A model is not technically a graphic until it is visually displayed. Due to 3D printing, 3D models are not confined to virtual space. A model can be displayed visually as a two-dimensional image through a process called 3D rendering, or used in non-graphical computer simulations and calculations. There are some 3D computer graphics software for users to create 3D images.

COMPUTER ANIMATION TECHNOLOGY

Just what is computer animation? For decades, animation has been a trade that rested solely in the hands of the entertainment industry; the process required a great deal of time, manpower, and complex equipment to accomplish. However, with the ever-
growing movement to computerize the industry, the animation process has become progressively simpler. What was once done with pencils, cells, and paint by a team of dozens of animators can now be accomplished by a single person with a powerful enough home computer and the right software.

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 screen 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 with television and motion pictures.

For 3D animations, objects (models) are built on the computer monitor (modelled) 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 on key 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 modelling 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.

Methods of Animating Virtual Characters

In most 3D computer animation systems, an animator creates a simplified representation of a character’s anatomy, analogous to a skeleton or stick. The position of each segment of the skeletal model is defined by animation variables, or Avars. In human and animal characters, many parts of the skeletal model correspond to actual bones, but skeletal animation is also used to animate other things, such as facial features (though other methods for facial animation exist). The character “Woody” in Toy Story, for example, uses 700 Avars, including 100 Avars in the face. The computer does not usually render the skeletal model directly (it is invisible), but uses the skeletal model to compute the exact position and orientation of the character, which is eventually rendered into an image. Thus by changing the values of Avars over time, the animator creates motion by making the character move from frame to frame.

There are several methods for generating the Avar values to obtain realistic motion. Traditionally, animators manipulate the Avars directly. Rather than set Avars for every frame, they usually set Avars at strategic points (frames) in time and let the computer interpolate or ‘tween’ between them, a process called keyframing. Keyframing puts control in the hands of the animator, and has roots in hand-drawn traditional animation. In contrast, a newer method called motion capture makes use of live action. When
computer animation is driven by motion capture, a real performer acts out the scene as if they were the character to be animated. His or her motion is recorded to a computer using video cameras and markers, and that performance is then applied to the animated character.

Each method has its advantages, and as of 2007, games and films are using either or both of these methods in productions. Keyframe animation can produce motions that would be difficult or impossible to act out, while motion capture can reproduce the subtleties of a particular actor. For example, in the 2006 film Pirates of the Caribbean: Dead Man’s Chest, actor Bill Nighy provided the performance for the character Davy Jones. Even though Nighy himself doesn’t appear in the film, the movie benefited from his performance by recording the nuances of his body language, posture, facial expressions, etc. Thus motion capture is appropriate in situations where believable, realistic behaviour and action is required, but the types of characters required exceed what can be done through conventional costuming.

Creating Characters and Objects on a Computer

3D computer animation combines 3D models of objects and programmed or hand “keyframed” movement. Models are constructed out of geometrical vertices, faces, and edges in a 3D coordinate system. Objects are sculpted much like real clay or plaster, working from general forms to specific details with various sculpting tools. A bone/joint animation system is set up to deform the CGI model (e.g. to make a humanoid model walk). In a process called rigging, the virtual marionette is given various controllers and handles for controlling movement. Animation data can be created using motion capture, or keyframing by a human animator, or a combination of the two.

3D models rigged for animation may contain thousands of control points - for example, the character “Woody” in Pixar’s movieToy Story, uses 700 specialized animation controllers. Rhythm and Hues Studios laboured for two years to create Aslan in the
movie *The Chronicles of Narnia: The Lion, the Witch and the Wardrobe* which had about 1851 controllers, 742 in just the face alone. In the 2004 film *The Day After Tomorrow*, designers had to design forces of extreme weather with the help of video references and accurate meteorological facts. For the 2005 remake of *King Kong*, actor Andy Serkis was used to help designers pinpoint the gorilla’s prime location in the shots and used his expressions to model “human” characteristics onto the creature. Serkis had earlier provided the voice and performance for Gollum in J. R. R. Tolkien’s *The Lord of the Rings* trilogy.

### Computer Animation Development Equipment

Computer animation can be created with a computer and animation software. Some impressive animation can be achieved even with basic Programmes; however, the rendering can take a lot of time on an ordinary home computer. Because of this, video game animators tend to use low resolution, low polygon count renders, such that the graphics can be rendered in real time on a home computer. Photorealistic animation would be impractical in this context. Professional animators of movies, television, and video sequences on computer games make photorealistic animation with high detail. This level of quality for movie animation would take tens to hundreds of years to create on a home computer. Many powerful workstation computers are used instead. Graphics workstation computers use two to four processors, and thus are a lot more powerful than a home computer, and are specialized for rendering. A large number of workstations (known as a render farm) are networked together to effectively act as a giant computer. The result is a computer-animated movie that can be completed in about one to five years (this process is not comprised solely of rendering, however). A workstation typically costs $2,000 to $16,000, with the more expensive stations being able to render much faster, due to the more technologically advanced hardware that they contain. Professionals also use digital movie cameras, motion capture or performance capture, bluescreens, film editing software, props, and other tools for movie animation.
MODELLING HUMAN FACES

The realistic modelling of human facial features is both one of the most challenging and sought after elements in computer-generated imagery. Computer facial animation is a highly complex field where models typically include a very large number of animation variables. Historically speaking, the first SIGGRAPH tutorials on *State of the art in Facial Animation* in 1989 and 1990 proved to be a turning point in the field by bringing together and consolidating multiple research elements, and sparked interest among a number of researchers.

The Facial Action Coding System (with 46 action units such as “lip bite” or “squint”) which had been developed in 1976 became a popular basis for many systems. As early as 2001 MPEG-4 included 68 facial animation parameters for lips, jaws, etc. and the field has made significant progress since then and the use of facial microexpression has increased.

In some cases, an affective space such as the PAD emotional state model can be used to assign specific emotions to the faces of avatars. In this approach the PAD model is used as a high level emotional space, and the lower level space is the MPEG-4 Facial Animation Parameters (FAP). A mid-level Partial Expression Parameters (PEP) space is then used to in a two level structure: the PAD-PEP mapping and the PEP-FAP translation model.

REALISM IN THE FUTURE OF COMPUTER ANIMATION

Realism in computer animation can mean making each frame look photorealistic, in the sense that the scene is rendered to resemble a photograph, or to making the animation of characters believable and life-like. This section focuses on the second definition. Computer animation can be realistic with or without photorealistic rendering.

One of the greatest challenges in computer animation has been creating human characters that look and move with the
highest degree of realism. Many animated films instead feature characters that are anthropomorphic animals (*Finding Nemo*, *Ice Age*, *Over the Hedge*), machines (*Cars*, *WALL-E*, *Robots*), fantasy creatures (*Monsters Inc.*, *Shrek*, *TMNT*), or humans with nonrealistic, cartoon-like proportions (*The Incredibles*, *Despicable Me*, *Up*).

Part of the difficulty in making pleasing, realistic human characters is the uncanny valley: a concept where, up to a point, people have an increasingly negative emotional response as a human replica looks and acts more and more human. Also, some materials that commonly appear in a scene like cloth, foliage, fluids, and hair have proven more difficult to faithfully recreate and animate than others. Consequently, special software and techniques have been developed to better simulate these specific elements.

In theory, realistic computer animation can reach a point where it is indistinguishable from real action captured on film. Where computer animation achieves this level of realism, it may have major repercussions for the film industry.

The goal of computer animation is not always to emulate live action as closely as possible. Computer animation can also be tailored to mimic or substitute for other types of animation, such as traditional stop motion animation (*Flushed Away*).

Some of the long-standing basic principles of animation, like squash and stretch, call for movement that is not strictly realistic, and such principles still see widespread application in computer animation.

**Media Notable for Realistic Human Characters**

- *Final Fantasy: The Spirits Within*: Often cited as the first computer-generated movie to attempt to show realistic-looking humans
- *The Polar Express*
- *Mars Needs Moms*
- *L.A. Noire*: Received attention for its use of MotionScan technology.
Movies

CGI short films have been produced as independent animation since, 1976, though the popularity of computer animation (especially in the field of special effects) skyrocketed during the modern era of U.S., animation. The first completely computer-generated television series was ReBoot, in 1994, and the first completely computer-generated animated movie was Toy Story.

AMATEUR ANIMATION

The popularity of websites that allow members to upload their own movies for others to view has created a growing community of amateur computer animators. With utilities and Programmes often included free with modern operating systems, many users can make their own animated movies and shorts. Several free and open source animation software applications exist as well. A popular amateur approach to animation is via the animated GIF format, which can be uploaded and seen on the web easily.

Detailed Examples and Pseudocode

In 2D computer animation, moving objects are often referred to as “sprites.” A sprite is an image that has a location associated with it. The location of the sprite is changed slightly, between each displayed frame, to make the sprite appear to move.

The following pseudocode makes a sprite move from left to right:

```plaintext
var int x := 0, y := screenHeight / 2;
while x < screenWidth
  drawBackground()
  drawSpriteAtXY (x, y) // draw on top of the background
  x := x + 5 // move to the right
```

Computer animation uses different techniques to produce animations. Most frequently, sophisticated mathematics is used to manipulate complex three dimensional polygons, apply “textures”,

lighting and other effects to the polygons and finally rendering the complete image.

A sophisticated graphical user interface may be used to create the animation and arrange its choreography. Another technique called constructive solid geometry defines objects by conducting boolean operations on regular shapes, and has the advantage that animations may be accurately produced at any resolution.

Let’s step through the rendering of a simple image of a room with flat wood walls with a grey pyramid in the centre of the room. The pyramid will have a spotlight shining on it. Each wall, the floor and the ceiling is a simple polygon, in this case, a rectangle. Each corner of the rectangles is defined by three values referred to as X, Y and Z. X is how far left and right the point is. Y is how far up and down the point is, and Z is far in and out of the screen the point is. The wall nearest us would be defined by four points: (in the order x, y, z). Below is a representation of how the wall is defined

(0, 10, 0) (10, 10, 0)
(0,0,0) (10, 0, 0)

The far wall would be:
(0, 10, 20) (10, 10, 20)
(0, 0, 20) (10, 0, 20)

The pyramid is made up of five polygons: the rectangular base, and four triangular sides. To draw this image the computer uses math to calculate how to project this image, defined by three dimensional data, onto a two dimensional computer screen.

First we must also define where our view point is, that is, from what vantage point will the scene be drawn. Our view point is inside the room a bit above the floor, directly in front of the pyramid. First the computer will calculate which polygons are visible. The near wall will not be displayed at all, as it is behind our view point. The far side of the pyramid will also not be drawn as it is hidden by the front of the pyramid.
Next each point is perspective projected onto the screen. The portions of the walls ‘furthest’ from the view point will appear to be shorter than the nearer areas due to perspective. To make the walls look like wood, a wood pattern, called a texture, will be drawn on them. To accomplish this, a technique called “texture mapping” is often used. A small drawing of wood that can be repeatedly drawn in a matching tiled pattern (like desktop wallpaper) is stretched and drawn onto the walls’ final shape. The pyramid is solid grey so its surfaces can just be rendered as grey. But we also have a spotlight. Where its light falls we lighten colours, where objects blocks the light we darken colours.

Next we render the complete scene on the computer screen. If the numbers describing the position of the pyramid were changed and this process repeated, the pyramid would appear to move.

GRAPHIC ANIMATION

Graphic animation is a variation of stop motion (and possibly more conceptually associated with traditional flat cel animation and paper drawing animation, but still technically qualifying as stop motion) consisting of the animation of photographs (in whole or in parts) and other non-drawn flat visual graphic material, such as newspaper and magazine clippings.

In its simpliest form, Graphic “animation” can take the form of the animation camera merely panning up and down and/or across individual photographs, one at a time, (filmed frame-by-frame, and hence, “animated”) without changing the photographs from frame to frame, as on Ken Burns various historical documentary films for PBS. But once the photos (or “graphics”) are also moved from frame to frame, more exciting montages of movement can be produced, such as on Los Angeles animator Mike Jittlov’s 1977 short film, Animato, also seen his feature film, The Wizard of Speed and Time, released to theaters in 1987 and to video in 1989. Graphic animation can be (and often is) combined with other forms of animation including direct manipulation animation and traditional cel animation.
Examples are Frank Mouris’ 1973 Oscar-winning short film *Frank Film*, and Charles Braverman’s *Condensed Cream of the Beatles* (1973), originally produced for Geraldo Rivera’s late night TV show of the time, *Goodbye America*. Graphic animation was also used as a History of Playboy Magazine piece used on *Saturday Night Live* when the magazine’s founder, Hugh Hefner, appeared on that show during the late 1970s or early 1980s.

**PIXILATION**

Pixilation (from *pixilated*) is a stop motion technique where live actors are used as a frame-by-frame subject in an animated film, by repeatedly posing while one or more frame is taken and changing pose slightly before the next frame or frames. The actor becomes a kind of living stop motion puppet. This technique is often used as a way to blend live actors with animated ones in a movie, such as in *The Secret Adventures of Tom Thumb* by the Bolex Brothers.

Early examples of this technique are *El hotel eléctrico* from 1908 and Émile Cohl’s 1911 movie *Jobard ne peut pas voir les femmes travailler*.

The term is widely credited to Grant Munro. He made an experimental movie named “Pixillation”, available in his DVD collection “Cut Up – The Films of Grant Munro”.

**Movies**

- Numerous Jan Švankmajer movies, but most notably *Food* (1992) and large sections of *Conspirators of Pleasure* (1996).
- Bolex Brothers’ *The Secret Adventures of Tom Thumb*
- Norman McLaren’s *A Chairy Tale* and Oscar-winner *Neighbours*
- Mike Jittlov’s short *The Wizard of Speed and Time*. Jittlov made a feature film with many pixilation sequences, also
titled *The Wizard of Speed and Time*, based on the making of the original short.

- Paul Cummings' and Tony Fiandaca's *Tony vs. Paul*
- What Cassandra Saw short listed for Virgin Media Shorts by Littlenobody
- Jan Kounen’s Gisele Kerozene
- Michael Langan’s *Doxology* (2007)
- *Monsieur Pointu* (1975)
- *Western Spaghetti* and the Academy Award-nominated *Fresh Guacamole* by PES utilize pixilation.
- Joe & Giles’s *Two Gentlemen of Honour* (2012)
- Jared Goldberg’s *Mister G Meets the Biker Babes* (2012)

**Television shows**

- *Angry Kid*
- *Sesame Street* (*Milo Counting, Ordering a Pizza, George the Farmer*)
- *The Goodies*

**Music videos**

- “Consolation Prizes” by Phoenix
- “Long Gone” by Fat City Reprise
- “Heard ‘Em Say” by Kanye West
- “Her Morning Elegance” by Oren Lavie
- “Hello Again” by The Cars
- “In your arms” by Kina Grannis
- “Paralyzed” by The Used
- “Point of No Return” by Nu Shooz
- “Road to Nowhere” by Talking Heads
- “Sledgehammer” by Peter Gabriel
- “Shopping Trolley” by Beth Orton
- “The Box” by Orbital
- “The End of the World” by The Cure
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“The Hardest Button to Button” by The White Stripes
“There There” by Radiohead
“Time Won’t Let Me Go” by The Bravery
“Vermilion” by Slipknot
“Sex Machine” by The Fat Boys
“Last Dance” by George Clinton
“Strawberry Swing” by Coldplay
“Every Teardrop Is A Waterfall” by Coldplay
“Fix” by Jean-Paul De Roover
“Les tartines” by Sttellla
“Now You See Her” by Crash Test Dummies
“Be Near Me” by ABC
“Ma Che Discorsi” by Daniele Silvestri
“End Love” by OK Go
“Lame Claim to Fame” by “Weird Al” Yankovic

Quebec band Les Colocs and Michel Gondry used pixilation in many of their music videos. The pixilation technique was also used for the opening of Claymation, Will Vinton’s 1978, 17-minute documentary about his animation studio’s production techniques, the first time the famous trademarked Claymation term was used, now a term synonymous with all clay animation.

The Czech animator Jan Švankmajer uses pixilation in most of his work; most notably Food. Jan Kounen’s Gisele Kerozene (1989), a short film that shows witches riding around a city on broomsticks, is another influential example of this technique. A recent example of the technique is the Stephen Malkmus’ video clip “Baby C’mon”. Pixilation is also used in Andrew Huang’s short video Fluxis. An effect similar to pixilation can be achieved by dropping occasional frames from a conventionally recorded movie. While obviously easier than the stop-frame technique, this does not achieve the same quality.
MULTIMEDIA

Multimedia is media and content that uses a combination of different content forms. The term can be used as a noun (a medium with multiple content forms) or as an adjective describing a medium as having multiple content forms. The term is used in contrast to media which use only rudimentary computer display such as text-only, or traditional forms of printed or hand-produced material. Multimedia includes a combination of text, audio, still images, animation, video, or interactivity content forms.

Multimedia is usually recorded and played, displayed or accessed by information content processing devices, such as computerized and electronic devices, but can also be part of a live performance. Multimedia (as an adjective) also describes electronic media devices used to store and experience multimedia content. Multimedia is distinguished from mixed media in fine art; by including audio, for example, it has a broader scope. The term “rich media” is synonymous for interactive multimedia. Hypermedia can be considered one particular multimedia application.

CATEGORIZATION OF MULTIMEDIA

Multimedia may be broadly divided into linear and non-
linear categories. Linear active content progresses often without any navigational control for the viewer such as a cinema presentation. Non—linear uses interactivity to control progress as with a video game or self-paced computer based training. Hypermedia is an example of non-linear content.

Multimedia presentations can be live or recorded. A recorded presentation may allow interactivity via a navigation system. A live multimedia presentation may allow interactivity via an interaction with the presenter or performer.

**Major Characteristics of Multimedia**

Multimedia presentations may be viewed by person on stage, projected, transmitted, or played locally with a media player. A broadcast may be a live or recorded multimedia presentation. Broadcasts and recordings can be either analog or digital electronic media technology. Digital online multimedia may be downloaded or streamed. Streaming multimedia may be live or on-demand.

Multimedia games and simulations may be used in a physical environment with special effects, with multiple users in an online network, or locally with an offline computer, game system, or simulator.

The various formats of technological or digital multimedia may be intended to enhance the users' experience, for example to make it easier and faster to convey information. Or in entertainment or art, to transcend everyday experience.

Enhanced levels of interactivity are made possible by combining multiple forms of media content. Online multimedia is increasingly becoming object-oriented and data-driven, enabling applications with collaborative end-user innovation and personalization on multiple forms of content over time. Examples of these range from multiple forms of content on Web sites like photo galleries with both images (pictures) and title (text) user-updated, to simulations whose co-efficients, events, illustrations, animations or videos are modifiable, allowing the multimedia "experience" to be altered without reprogramming. In addition to
seeing and hearing, Haptic technology enables virtual objects to be felt. Emerging technology involving illusions of taste and smell may also enhance the multimedia experience.

**Virtual Reality**

Virtual reality is an artificial environment that is created with software and presented to the user in such a way that the user suspends belief and accepts it as a real environment. On a computer, virtual reality is primarily experienced through two of the five senses: sight and sound.

The simplest form of virtual reality is a 3D image that can be explored interactively at a personal computer, usually by manipulating keys or the mouse so that the content of the image moves in some direction or zooms in or out. More sophisticated efforts involve such approaches as wraparound display screens, actual rooms augmented with wearable computers, and haptics devices that let you feel the display images. Virtual reality is often used to describe a wide variety of applications commonly associated with immersive, highly visual, 3D environments. The development of CAD software, graphics hardware acceleration, head mounted displays, database gloves, and miniaturization have helped popularize the notion. In the book *The Metaphysics of Virtual Reality* by Michael R. Heim, seven different concepts of virtual reality are identified: simulation, interaction, artificiality, immersion, telepresence, full-body immersion, and network communication. People often identify VR with head mounted displays and data suits.

*Virtual reality can be divided into:*

- The simulation of a real environment for training and education.
- The development of an imagined environment for a game or interactive story.

Popular products for creating virtual reality effects on personal computers include Bryce, Extreme 3D, Ray Dream Studio, trueSpace, 3D Studio MAX, and Visual Reality. The Virtual Reality
Modelling Language (VRML) allows the creator to specify images and the rules for their display and interaction using textual language statements.

Virtual reality can trace its roots to the 1860s, when 360-degree art through panoramic murals began to appear. An example of this would be Baldassare Peruzzi’s piece titled, Sala delle Prospettive. In the 1920s, vehicle simulators were introduced. Morton Heilig wrote in the 1950s of an “Experience Theatre” that could encompass all the senses in an effective manner, thus drawing the viewer into the onscreen activity. He built a prototype of his vision dubbed the Sensorama in 1962, along with five short films to be displayed in it while engaging multiple senses (sight, sound, smell, and touch). Predating digital computing, the Sensorama was a mechanical device, which reportedly still functions today. Around this time, Douglas Englebart uses computer screens as both input and output devices. In 1966, Thomas A. Furness III introduces a visual flight stimulator for the Air Force. In 1968, Ivan Sutherland, with the help of his student Bob Sproull, created what is widely considered to be the first virtual reality and augmented reality (AR) head mounted display (HMD) system. It was primitive both in terms of user interface and realism, and the HMD to be worn by the user was so heavy it had to be suspended from the ceiling. The graphics comprising the virtual environment were simple wireframe model rooms. The formidable appearance of the device inspired its name, The Sword of Damocles. Also notable among the earlier hypermedia and virtual reality systems was the Aspen Movie Map, which was created at MIT in 1977. The Programme was a crude virtual simulation of Aspen, Colorado in which users could wander the streets in one of three modes: summer, winter, and polygons. The first two were based on photographs—the researchers actually photographed every possible movement through the city’s street grid in both seasons—and the third was a basic 3D model of the city. In the late 1980s, the term “virtual reality” was popularized by Jaron Lanier, one of the modern pioneers of the field. Lanier had founded the company VPL.
Research in 1985, which developed and built some of the seminal “goggles and gloves” systems of that decade. In 1991, Antonio Medina, a MIT graduate and NASA scientist, designed a virtual reality system to “drive” Mars rovers from Earth in apparent real time despite the substantial delay of Mars-Earth-Mars signals. The system, termed “Computer-Simulated Teleoperation” as published by Rand, is an extension of virtual reality.

**Impact**

There has been an increase in interest in the potential social impact of new technologies, such as virtual reality. In the new book (2011) *Infinite Reality: Avatars, Eternal Life, New Worlds, and the Dawn of the Virtual Revolution*, Blascovich and Bailenson review the literature on the psychology and sociology behind life in virtual reality. In addition, Mychilo S. Cline, in his book *Power, Madness, and Immortality: The Future of Virtual Reality*, argues that virtual reality will lead to a number of important changes in human life and activity.

*He argues that:*

- Virtual reality will be integrated into daily life and activity, and will be used in various human ways. Another such speculation has been written up on how to reach ultimate happiness via virtual reality.
- Techniques will be developed to influence human behaviour, interpersonal communication, and cognition.
- As we spend more and more time in virtual space, there will be a gradual “migration to virtual space”, resulting in important changes in economics, worldview, and culture.

**Haptic Interfaces and Devices**

Before the widespread use of computers in the work place, almost all human tasks involved the use of exquisite sensory-motor skills. By and large, computer interfaces have not taken great advantage of these fundamental human capabilities. With the exception of input devices such as the mouse, computer interaction relies on skills similar to those needed for using
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typewriters. Haptic interfaces may be viewed as an approach to address this limitation. It is thus possible to classify haptics in the area of computer-human interfaces. Unlike traditional interfaces that provide visual and auditory information, haptic interfaces generate mechanical signals that stimulate human kinesthetic and touch channels. Haptic interfaces also provide humans with the means to act on their environment. We can therefore attempt to define haptic interfaces as being concerned with the association of gesture to touch and kinesthesia to provide for communication between the humans and machines.

The field is inherently multidisciplinary and borrows from many areas, including robotics, experimental psychology, biology, computer science, systems and control, and others.

The Field of haptics is also growing rapidly. At present, the number of published papers with the word “haptic” in them approaches a thousand a year, all disciplines included. Just 10 years back, there were only a few dozens.

The word haptics refers to the capability to sense a natural or synthetic mechanical environment through touch. Haptics also includes kinesthesia (or proprioception), the ability to perceive one’s body position, movement and weight.

It has become common to speak of the “haptic channel” to collectively designate the sensory and motor components of haptics. This is because certain anatomical parts (in particular the hand) are unitary organs in which perceiving the world and acting upon it are activities that take place together.

For example, grasping an unfamiliar object also involves exploring it actively with our hands.

Tactile and kinesthetic channels work together to provide humans with means to perceive and act on their environment.

The Function of Haptic Interfaces

The idea of using touch as a means of communication was popularized by Craig and Rollman (1999) and Sherrick (1985):
Our understanding of how simple patterns combine to yield the complexity needed to increase channel capacity for continuous information streams is still primitive.

It certainly still is the case today. It is possible to discuss the function of a haptic interface by considering, on the one hand, an input device such as a computer mouse, and on the other hand a sheet of paper, viewed as a display device. Consider first, a blank sheet of paper: it contains little information (barring being a sheet of paper). The sheet is intended to support the information coded in the form of structure and discontinuities laid out on it by means of ink to change its respective properties. Next, consider a computer screen with graphics capabilities.

It can be programmed pixel by pixel to display information, also using structured discontinuities. Analogously, a computer mouse (or any other conventional input device) contains little mechanically-encoded information (just a fixed weight, shape, and rubbing properties). It is not programmable.

The step that was made to move from the sheet of paper to the graphics screen is analogous to the step made to move from a computer mouse to a haptic interface. Whereas the graphics screen can change its optical properties under computer control, a haptic device can change its mechanical properties under computer control.

The ability to have programmable mechanical properties provides for a bidirectional exchange of energy, and therefore information, between the user and the outside world.

While the term haptic display is sometimes used, it is probably not the best suited because it emphasizes unidirectional information transfer like that of typical graphic displays (such as cathode ray tubes) and audio systems (like high fidelity music reproduction systems).

This fundamental difference can be understood by considering, in which a regular mouse is compared to a haptically enabled mouse with programmable mechanical properties. The arrows
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represent the direction of information flow. With a typical mouse, this is limited to a unidirectional input from the mouse to the computer. The user of a conventional mouse receives almost no information from its movements, although its friction and inertial properties may assist the user in performing skillful movements. The buttons on it are considerably richer: their mechanical detent and the small acoustical noise they produce inform the user that a discrete-state change has occurred. Nevertheless, the buttons are not programmable.

The haptic mouse, on the other hand, can provide the user with programmable feedback based on the sense of touch, allowing a faster and more intuitive interaction with the machine. In general, haptic interfaces attempt to make the information flow non-zero to the user, as in the example of moving from the blank sheet of paper to the graphics screen. This can be further explained from an information-theoretic viewpoint: consider a channel in which $x$ is the input and $y$ is the output. In a lossless channel, the entropy of $x$ given $y$, $H(x|y)$, is zero: the output uniquely specifies the input. In a useless channel $H(x|y) = H(x)$; the knowledge of the output says nothing about the input, $x$ and $y$ are independent. This is the case of ordinary input devices such as a mouse. They can be moved here and there, but the mechanical signals they produce are unrelated to the state of the machine; they are useless as a channel.

This distinction is also most apparent if one considers that visual, auditory, olfactory and vestibular signals can be recorded and replayed (people watch movies, listen to audio recordings, or have machine-controlled rides in vehicle simulators). On the other hand, recording and replaying kinesthetic and tactile sensations must involve user movement, except possibly for the display of vibro-tactile sensations.

All objects, natural or manufactured, fall into one of the two categories. They are inert or active, roughly speaking, inanimate or animate. Inert objects can only dissipate mechanical energy, while active ones may supply some energy. Thus, there can be two
kinds of haptic devices, conventionally termed passive or active, but they all share the property of being programmable.

Passive devices are often designed to have programmable dissipation, as a function of position or time. To this category belong the devices having controllable brakes. Another category of passive devices consists of those that rely on non-holonomic constraints (constraints involving velocity). Yet another possibility is to modify the elastic behaviour of an element to become harder or softer. The programmability of passive devices comes from the possibility of modifying these constraints under computer control.

As for active devices, the energy exchange between a user and the machine is entirely a function of the feedback control which is applied. Then two categories arise: either the actuators act as a force source (a variable of effort), and position is measured, or the actuators act as a position source and then force is measured. The former case is termed isotonic (force does not change with position) while the latter is called isometric (position does not change with force). Closing the loop around an isotonic device corresponds to specifying an impedance to produce a simulation, and the other case corresponds to an admittance.

It is often desired that active devices be used to reproduce synthetic environments such that these environments are passive, for example to simulate a surgical act. How well this is achieved is, in fact, a particular challenge. Conversely, the ability to create a temporally active simulation can be quite useful to increase the flow of information between the machine and the user. For example, simulating the behaviour of the steering wheel of a race car requires the interaction to be active.

Passive devices cannot create active simulations. Finally, it must be noticed that the possibility exists in unstable interactions with passive environments (a drum roll, for example) if the conditions are such that the user can supply the energy needed to sustain the oscillation. To summarize, regardless of the approach to their design, bi-directionality is the single most distinguishing
feature of haptic interfaces, when compared with other machine interfaces, and this observation explains in part why they create a strong sensation of immediacy. A haptic device must be designed to ‘read and write’ from the human hand (or foot, or other body parts).

This combined read and write property may explain why the first applications of this technology involved fast-paced interactivity. As it turns out, the read part has been extensively explored, and a great many types of devices already exist (knobs, keys, joysticks, pointing devices, etc.). The ‘write’ part is comparatively more difficult to achieve.

More specifically, the function of the haptic interface is to recreate constitutive properties: relationships between variables of flow and effort. Haptic interfaces are concerned with the technical means needed to make use of the extensive and exquisite capabilities of human touch, including proprioception, motor control, etc. To achieve this, they must be programmable devices capable of recreating mechanical phenomena of perceptual relevance and functional importance.

It is also important to recall that haptics, as a technological niche, inherits much from teleoperation, which can be considered as its mother discipline. In a sense, haptics is like teleoperation, but the remote slave system is purely computational, i.e., virtual. The virtual aspect has been helped greatly by the tremendous progress in computing and telecommunications. Plainly speaking, one replaces the teleoperator slave by a computer, thereby creating the possibility of virtuality: the slave and the world are computational, and thereby can be imaginary, or not restricted by normal physical constraints (as a matter of fact, virtual reality simulations rarely are). Driven by this, haptics became an independent technological niche in the past decade.

There is another relationship to robotics. Haptic devices can be regarded as robots, however, as robots having a very special function or task, that of interacting with humans. This occurs mostly through the hand, but also via other anatomical regions,
often, but not always, limbs and extremities. Thus, many robotic problems are relevant to haptic interfaces and *vice-versa*.

**Examples of Applications**

Graphical user interfaces (GUIs) have demonstrated that interactive presentation of data does not have to imitate reality, not even remotely. Being suggestive is what matters the most. Pull-down menus and scrolling slider bars cannot be found anywhere, but on computer screens; real paper file folders are not infinitely recursive, and so on.

The same holds for haptic interfaces. For example, the interaction forces that we experience when moving objects occur when these objects contact one another (except with magnets and inertial effects). With haptics, we can perfectly suggest a relationship between two distinct objects by creating a mutual interaction force, even if they are visually presented as being disconnected. Alternatively, some applications demand a significant amount of fidelity with respect to the actual tasks being recreated.

In other words, haptic interfaces can be designed to provide for a literal reproduction of the phenomena that occur during actual manipulation. This is what is called quest for realism in computer graphics. The training of sensory-motor skills such as surgical ability is one example in which the need for realism exists.

It is useful to keep these distinctions in mind while surveying the applications of haptic devices. An interesting aspect of this technology is that some applications are presently part of the commercial activities, good many of them at the precompetitive stage.

For example, one of the earliest researched application of haptic interfaces was the layering of haptic cues on conventional graphical interfaces. Currently, this has reached the consumer arena.

In the following subsections, applications are surveyed in terms of activity areas. The research is now so intense that only a few references will be included.
Force-reflecting Input Devices for use with Graphical User Interfaces

As mentioned, one of the first researched applications of haptic interfaces was the enhancement of existing graphical user interfaces. Elements of these GUIs (windows, pushbuttons, pull-down menus, words of a text, drawings) can be rendered mechanically. Human factor studies indicate improvements in routine computer interactions in speed, precision, and reduction of fatigue. More specifically, cases that benefit from the enhancement of designation tasks (point and click, dragging, snap-to and so on) include drawing packages, text editors, spreadsheets, hypertext navigation, and operating system interfaces. In the latter case, haptic cues can further be used to represent topological relationships in terms of importance: strength, recency, or urgency. Haptic cues may also be used to provide for interactive annotations. For example, haptic tabs can be inserted for efficient retrieval in large documents and databases by specific users. They can also provide for efficient multi-author document editing.

Games

Modes of interaction and the sense of user immersion are greatly enhanced by applying force feedback to the player. Dexterity games available earlier in fixed form can be made infinitely programmable: placing, balancing, hitting and bouncing.

As well, many opportunities exist for educational games. It is possible to illustrate concepts in dynamics, kinematics, magnetism, waves, flows and many other physical phenomena, or in mathematics and anatomy. Other kinds of games include combinatorial mind games, puzzles, and guess games that include visual and mechanical constraints, as well as most situation games. In the latter case, force feedback is already at the commercial stage, to assist in driving, piloting, exploring, and so on.

Multimedia Publishing

Current multimedia and hypertext applications include text,
sound, images, and video. For lack of appropriate devices so far, haptics has been ignored as a medium of communication. One could envision mechanical documents. For example, a new form of document that would include movement which can be experienced visually (video), auditively (spatialization), and also haptically. This raises the question of authoring tools (such as Immersion Studioe) and their necessity for the design of haptic sensations. Material properties can also be conveyed. A frequently mentioned application of this capability is the creation of online catalogues with haptic feedback. These would however benefit greatly from the development of practical, distributed tactile displays, which are not yet available.

**Scientific Discovery**

Data display was in fact one of the earliest applications of haptics, with the molecule docking project. Other display applications include: multidimensional maps, data mining in geology (or in related, applied fields such as oil and gas prospecting), remote sensing, and the display of fields and flows. An attractive property of haptics is the ability to convey the existence of small details, which typically clutter the graphical presentation of data, while minimizing the need to zoom in and out. Projects exist to use haptics to enhance the human interface of imaging instruments such as scanning, tunnelling, and atomic force microscopes.

**Arts and Creation**

Musicians and visual artists are increasingly using computers. However, creators often prefer to use their hands as directly as possible (as in sketching). Haptic communication with computers opens completely new opportunities.

In music, advances in real-time synthesis tools increase the demand for interactive controllers which are presently mostly confined to the existing MIDI Fixed interfaces. In the graphic arts and design, especially the creation of animation, much activity is under way.
Editing Sounds and Images

Haptics can provide for rapid access, and browsing through sound and video documents for editing, splicing, and mixing.

Vehicle Operation and Control Rooms

In stressful, and fast-paced environments, haptic communication can be used to alleviate visual load. Haptic controllers are already commercially available in cars (iDrivee equipped BMW 7 series and Rolls-Royce Phantom). With a single programmable rotary controller, users can navigate menus, scroll lists, control sliders, etc. by experiencing distinctive haptic sensations for each widget.

In this fashion a single controller serves as the input for a multitude of functions, with the haptic feedback serving to make the interface more intuitive and natural to use. Similarly, applications are ending their way into control rooms (air traffic control, nuclear).

Engineering

In computer-aided design, designers can experience minute details with their hands, such as wanted or unwanted artefacts of a design which are cumbersome to display visually. Simulated structures can be manually tested, assessed and debugged.

Manufacturing

In manufacturing, many opportunities exist. For example, haptics can assist design for assembly, in terms of reducing the need for prototyping, and as well as for rapid prototyping. It is also possible to assess human maintainability of complex systems before they are built. Programming of complex manufacturing devices such as multi-axis, numerically-controlled machines or robots can be facilitated.

Telerobotics and Teleoperation

As commented earlier, teleoperation is the mother discipline. Haptic devices are used in supervisor control modes such as
teleprogramming, predictive displays, etc. Teleoperation systems still have a need for high-quality manual controllers.

**Education and Training**

Dangerous systems or systems with very limited availability (e.g., surgery patients) can be simulated using haptics for training purposes. Surgical training, in particular, is the subject of intense research. Other opportunities include the training of sensory-motor skills in general.

**Rehabilitation**

Applications include the improvement of working conditions for visually impaired people, and better interfaces to alleviate motor system impairment.

**Scientific Study of Touch**

Last but not the least, the availability of haptic devices makes it possible to study the haptic channel in humans (and other species) in exciting and perhaps earlier impossible ways.

Haptic devices allow the creation of special, computer-controlled stimuli which are used in studies that explore the sense of touch functions. This is analogous to the use of programmable sound cards and computer graphics in human hearing and vision studies. In turn, the knowledge gained of the haptic function contributes to the development of new haptic interfaces and applications.

**PRINCIPLE OF OPERATION**

**Tactile Sensations and the Kinesthetic Sense**

In general, tactile sensations include pressure, texture, puncture, thermal properties, softness, wetness, friction-induced phenomena such as slip, adhesion, and micro failures, as well as local features of objects such as shape, edges, embossings and recessed features. In addition, vibrotactile sensations refer to the perception of oscillating objects in contact with the skin. This is
appreciated by attending to the sensations experienced while holding a sheet of paper where the three main functions of touch are used.

The grade and texture of the paper are perceived by gently rubbing it (identify material), and its border is found by exploring the edges (identify shape). Speaking loudly near it causes vibrotactile sensations to be experienced (rapid oscillations). This distinction appears to correspond to specific mechanoreceptors and neural codes.

Several kinds of receptors have been found to mediate tactile sensation in the skin or in the subcutaneous tissues; consequently, it is customary to designate the skin as the seat of this sense (A very large organ, indeed; it covers roughly 2m²; it weighs about 5m²kg, its innervation is up to hundreds of receptors per square centimetre). The biophysical attributes of the skin vary tremendously with the parts of the body it covers. The tactile system occupies a great part of the afferent pathways of the peripheral nervous system, as well as a significant part of the central nervous system.

Proprioceptive, or kinesthetic perception, refers to the awareness of one’s body state, including position, velocity and forces supplied by the muscles through a variety of receptors located in the skin, joints, skeletal muscles, and tendons. Together, proprioception and tactile sensations are fundamental to manipulation and locomotion.

**Human Perception and Haptic Interfaces**

When we watch a high-resolution digital movie, we do not perceive a series of still pictures that are presented in sequence, nor do we apprehend an array of coloured pixels. Instead, we perceive a visual scene that is strikingly close to everyday visual experiences. This is possible because the temporal sensitivity of the human visual system is not sufficient to detect the fast presentation of the movie frames nor it can resolve individual pixels. This is an example of how the architecture and limitations
of a perceptual system can be exploited to build engineering systems that elicit realistic, complex perceptual experiences. Examples of these systems include graphics screens, TV, tape recorders, audio synthesizers, right simulators, and, not surprisingly, haptic interfaces. The sense of touch differs from the visual system in that it requires update rates significantly higher than those needed to display video (1 kHz or more is required to satisfy the signal representation theorem and to minimize interaction delay). The physical interface that enables user-machine interaction can also have a great deal of variability. It is in general very difficult to produce perfectly realistic haptic interaction. Fortunately, even while using an imperfect haptic device, a user quickly adapts to its interference, ignores its imperfections, and naturally associates the device’s mechanical stimulation to everyday experiences such as perceiving surface texture and shape of the objects through touch. Also, when haptic interfaces are combined with graphic displays, the user readily associates adequate haptic stimulation to a graphically displayed object. It is not unusual to perceive the haptic sensations as if they occurred at the graphic display itself. This happens even though what is seen and what is haptically felt may occur in completely different spatial locations (i.e., the haptic interface may be on a table alongside the graphic display where the objects are viewed).

However, if the imperfections in the haptic device are too obtrusive, the sense of haptic realism breaks down. This is analogous to what happens if a movie projector slows down to one frame per second: the movie turns into a series of stills. The quality of the illusory haptic experience as with any other technological devices is a function of the interplay between the user’s perceptual system and the intrinsic technical qualities of the interfaces, such as dynamic range, resolution, and appropriateness of the signals being generated.

Components

A complete haptic interface usually includes one or several electromechanical transducers (sensors and actuators) in contact
with a user in order to apply mechanical signals to distinct areas of the body, and to measure other mechanical signals at the same distinct areas of the body. Whether these signals should refer to forces, displacements, or a combination of these and their time derivatives, is still the object of debate.

Another important part of a complete interface is the computational system driving the transducers. The function of this computational system is to provide haptic rendering capabilities, which are analogous to the visual rendering functions of common graphic systems.

Haptic rendering, however, stresses the bidirectional exchange of information between the interface and the user. The computational task in haptic rendering is to generate signals that are relevant to a particular application. Several approaches exist for creating such haptic feedback. For example, a model may be used to represent an environment, and its equations solved computationally to and forces as a function of displacements and their derivatives (or vice-versa). The model may be developed from First principles, or parameterized to represent only certain desired aspects.

The characteristics of the human haptic system allow in some cases the use of simplified physical models to render haptic objects that compete in realism with actually physical objects. Another possibility is the recording of ground data and replaying it as a function of state variables and/or time. The computational task can range from the light (translation of a GUI into a force Field) to the intractable (for example, objects described by continuum mechanics). So many possibilities exist, that this should be the topic of a separate discussion. This computational task is usually mapped onto a data processing hierarchy consisting of several computing units and communication channels. The engineering problem is to map the computational task onto the computational hierarchy so that no constraint is violated in terms of update rates and data transfer rates. For a recent survey of haptic rendering,
DEVICES: CONCEPTS AND EXAMPLES

We examine a cross-section of the existing devices selected to illustrate the diversity of design niches being explored and the vitality of the activity in this Field (a complete survey would be much too long). We also comment on prominent features of these designs. Specific technical requirements of devices are reviewed in Hayward and Astley.

In this chapter, the description of entire families of haptic devices, completely passive devices, and foot contacting devices, and distributed tactile displays, unfortunately had to be omitted, despite significant activity in all these areas.

Programmable Keyboard

One of the most documented examples of a multiple force-feedback implementation is the Clavier Réactif Modulaire, a project headed by Cadoz, which consists of a piano-like Lorentz-actuated keyboard providing computer-driven force feedback for each of its 16 keys and directed at musical creation research.

Exoskeletons

The exoskeleton devices developed by Bergamasco and co-workers incorporate many observations regarding the human biomechanics. To achieve wearability, the system uses a variety of techniques including motor remotizing, sophisticated cable routing, and friction reduction by feedback. Being worn, the device body interface is partly bracing and partly held. Many other devices have been designed by this laboratory.

Desktop Scale

A six degree of freedom device is the result of the pioneering work of Iwata, who advocated the design of small devices. It adopts a parallel platform design supported by three gear driven five bar linkages. The result is a compact and powerful table top design. The initial design is described by Iwata; several versions have been developed thereafter.
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Grasping

Howe designed a double, two degree of freedom apparatus intended for two-finger grasping studies. It uses direct-driven, parallel linkages resulting in a very wide dynamic range. The user’s fingers interact unilaterally with the device on the inner side of boxes, allowing precision grip.

Point Interaction

The Phantome has become a popular device in research laboratories. There are several variants, but generally a stylus is grasped, or a thimble braces the user’s finger. There are three actuated degrees of freedom and three sensed orientations. A typical configuration has a work volume of 2.7 dm3. A key design aspect is a capstan drivewhich avoids the use of gears and makes it possible to amplify the torque of small DC motors with a concomitant increase of damping and inertia. The initial design is described in Massie and Salisbury and is commercially available.

High Power Devices

Colgate and his group have created number of devices that were used for studies in control. One early design, described in Millman et al., features high power and bandwidth for tool use simulation. This group also investigates a number of designs in the family of passive devices. Other high power devices were developed by Ellis et al. and by Hannaford’s group.

Augmented Mice

An innovative system is described by Akamatsu et al.. It has the general shape and function of a computer mouse, but includes two haptic feedback features. One is an electromagnetic braking system which provides programmable dissipative friction forces, and the other is a transducer to provide vibro-tactile sensations.

Joystick

The force-feedback two degree of freedom joystick described by Adelstein and Rosen is one example of a device designed with
specific performance figures in mind. Many other force-feedback joysticks were designed for various applications.

**Separate Carrier**

Luecke *et al.* describe a design concept whereby individual high-fidelity and direct-driven force feedback devices act on the fingers of the hand and are moved about by a large workspace stiff robotic carrier.

**Horizontal Planar Workspace**

The Pantograph has been made in many variants, which were characterized by simplicity and a uniform peak acceleration ratio contained in a 3 dB band. It has two actuated degrees of freedom in the horizontal plane, provided by a stiff parallel linkage driven without transmission. The finger rests on the interface, resulting in a unilateral interaction. One variant is operated by the thumb and its in the hand. Larger ones have a working area of 1.6 dm2. An industrial version, the PenCat/Proe, has a sensed 2.5 cm vertical movement, passively actuated by an elastic return.

**VRML (VIRTUAL REALITY MODELLING LANGUAGE)**

VRML (Virtual Reality Modelling Language) is a language for describing three-dimensional (3D) image sequences and possible user interactions to go with them. Using VRML, you can build a sequence of visual images into Web settings with which a user can interact by viewing, moving, rotating, and otherwise interacting with an apparently 3D scene. For example, you can view a room and use controls to move the room as you would experience it if you were walking through it in real space.

To view a VRML file, you need a VRML viewer or browser, which can be a plug-in for a Web browser you already have. Among viewers you can download for the Windows platforms are blaxxun’s CC Pro, Platinum’s Cosmo Player, WebFX, WorldView, and Fountain. Whurlwind and Voyager are two viewers for the Mac.
Virtual Reality Modelling Language pronounced as vermal and its started to use in year 1995. Initially, this is also called by a name Virtual Really Markup language. This is a standard language which is used for interactive simulation with in the world wide web. It allows to represent 3-dimensional interactive vector graphics and a “virtual worlds” networked via internet and hyper linked with the world wide web. VRML is text file format Which able to design vertices and edges for 3D polygon with any of the specified colour. It is also used to perform UV mapping which create the 3D models of the 2D image. VRML files are commonly called with a name of “worlds” and have .wrl extension. VRML worlds contain the text format so that it easily compressed by using the gzip and compressed file transfer through internet more quickly.

VRML architecture includes the Input processor, Simulation processor, Rendering Processor and World Database. Input Processor is used to control the input information to the computer e.g., Keyboard, mouse, 3D position trackers and a voice recognition system. Simulation Processor is the heart of Virtual Reality system. It takes the user input along with a number of task that are programmed with it and determine the actions that will take place in the virtual environment. Rendering processor is used to create sensation that are output to the user. World Database is also known as World Description Files. It stores the objects that describe the actions of all those objects. VRML is successfully used in various fields like Entertainment, Medicine, Manufacturing, Education and training. In Entertainment, it is helpful in designing a more attractive and exciting virtual environment. In medicine, used to perform the practice test of surgery, surgery on remote patient and teach new skills in a safe, controlled environment. In manufacturing, used to make a low cost and highly efficient products. In education and training used to driving, flight, ship and tank simulators.

The VRML or Virtual Reality Modelling Language is a modelling language for interactive graphics specification. VRML
was originally known as Virtual Reality Markup Language. As the name implies it was used just like other markup languages to be used among many platform. VRML is platform independent and can be used by downloading the required files. VRML is a graphics modelling and specification language for interactive animations with high originality. VRML is used to specify the graphics properties using VRML file. VRML files are text description of various geometries. It allows web developers to design three dimensional space and objects in full range of effects and properties. VRML is used to provide special texture, lighting effects and animations. This enables the users to feel the virtual reality on the web.

VRML (Virtual Reality Modelling Language) is used to create a virtual world and present it to users via the Internet. It shows a realistic looking virtual world without using a special set of glasses or virtual reality helmet.

VRML uses vector graphics to present a 3D world to users using a 2D screen. As the user chooses to change their vantage point, the world view is recalculated and then presented. VRML (Virtual Reality Modelling Language) stores the vector information for the locations of objects, their edges and vertices. Information about the object such as its colour and texture are also stored in the VRML file, typically with a.wrl extension. When the user moves so that the object is deemed to come into their view, its shape and visual effects are generated.

A wide range of 3D file formats can be converted to VRML. For example, AutoCAD DXF and Autodesk 3D studio files can be converted to VRML (Virtual Reality Modelling Language) files. Converters also exist to turn IGES and Alias wire files into VRML. Users converting files into VRML (Virtual Reality Modelling Language) need to be careful to use binary file conversion. Texture information is kept in an.rgb format when added to the VRML presentation.

VRML (Virtual Reality Modelling Language) has been used in gaming. VRML has been used extensively in academia such as
the display of complex molecules, the demonstration of proposed structures for folding proteins and showing changes to materials over time. VRML has also been used to build interactive engineering models of transportation grids and structural designs.

The two most commonly VRML (Virtual Reality Modelling Language) viewers are Worldview by Intervista and WebSpace by SGI. Cortona3D Viewer is a browser plug-in for Internet Explorer.

**Format**

VRML is a text file format where, e.g. vertices and edges for a 3D polygon can be specified along with the surface colour, UV mapped textures, shininess, transparency, and so on. URLs can be associated with graphical components so that a web browser might fetch a webpage or a new VRML file from the Internet when the user clicks on the specific graphical component. Animations, sounds, lighting, and other aspects of the virtual world can interact with the user or may be triggered by external events such as timers. A special Script Node allows the addition of Programme code (e.g. written in Java or JavaScript (ECMAScript)) to a VRML file. VRML files are commonly called “worlds” and have the *.wrl extension (for example island.wrl). VRML files are in plain text and generally compresses well using gzip which is useful for transferring over the internet more quickly (some gzip compressed files use the *.wrz extension). Many 3D modelling Programmes can save objects and scenes in VRML format.

**MULTIPLEXING THE DISPLAY**

Animation can be used to show multiple information objects in the same space. A typical example is client-side imagemaps with explanations that pop up as the user moves the cursor over the various hypertext anchors.

**Enriching Graphical Representations**

Some types of information are easier to visualize with movement than with still pictures. Consider, for example, how to visualize the tool used to remove pixels in a graphics application.
Visualizing three-dimensional Structures

As you know the computer screen is two-dimensional. Hence users can never get a full understanding of a three-dimensional structure by a single illustration, no matter how well designed. Animation can be used to emphasize the three-dimensional nature of objects and make it easier for users to visualize their spatial structure. The animation need not necessarily spin the object in a full circle - just slowly turning it back and forth a little will often be sufficient. The movement should be slow to allow the user to focus on the structure of the object. You can also move three-dimensional objects, but often it is better if you determine in advance how best to animate a movement that provides optimal understanding of the object. This pre-determined animation can then be activated by simply placing the cursor over the object. On the other hand, user-controlled movements requires the user to understand how to manipulate the object (which is inherently difficult with a two-dimensional control device like the mouse used with most computers - to be honest, 3D is never going to make it big time in user interfaces until we get a true 3D control device).

Attracting Attention

Finally, there are a few cases where the ability of animation to dominate the user’s visual awareness can be turned to an advantage in the interface. If the goal is to draw the user’s attention to a single element out of several or to alert the user to updated information then an animated headline will do the trick. Animated text should be drawn by a one-time animation (e.g., text sliding in from the right, growing from the first character, or smoothly becoming larger) and never by a continuous animation since moving text is more difficult to read than static text. The user should be drawn to the new text by the initial animation and then left in peace to read the text without further distraction. One of the excellent software available to create animation is Animator Pro. This provides tools to create impressive animation for multimedia development.
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Video

Beside animation there is one more media element, which is known as video. With latest technology it is possible to include video impact on clips of any type into any multimedia creation, be it corporate presentation, fashion design, entertainment games, etc.

The video clips may contain some dialogues or sound effects and moving pictures. These video clips can be combined with the audio, text and graphics for multimedia presentation. Incorporation of video in a multimedia package is more important and complicated than other media elements. One can procure video clips from various sources such as existing video films or even can go for an outdoor video shooting.

All the video available are in analog format. To make it usable by computer, the video clips are needed to be converted into computer understandable format, i.e., digital format. Both combinations of software and hardware make it possible to convert the analog video clips into digital format. This alone does not help, as the digitised video clips take lots of hard disk space to store, depending on the frame rate used for digitisation. The computer reads a particular video clip as a series of still pictures called frames. Thus video clip is made of a series of separate frames where each frame is slightly different from the previous one. The computer reads each frame as a bitmap image. Generally there are 15 to 25 frames per second so that the movement is smooth. If we take less frames than this, the movement of the images will not be smooth.

To cut down the space there are several modern technologies in windows environment. Essentially these technologies compress the video image so that lesser space is required.

However, latest video compression software makes it possible to compress the digitised video clips to its maximum. In the process, it takes lesser storage space. One more advantage of using digital video is, the quality of video will not deteriorate from copy to copy.
as the digital video signal is made up of digital code and not electrical signal. Caution should be taken while digitizing the video from analog source to avoid frame droppings and distortion. A good quality video source should be used for digitization.

Currently, video is good for:

- promoting television shows, films, or other non-computer media that traditionally have used trailers in their advertising.
- giving users an impression of a speaker’s personality.
- showing things that move. For example a clip from a motion picture. Product demos of physical products are also well suited for video.

Audio

Audio has a greater role to play in multimedia development. It gives life to the static state of multimedia. Incorporation of audio is one of the most important features of multimedia, which enhance the multimedia usability to its full potential. There are several types of sound, which can be used in multimedia. They are human voices, instrumental notes, natural sound and many more. All these can be used in any combination as long as they give some meaning to their inclusion in multimedia.

- There are many ways in which these sounds can be incorporated into the computer. For example;
  - Using microphone, human voice can directly be recorded in a computer.
  - Pre-recorded cassettes can be used to record the sound into computer.
  - Instrumental sound can also be played directly from a musical instrument for recording into the computer.

The sound transmitted from these sources is of analog nature. To enable the computer to process this sound, they need to be digitised.

As all of us know that sound is a repeated pattern of pressure in the air and a microphone converts a sound wave into an electrical
wave. The clarity of sound, the final output depends entirely on the shape and frequency of the sound wave. When digitised (recording into computer), the error in sound can be drastically reduced. Audio need to be converted into digital format to produce digitised audio in order to use them in multimedia. And these digitised sounds again can be re-converted into analog form so that the user can hear them though the speakers.

Musical Instrument Digitisation Interface or MIDI provides a protocol or a set of rules, using which the details of a musical note from an instrument is communicated to the computer. But MIDI data is not digitized sound. It is directly recorded into the computer from musical instruments, whereas digitised audio is created from the analog sound. The quality of MIDI data depends upon the quality of musical instrument and the sound system. A MIDI file is basically a list command to produce the sound. For example, pressing of a guitar key can be represented as a computer command. When the MIDI device processes this command, the result will be the sound from the guitar. MIDI files occupy lesser space as compared to the digitised audio and they are editable also.

The main benefit of audio is that it provides an exclusive channel that is separate from that of the display. Speech can be used to offer commentary or help without obscuring information on the screen. Audio can also be used to provide a sense of place or mood. Mood-setting audio should employ very quiet background sounds in order not to compete with the main information for the user’s attention. Music is probably the most obvious use of sound. Whenever you need to inform the user about a certain work of music, it makes much more sense to simply play it than to show the notes or to try to describe it in words.

**MULTIMEDIA HARDWARE REQUIREMENTS**

For producing multimedia you need hardware, software and creativity. The multimedia equipment required in a personal computer (PC) so that multimedia can be produced.
Central Processing Unit

As you know, Central Processing Unit (CPU) is an essential part in any computer. It is considered as the brain of computer, where processing and synchronization of all activities takes place. The efficiency of a computer is judged by the speed of the CPU in processing of data. For a multimedia computer a Pentium processor is preferred because of higher efficiency. However, the CPU of multimedia computer should be at least 486 with math coprocessor. The Pentium processor is one step up the evolutionary chain from the 486 series processor and Pentium Pro is one step above the Pentium. And the speed of the processor is measured in megahertz. It defines the number of commands the computer can perform in a second.

The faster the speed, the faster the CPU and the faster the computer will be able to perform. As the multimedia involves more than one medial element, including high-resolution graphics, high quality motion video, and one need a faster processor for better performance.

In today’s scenario, a Pentium processor with MMX technology and a speed of 166 to 200 MHz (Megahertz) is an ideal processor for multimedia. In addition to the processor one will need a minimum 16 MB RAM to run WINDOWS to edit large images or video clips. But a 32 or 64 MB RAM enhances the capacity of multimedia computer.

Monitor

As you know that monitor is used to see the computer output. Generally, it displays 25 rows and 80 columns of text. The text or graphics in a monitor is created as a result of an arrangement of tiny dots, called pixels. Resolution is the amount of details the monitor can render. Resolution is defined in terms of horizontal and vertical pixel (picture elements) displayed on the screen. The greater the number of pixels, better visualization of the image.

Like any other computer device, monitor requires a source of input. The signals that monitor gets from the processor are routed
through a graphics card. But there are computers available where this card is in-built into the motherboard. This card is also called the graphics adapter or display adapter. This card controls the individual pixels or tiny points on a screen that make up image. There are several types of display adapter available. But the most popular one is Super Virtual Graphics Arrays (SVGA) card and it suits the multimedia requirement. The advantage of having a SVGA card is that the quality of graphics and pictures is better.

Now the PCs, which are coming to the market, are fitted with SVGA graphics card. That allows images of up to 1024 × 768 pixels to be displayed in up to 16 millions of colours. What determines the maximum resolution and colour depth is the amount of memory on the display adapters. Often you can select the amount of memory required such as 512KB, 1MB, 2MB, 4MB, etc. However, standard multimedia requirement is a 2MB of display memory (or Video RAM). But one must keep in mind that this increases the speed of the computer, also it allows displaying more colours and more resolutions. One can easily calculate the minimum amount of memory required for display adapter as (Max. Horizontal Resolution × Max. Vertical Resolution × Colour Depths. in Bits) / 8192 = The minimum video (or display) memory required in KB.

For example, if SVGA resolution (800×600) with 65,536 colours (with colour depth of 16) you will need

\[
(800 \times 600 \times 16) / 8192
\]

= 937.5 KB, i.e., approximately 1 MB of display memory.

Another consideration should be the refresh rate, i.e., the number of times the images is painted on the screen per second. More the refresh rate, better the image formation. Often a minimum of 70-72Mhz is used to reduce eye fatigue. As a matter of fact higher resolution requires higher refresh rates to prevent screen flickers.

**Video Grabbing Card**

We need to convert the analog video signal to digital signal for processing in a computer. Normal computer will not be able
to do it alone. It requires special equipment called video grabbing card and software to this conversion process. This card translates the analog signal it receives from conventional sources such as a VCR or a video camera, and converts them into digital format. The software available with it will capture this digital signal and store them into computer file. It also helps to compress the digitized video so that it takes lesser disk space as compared to a non-compressed digitized video. This card is fitted into a free slot on the motherboard inside the computer and gets connected to an outside source such as TV, VCR or a video camera with the help of a cable. This card receives both video and audio signal from the outside source and conversion from analog to digital signal takes place. This process of conversion is known as sampling. This process converts the analog signal to digital data streams so that this signal can be stored in binary data format of 0’s and 1’s. This digital data stream is then compressed using the video capturing software and stores them in the hard disk as a file. This file is then used for incorporation into multimedia. This digitized file can also be edited according to the requirements using various editing software such as Adobe Premiere. A number of digitizer or video grabbing cards are available in the market. However, one from Intel called Intel Smart Video Recorder III does a very good job of capturing and compressing video.

**Sound Card**

Today’s computers are capable of creating the professional multimedia needs. Not only you can use computer to compose your own music, but it can also be used for recognition of speech and synthesis. It can even read back the entire document for you. But before all this happens, we need to convert the conventional sound signal to computer understandable digital signals. This is done using a special component added to the system called sound card. This is installed into a free slot on the computer motherboard. As in the case of video grabber card, sound card will take the sound input from outside source (such as human voice, pre-recorded sounds, natural sounds etc.) and convert them into digital
sound signal of 0’s and 1’s. The recording software used alongwith the sound card will store this digitised sound stream in a file. This file can latter be used with multimedia software. One can even edit the digitised sound file and add special sound effects into it. Most popular sound card is from Creative Systems such as Sound Blaster-16, AWE32, etc. AWE32 sound card supports 16 channel, 32 voice and 128 instruments and 10 drums sound reproduction. It also has CD-ROM interface.

**CD-ROM Drive**

CD-ROM is a magnetic disk of 4.7 inches diameter and it can contain data up to 680 Megabytes. It has become a standard by itself basically for its massive storage capacity, faster data transfer rate. To access CD-ROM a very special drive is required and it is known as CD-ROM drive. Let us look into the term ROM that stands for ‘Read Only Memory’. It means the material contained in it can be read (as many times, as you like) but the content cannot be changed. As multimedia involves high resolution of graphics, high quality video and sound, it requires large amount of storage space and at the same time require a media, which can support faster data transfer. CD-ROM solves this problem by satisfying both requirements. Similar to the hard disk drive, the CD-ROM drive has certain specification which will help to decide which drive suit best to your multimedia requirement.

**Transfer Rate**

Transfer rate is basically the amount of data the drive is capable of transferring at a sustained rate from the CD to the CPU. This is measured in KB per second. For example, 1x drive is capable of transferring 150KB of data from the CD to the CPU. In other terms 1x CD drive will sustain a transfer rate of 150KB/sec, where x stands for 150 KB. This is the base measurement and all higher rates are multiple of this number, x. Latest CD-ROM drive available is of 64x, that means it is capable of sustaining a data transfer rate of $64 \times 150 = 9600$ KB = 9.38MB per second from the CD to the CPU.
Average Seek time

The amount of time lapses between request and its delivery is known as average seeks time. The lower the value better the result and time is measured in milliseconds. A good access time is 150ms. Recently computer technology has made tremendous progress. You can now have CDs which can ‘write many, read many’ times. This means you can write your files in to a blank CD through a laser beam. The written material can be read many times and they can even be erased and re-written again. Basically this re-writable CD’s can be used a simple floppy disk.

Scanner

Multimedia requires high quality of images, graphics to be used. And it takes lot of time creating them. However there are ready-made sources such as real life photographs, books, arts, etc. available from where one easily digitized the required pictures. To convert these photographs to digital format, one need a small piece of equipment called scanner attached to the computer. A scanner is a piece of computer hardware that sends a beam of light across a picture or document and records it. It captures images from various sources such as photograph, poster, magazine, book, and similar sources. These pictures then can be displayed and edited on a computer. The captured or scanned pictures can be stored in various formats like;

   File Format Explanation

   PICT - A widely used format compatible with most Macintosh
   JPEG - Joint Photographic Experts Group - a format that compresses files and lets you choose compression versus quality
   TIFF - Tagged Image File Format - a widely used format compatible with both Macintosh and Windows systems
   Windows BMP - A format commonly used on MS-DOS and MS-Windows computers
   GIF - Graphics Interchange Format - a format used on the Internet, GIF supports only 256 colours or grays
Scanners are available in various shapes and sizes like hand-held, feed-in, and flatbed types. They are also for scanning black-and-white only or colour. Some of the reputed vendors of scanner are Epson, Hewlett-Packard, Microtek and Relisys.

**Touchscreen**

As the name suggests, touchscreen is used where the user is required to touch the surface of the screen or monitor. It is basically a monitor that allows user to interact with computer by touching the display screen. This uses beams of infrared light that are projected across the screen surface. Interrupting the beams generates an electronic signal identifying the location of the screen. And the associated software interprets the signal and performs the required action. For example, touching the screen twice in quick succession works as double clicking of the mouse. Imagine how useful this will be for visually handicapped people who can identify things by touching a surface. Touchscreen is normally not used for development of multimedia, it is rather used for multimedia presentation arena like trade show, information kiosk, etc.
INTRODUCTION

A Flash animation or Flash cartoon is an animated film that is created by Adobe Flash or similar animation software and often distributed in the SWF file format. The term Flash animation refers to both the file format and the medium in which the animation is produced. With dozens of Flash-animated television series, countless more Flash-animated television commercials, and award-winning online shorts in circulation, Flash animation is currently enjoying a renaissance.

In the late 1990s, when bandwidth was still at 56 kbit/s for most Internet users, many Flash animation artists employed limited animation or cutout animation when creating projects intended for web distribution. This allowed artists to release shorts and interactive experiences well under 1 MB, which could stream both audio and high-end animation.

Flash is able to integrate bitmaps and other raster-based art, as well as video, though most Flash films are created using only vector-based drawings, which often result in a somewhat clean graphic appearance. Some hallmarks of poorly produced Flash animation are jerky natural movements (seen in walk-cycles and gestures), auto-tweened character movements, lip-sync without interpolation, and abrupt changes from front to profile view.
Flash animations are typically distributed by way of the World Wide Web, in which case they are often referred to as Internet cartoons, online cartoons, or webtoons. Web Flash animations may be interactive and are often created in a series. A Flash animation is distinguished from a Webcomic, which is a comic strip distributed via the Web, rather than an animated cartoon. Flash animation is now taught in schools throughout the UK and can be taken as a GCSE and A-level.

HISTORY

The first prominent use of the Flash animation format was by Ren & Stimpy creator John Kricfalusi. On October 15, 1997, he launched *The Goddamn George Liquor Program*, the first cartoon series produced specifically for the Internet. The series starred George Liquor (a fictional character rumored to have ended Kricfalusi’s employment on *Ren & Stimpy*) and his dim-witted nephew Jimmy The Hapless Idiot Boy. Later, Kricfalusi produced more animated projects with Flash including several online shorts for Icebox.com, television commercials, and a music video. Soon after that, web cartoons began appearing on the Internet with more regularity.

On February 26, 1999, in a major milestone for Flash animation, the popular web series *WhirlGirl* became the first regularly scheduled Flash animated web series when it premiered on the premium cable channel Showtime in an unprecedented telecast and simultaneous release on the Showtime website. Created by David B. Williams and produced by Visionary Media, the studio he founded, *WhirlGirl* follows the adventures of a young super-heroine fighting for freedom in a future ruled by an all-powerful “mediatech empire”.

The series originally launched in the spring of 1997 as a web comic with limited animation and sound. After gaining online syndication partners including Lycos.com and WebTV, the series first adopted Flash animation in July 1998. Following her Showtime debut, the titular heroine appeared in over 50 Flash webisodes on
the Showtime website and starred in a million-dollar multimedia Showtime marketing campaign.

About the same time, Joe Cartoon launched the interactive animation “Frog in a Blender” to become one of the very first true “viral hits” on the Internet, gaining more than 90 million views since its release in 1999.

*The Von Ghouls* went live in November 1999, featuring the first music group with cartoon episodes online including original songs, in the vein of Saturday morning cartoons of the 1970s. A number of popular portal sites featured Flash animation during the dot-com boom of the late 1990s, including Newgrounds, Icebox, MondoMedia, CampChaos, MediaTrip, Bogbeast and AtomFilms. Stan Lee of Marvel Comics launched an animated comics site.

The Internet also saw the proliferation of many adult-only Flash cartoon sites. Some of the shows from that period made the transition to traditional media, including Queer Duck, Gary the Rat, Happy Tree Friends, and the politically minded JibJab shorts. Occasionally, the trend has been reversed: after being canceled from both ABC and Fox, *Atom Films* and Flinch Studio created net-only episodes of *The Critic* in 2000–2001. In another instance, Flash almost made the transition to the big screen. In 2001, production began on what would have been the first Flash-animated feature film, the ill-fated *Lil’ Pimp*, which also began life as an Internet series. As potentially controversial as its subject matter was, it had a relatively large budget, a number of well-known actors (including William Shatner, Bernie Mac, and Lil’ Kim), a full crew, and a running time of nearly 80 minutes. Although Sony Pictures decided not to release the film, it was eventually released on DVD by Lion’s Gate.

In 2000, another major milestone occurred in the world of animation when the first broadcast-quality Flash animation aired on television. Dice Raw’s music video “Thin Line between Raw and Jiggy” appeared on the big screen at Resfest 2000, on television via BET, and the Web on sites such as Sputnik7.com, Shockwave.com, Heavy.com and was also included with the CD.
Its creation became one of media history’s first convergent entertainment productions. Todd Wahnish, who would later go on to create Marvel Entertainment’s “All Winners Squad”, pioneered the early conversion of traditional hand-drawn techniques into vector-based animation seen in the video. The video triggered a flood of Flash-based television animation.

Several recording companies experimented with releasing animated music videos to promote their artists’ releases online, including Madonna, Beastie Boys and Tenacious D; however, none became the hit that allowed for the expansion of Flash animated music videos. Adam Sandler and Tim Burton, among others, released original Internet-only animated works, but were not able to devise successful financial models and the trend dissipated, largely as a result of a lack of viable micro-payment systems.

Several popular online series are currently produced in Flash, such as the Emmy Award-winning Off-Mikes, produced by ESPN and Animax Entertainment; Gotham Girls, produced by Warner Bros.; Crime Time, produced by Future Thought Productions and Homestar Runner produced by Mike and Matt Chapman.

Alejo & Valentina, an Argentine flash cartoon series launched in 2002, began to be broadcast by MTV in 2005.

The theatrical release of the 1986 animated film The Great Mouse Detective has the CGI gears inside Big Ben with hand-drawn animated characters. Many today animated television series are produced using Macromedia Flash, inspired by both the comparatively low cost of production and the unique arrays of new animation styles that can be achieved through the medium, including Metalocalypse, Being Ian, Foster’s Home For Imaginary Friends, Kappa Mikey, Hi Hi Puffy AmiYumi, Happy Tree Friends, Odd Job Jack, Wow! Wow! Wubbzy!, the BBC Three show Monkey Dust, the Channel Four show Modern Toss, Yin Yang Yo!, Aaagh! It’s the Mr. Hell Show, Jake and the Never Land Pirates, My Little Pony: Friendship Is Magic on The Hub (however, this show uses a heavily modified version of Flash 8), Cinemax’s Eli’s Dirty Jokes, Queer
Flash Animation

Duck from Showtime, The Mr. Men Show from Cartoon Network and Shorties Watching Shorties on Comedy Central.

Other TV shows, such as Home Movies and Harvey Birdman, Attorney at Law, which are both broadcast on Cartoon Network’s Adult Swim programming block, have switched to Flash from other animation technology.

Many animation film festivals have responded to the popularity of Flash animation by adding separate categories in competition for “web cartoons” or “Internet cartoons”. Additionally, several exclusively web-based Flash competitions have been established. It is speculated that only the category “made for Internet” will survive, as competitions at animation film festivals are typically arranged in categories defined by film length and distribution channel, rather than by animation techniques or tools used to create it.

DISTRIBUTION

While the creation of animation using Flash can be easier and less expensive than traditional animation techniques, the amount of time, money, and skill required to produce a project using the software depends on the chosen content and style. Internet distribution is considerably easier and less expensive than television broadcasting, and websites such as Newgrounds provide free hosting. Many Flash animations are created by individual or amateur artists. Many Flash animations first distributed on the web became popular enough to be broadcast on television, particularly on such networks as MTV and G4.

PROFESSIONAL STUDIOS

Flash animation production is enjoying considerable popularity in major animation studios around the world, as animators take advantage of the software’s ability to organize a large number of assets (such as characters, scenes, movements, and props) for later re-use. Because Flash files are in vector file format, they can be
used to transfer animation to 35 mm film without any compromise in image quality. This feature is used by several independent animators worldwide, including Phil Nibbelink, who saw his 77-minute feature film Romeo & Juliet: Sealed with a Kiss released in theaters in 2006, and Nina Paley, who released Sita Sings the Blues in 2008. For Disneyland’s 50 Magical Years film featuring Live action Steve Martin interacting with Donald Duck, the hand drawn animation of Donald Duck was cleaned up and colored in Flash. The Drawn Together Movie: The Movie!, a straight-to-DVD feature of the animated series Drawn Together, produced by Comedy Central and released in April 2010, discarded the series’ traditional animation and used Flash animation instead.

CREATING FLASH ANIMATION FROM OTHER SOFTWARE

There are a number of other software packages available that can create output in the swf format. Among these are GoAnimate, Toon Boom, Xara Photo & Graphic Designer, Toufee, Express Animator and Anime Studio. These front-ends often provide additional support for creating cartoons, especially with tools more tailored to traditionally trained animators, as well as additional rigging for characters, which can speed up character animation considerably.

HISTORY

FutureWave

The precursor to Flash was a product named SmartSketch, published by FutureWave Software. The company was founded by Charlie Jackson, Jonathan Gay, and Michelle Welsh. SmartSketch was a vector drawing application for pen computers running the PenPoint OS. When PenPoint failed in the marketplace, SmartSketch was ported to Microsoft Windows and Mac OS.

As the Internet became more popular, FutureWave realized the potential for a vector-based web animation tool that might
Flash Animation

challenge Macromedia Shockwave technology. In 1995, FutureWave modified SmartSketch by adding frame-by-frame animation features and released this new product as FutureSplash Animator on Macintosh and PC.

FutureWave approached Adobe Systems with an offer to sell them FutureSplash in 1995, but Adobe turned down the offer at that time. Microsoft wanted to create an “online TV network” (MSN) and adopted FutureSplash animated content as a central part of it. Disney Online used FutureSplash animations for their subscription-based service Disney’s Daily Blast. Fox Broadcasting Company launched The Simpsons using FutureSplash.

Macromedia

In November 1996, FutureSplash was acquired by Macromedia, and Macromedia re-branded and released FutureSplash Animator as Macromedia Flash 1.0. Flash was a two-part system, a graphics and animation editor known as Macromedia Flash, and a player known as Macromedia Flash Player.

FutureSplash Animator was an animation tool originally developed for pen-based computing devices, but due to the small size of the FutureSplash Viewer, it was particularly suited for download over the Web. Macromedia distributed Flash Player as a free browser plugin in order to quickly gain market share. As of 2005, more computers worldwide had the Flash Player installed than any other Web media format, including Java, QuickTime, RealNetworks and Windows Media Player.

Macromedia upgraded the Flash system significantly from 1996 to 1999, adding MovieClips, Actions (the precursor to ActionScript), Alpha transparency, and other features. As Flash matured, Macromedia’s focus shifted from marketing it as a graphics and media tool to promoting it as a Web application platform, adding scripting and data access capabilities to the player while attempting to retain its small footprint.

In 2000, the first major version of ActionScript was developed, and released with Flash 5. Actionscript 2.0 was released with Flash
MX 2004 and supported object-oriented programming, improved UI components, and other advanced programming features. The last version of Flash released by Macromedia was Flash 8, which focused on graphical upgrades such as filters (blur, drop shadow, etc.), blend modes (similar to Adobe Photoshop), and advanced features for FLV video.

Adobe

Macromedia was acquired by Adobe Systems in 2005, and the entire Macromedia product line including Flash, Dreamweaver, Director/Shockwave and Authorware is now handled by Adobe.

In 2007, Adobe released Adobe Flash CS3 Professional, the first version released under Adobe, and the ninth major version of Flash. It introduced the ActionScript 3.0 programming language, which supported modern programming practices and enabled business applications to be developed with Flash. Adobe Flex Builder (built on Eclipse) targeted the enterprise application development market, and was also released the same year. Flex Builder included the Flex SDK, a set of components that included charting, advanced UI, and data services (Flex Data Services).

In 2008, Adobe released the historic tenth version of Flash, Adobe Flash CS4. Flash 10 improved animation capabilities within the Flash editor, adding a motion editor panel (similar to Adobe After Effects), inverse kinematics (bones), basic 3D object animation, object-based animation, and other advanced text and graphics features. Flash Player 10 included the first in-built 3D engine (without GPU acceleration), that allowed basic object transformations in 3D space (position, rotation, scaling).

Also in 2008, Adobe released the first version of Adobe Integrated Runtime (later re-branded as Adobe AIR), a runtime engine that replaced Flash Player, and provided additional capabilities to the ActionScript 3.0 language to build desktop and mobile applications. With AIR, developers could access the file system (files & folders), and connected devices (joystick, gamepad,
sensors) for the first time. In 2011, Adobe Flash Player 11 was released, and with it the first version of Stage3D, allowing for GPU-accelerated 3D rendering for Flash applications and games, on desktop platforms such as Microsoft Windows and Mac OS X. Adobe further improved 3D capabilities from 2011 to 2013, adding support for 3D rendering on Android and iOS platforms, alpha-channels, compressed textures, texture atlases, and other features. Adobe AIR was upgraded to support 64-bit computers, and developers could now add additional functionality to the AIR runtime using AIR Native Extensions (ANE).

In 2014, Adobe AIR reached a milestone when over 100,000 unique applications were built on AIR, and over 1 billion installations of the same were logged from users across the world (May 2014). Adobe AIR was voted as the Best Mobile Application Development product at the Consumer Electronics Show for two consecutive years (CES 2014 and CES 2015).

Format

**FLA**

Flash source files are in the FLA format, and contain graphics, animation as well as embedded assets such as bitmap images, audio files and FLV video files. The Flash source file format is a proprietary format and Adobe Animate is the only available authoring tool capable of editing such files. Flash source files (.fla) may be compiled into Flash movie files (.swf) using Adobe Animate. Note that FLA files can be edited, but output (.swf) files cannot.

**SWF**

Flash movie files are in the SWF format, traditionally called “ShockWave Flash” movies, “Flash movies”, or “Flash applications”, usually have a.swf file extension, and may be used in the form of a web page plug-in, strictly “played” in a standalone Flash Player, or incorporated into a self-executing Projector movie (with the.exe extension in Microsoft Windows). Flash Video files have a.flv file extension and are either used from within.swf files
or played through a flv-aware player, such as VLC, or QuickTime and Windows Media Player with external codecs added.

The use of vector graphics combined with program code allows Flash files to be smaller—and thus allows streams to use less bandwidth—than the corresponding bitmaps or video clips. For content in a single format (such as just text, video, or audio), other alternatives may provide better performance and consume less CPU power than the corresponding Flash movie, for example when using transparency or making large screen updates such as photographic or text fades.

In addition to a vector-rendering engine, the Flash Player includes a virtual machine called the ActionScript Virtual Machine (AVM) for scripting interactivity at run-time, with video, MP3-based audio, and bitmap graphics. As of Flash Player 8, it offers two video codecs: On2 Technologies VP6 and Sorenson Spark, and run-time JPEG, Progressive JPEG, PNG, and GIF capability. In the next version, Flash is slated to use a just-in-time compiler for the ActionScript engine.

3D

Flash Player 11 introduced a full 3D shader API, called Stage3D, which is fairly similar to WebGL. Stage3D enables GPU-accelerated rendering of 3D graphics within Flash games and applications, and has been used to build Angry Birds, and a couple of other notable games.

Various 3D frameworks have been built for Flash using Stage3D, such as Away3D 4, CopperCube, Flare3D, Starling. Professional game engines like Unreal Engine and Unity also export Flash versions which use Stage3D to render 3D graphics.

Flash Video

Virtually all browser plugins for video are free of charge and cross-platform, including Adobe’s offering of Flash Video, which was first introduced with Flash version 6. Flash Video has been a popular choice for websites due to the large installed user base
and programmability of Flash. In 2010, Apple publicly criticized Adobe Flash, including its implementation of video playback for not taking advantage of hardware acceleration, one reason Flash is not to be found on Apple’s mobile devices. Soon after Apple’s criticism, Adobe demoed and released a beta version of Flash 10.1, which takes advantage of GPU hardware acceleration even on a Mac. Flash 10.2 beta, released December 2010, adds hardware acceleration for the whole video rendering pipeline.

Flash Player supports two distinct modes of video playback, and hardware accelerated video decoding may not be used for older video content. Such content causes excessive CPU usage compared to comparable content played with other players.

- **Software Rendered Video**: Flash Player supports software rendered video since version 6. Such video supports vector animations displayed above the video content. This obligation may, depending on graphic APIs exposed by the operating system, prohibit using a video overlay, like a traditional multimedia player would use, with the consequence that color space conversion and scaling must happen in software.

- **Hardware Accelerated Video**: Flash Player supports hardware accelerated video playback since version 10.2, for H.264, F4V, and FLV video formats. Such video is displayed above all Flash content, and takes advantage of video codec chipsets installed on the user’s device. Developers must specifically use the “StageVideo” technology within Flash Player in order for hardware decoding to be enabled. Flash Player internally uses technologies such as DirectX Video Acceleration and OpenGL to do so.

In tests done by Ars Technica in 2008 and 2009, Adobe Flash Player performed better on Windows than Mac OS X and Linux with the same hardware. Performance has later improved for the latter two, on Mac OS X with Flash Player 10.1, and on Linux with Flash Player 11.
Flash Audio

Flash Audio is most commonly encoded in MP3 or AAC (Advanced Audio Coding) however it can also use ADPCM, Nellymoser (Nellymoser Asao Codec) and Speex audio codecs. Flash allows sample rates of 11, 22 and 44.1 kHz. It cannot have 48 kHz audio sample rate, which is the standard TV and DVD sample rate.

On August 20, 2007, Adobe announced on its blog that with Update 3 of Flash Player 9, Flash Video will also implement some parts of the MPEG-4 international standards. Specifically, Flash Player will work with video compressed in H.264 (MPEG-4 Part 10), audio compressed using AAC (MPEG-4 Part 3), the F4V, MP4 (MPEG-4 Part 14), M4V, M4A, 3GP and MOV multimedia container formats, 3GPP Timed Text specification (MPEG-4 Part 17), which is a standardized subtitle format and partial parsing capability for the ‘ilst’ atom, which is the ID3 equivalent iTunes uses to store metadata. MPEG-4 Part 2 and H.263 will not work in F4V file format. Adobe also announced that it will be gradually moving away from the FLV format to the standard ISO base media file format (MPEG-4 Part 12) owing to functional limits with the FLV structure when streaming H.264. The final release of the Flash Player implementing some parts of MPEG-4 standards had become available in Fall 2007.

Adobe Flash Player 10.1 does not have acoustic echo cancellation, unlike the VoIP offerings of Skype and Google Voice, making this and earlier versions of Flash less suitable for group calling or meetings. Flash Player 10.3 Beta incorporates acoustic echo cancellation.

Scripting language

ActionScript is the programming language used by Flash. It is an enhanced superset of the ECMAScript programming language, with a classical Java-style class model, rather than JavaScript’s prototype model.
Specifications

In October 1998, Macromedia disclosed the Flash Version 3 Specification on its website. It did this in response to many new and often semi-open formats competing with SWF, such as Xara’s Flare and Sharp’s Extended Vector Animation formats. Several developers quickly created a C library for producing SWF. In February 1999, Morphlink 99 was introduced, the first third-party program to create SWF files. Macromedia also hired Middlesoft to create a freely available developers’ kit for the SWF file format versions 3 to 5.

Macromedia made the Flash Files specifications for versions 6 and later available only under a non-disclosure agreement, but they are widely available from various sites.

In April 2006, the Flash SWF file format specification was released with details on the then newest version format (Flash 8). Although still lacking specific information on the incorporated video compression formats (On2, Sorenson Spark, etc.), this new documentation covered all the new features offered in Flash v8 including new ActionScript commands, expressive filter controls, and so on. The file format specification document is offered only to developers who agree to a license agreement that permits them to use the specifications only to develop programs that can export to the Flash file format. The license does not allow the use of the specifications to create programs that can be used for playback of Flash files. The Flash 9 specification was made available under similar restrictions.

In June 2009, Adobe launched the Open Screen Project (Adobe link), which made the SWF specification available without restrictions. Previously, developers could not use the specification for making SWF-compatible players, but only for making SWF-exporting authoring software. The specification still omits information on codecs such as Sorenson Spark, however.
INTRODUCTION

A Fireball In The Dark

The illusions or tricks of the eye used in the film, television, theatre, video game, and simulator industries to simulate the imagined events in a story or virtual world are traditionally called special effects (often abbreviated as SFX, SPFX, or simply FX).

Bluescreens are commonly used in chroma key special effects.

Special effects are traditionally divided into the categories of optical effects and mechanical effects. With the emergence of digital filmmaking a distinction between special effects and visual effects has grown, with the latter referring to digital post-production while “special effects” referring to mechanical and optical effects.
A methane bubble bursting

Mechanical effects (also called practical or physical effects) are usually accomplished during the live-action shooting. This includes the use of mechanized props, scenery, scale models, animatronics, pyrotechnics and atmospheric effects: creating physical wind, rain, fog, snow, clouds, etc. Making a car appear to drive by itself and blowing up a building are examples of mechanical effects. Mechanical effects are often incorporated into set design and makeup. For example, a set may be built with break-away doors or walls to enhance a fight scene, or prosthetic makeup can be used to make an actor look like a non-human creature.

Optical effects (also called photographic effects) are techniques in which images or film frames are created photographically, either “in-camera” using multiple exposure, mattes, or the Schüfftan process, or in post-production using an optical printer. An optical effect might be used to place actors or sets against a different background.

Since the 1990s, computer generated imagery (CGI) has come to the forefront of special effects technologies. It gives filmmakers greater control, and allows many effects to be accomplished more safely and convincingly and—as technology improves—at lower costs. As a result, many optical and mechanical effects techniques have been superseded by CGI.
DEVELOPMENTAL HISTORY

Early development

In 1856, Oscar Rejlander created the world’s first “trick photograph” by combining different sections of 30 negatives into a single image. In 1895, Alfred Clark created what is commonly accepted as the first-ever motion picture special effect. While filming a reenactment of the beheading of Mary, Queen of Scots, Clark instructed an actor to step up to the block in Mary’s costume. As the executioner brought the axe above his head, Clark stopped the camera, had all of the actors freeze, and had the person playing Mary step off the set. He placed a Mary dummy in the actor’s place, restarted filming, and allowed the executioner to bring the axe down, severing the dummy’s head. “Such… techniques would remain at the heart of special effects production for the next century.”

Not only the first use of trickery in the cinema, it was the first type of photographic trickery only possible in a motion picture, i.e. the “stop trick”.

In 1896, French magician Georges Méliès accidentally discovered the same “stop trick.” According to Méliès, his camera jammed while filming a street scene in Paris. When he screened the film, he found that the “stop trick” had caused a truck to turn into a hearse, pedestrians to change direction, and men turn into women. Méliès, the stage manager at the Theatre Robert-Houdin, was inspired to develop a series of more than 500 short films, between 1914, in the process developing or inventing such techniques as multiple exposures, time-lapse photography, dissolves, and hand painted colour. Because of his ability to seemingly manipulate and transform reality with the cinematograph, the prolific Méliès is sometimes referred to as the “Cinemagician.” His most famous film, *Le Voyage dans la lune* (1902), a whimsical parody of Jules Verne’s *From the Earth to the Moon*, featured a combination of live action and animation, and also incorporated extensive miniature and matte painting work.
From 1910 to 1920, the main innovations in special effects were the improvements on the matte shot by Norman Dawn. With the original matte shot, pieces of cardboard were placed to block the exposure of the film, which would be exposed later. Dawn combined this technique with the “glass shot.” Rather than using cardboard to block certain areas of the film exposure, Dawn simply painted certain areas black to prevent any light from exposing the film. From the partially exposed film, a single frame is then projected onto an easel, where the matte is then drawn. By creating the matte from an image directly from the film, it became incredibly easy to paint an image with proper respect to scale and perspective (the main flaw of the glass shot). Dawn’s technique became the textbook for matte shots due to the natural images it created.

During the 1920s and 30s, special effects techniques were improved and refined by the motion picture industry. Many techniques—such as the Schüfftan process—were modifications of illusions from the theater (such as pepper’s ghost) and still photography (such as double exposure and matte compositing). Rear projection was a refinement of the use of painted backgrounds in the theater, substituting moving pictures to create moving backgrounds. Lifecasting of faces was imported from traditional maskmaking. Along with makeup advances, fantastic masks could be created which fit the actor perfectly. As material science advanced, horror film maskmaking followed closely.

Several techniques soon developed, such as the “stop trick”, wholly original to motion pictures. Animation, creating the illusion of motion, was accomplished with drawings (most notably by Winsor McCay in *Gertie the Dinosaur*) and with three-dimensional models (most notably by Willis O’Brien in *The Lost World* and *King Kong*). Many studios established in-house “special effects” departments, which were responsible for nearly all optical and mechanical aspects of motion-picture trickery.

Also, the challenge of simulating spectacle in motion encouraged the development of the use of miniatures. Naval battles could be depicted with models in studio. Tanks and airplanes
could be flown (and crashed) without risk of life and limb. Most impressively, miniatures and matte paintings could be used to depict worlds that never existed. Fritz Lang’s film *Metropolis* was an early special effects spectacular, with innovative use of miniatures, matte paintings, the Schüfftan process, and complex compositing.

An important innovation in special-effects photography was the development of the optical printer. Essentially, an optical printer is a projector aiming into a camera lens, and it was developed to make copies of films for distribution. Until Linwood G. Dunn refined the design and use of the optical printer, effects shots were accomplished as in-camera effects. Dunn demonstrating that it could be used to combine images in novel ways and create new illusions. One early showcase for Dunn was Orson Welles’ *Citizen Kane*, where such locations as Xanadu (and some of Gregg Toland’s famous ‘deep focus’ shots) were essentially created by Dunn’s optical printer.

**Color Era**

The development of color photography required greater refinement of effects techniques. Color enabled the development of such *travelling matte* techniques as bluescreen and the sodium vapour process. Many films became landmarks in special-effects accomplishments:*Forbidden Planet* used matte paintings, animation, and miniature work to create spectacular alien environments. In *The Ten Commandments*, Paramount’s John P. Fulton, A.S.C., multiplied the crowds of extras in the Exodus scenes with careful compositing, depicted the massive constructions of Rameses with models, and split the Red Sea in a still-impressive combination of travelling mattes and water tanks.

Ray Harryhausen extended the art of stop-motion animation with his special techniques of compositing to create spectacular fantasy adventures such as *Jason and the Argonauts* (whose climax, a sword battle with seven animated skeletons, is considered a landmark in special effects).
The science fiction boom

Through the 1950s and 60s numerous new special effects were developed which would dramatically increase the level of realism achievable in science fiction films. The pioneering work of directors such as Pavel Klushantsev would be used by major motion pictures for decades to come.

If one film could be said to have established a new high-bench mark for special effects, it would be 1968’s *2001: A Space Odyssey*, directed by Stanley Kubrick, who assembled his own effects team (Douglas Trumbull, Tom Howard, Con Pedersen and Wally Veevers) rather than use an in-house effects unit. In this film, the spaceship miniatures were highly detailed and carefully photographed for a realistic depth of field. The shots of spaceships were combined through hand-drawn rotoscopes and careful motion-control work, ensuring that the elements were precisely combined in the camera – a surprising throwback to the silent era, but with spectacular results. Backgrounds of the African vistas in the “Dawn of Man” sequence were combined with soundstage photography via the then-new front projection technique. Scenes set in zero-gravity environments were staged with hidden wires, mirror shots, and large-scale rotating sets. The finale, a voyage through hallucinogenic scenery, was created by Douglas Trumbull using a new technique termed slit-scan.

The 1970s provided two profound changes in the special effects trade. The first was economic: during the industry’s recession in the late 1960s and early 1970s, many studios closed down their in-house effects houses. Many technicians became freelancers or founded their own effects companies, sometimes specializing on particular techniques (opticals, animation, etc.).

The second was precipitated by the blockbuster success of two science fiction and fantasy films in 1977. George Lucas’s *Star Wars* ushered in an era of science-fiction films with expensive and impressive special-effects. Effects supervisor John Dykstra, A.S.C. and crew developed many improvements in existing effects
technology. They developed a computer-controlled camera rig called the “Dykstraflex” that allowed precise repeatability of camera motion, greatly facilitating travelling-matte compositing. Degradation of film images during compositing was minimized by other innovations: the Dykstraflex used VistaVision cameras that photographed widescreen images horizontally along stock, using far more of the film per frame, and thinner-emulsion filmstocks were used in the compositing process.

The effects crew assembled by Lucas and Dykstra was dubbed Industrial Light and Magic, and since 1977 has spearheaded most effects innovations.

That same year, Steven Spielberg’s film Close Encounters of the Third Kind boasted a finale with impressive special effects by 2001 veteran Douglas Trumbull. In addition to developing his own motion-control system, Trumbull also developed techniques for creating intentional “lens flare” (the shapes created by light reflecting in camera lenses) to provide the film’s undefinable shapes of flying saucers.

The success of these films, and others since, has prompted massive studio investment in effects-heavy science-fiction films. This has fueled the establishment of many independent effects houses, a tremendous degree of refinement of existing techniques, and the development of new techniques such as CGI.

It has also encouraged within the industry a greater distinction between special effects and visual effects; the latter is used to characterize post-production and optical work, while special effects refers more often to on-set and mechanical effects.

**Introduction of computer generated imagery (CGI)**

A recent and profound innovation in special effects has been the development of computer generated imagery, or CGI which has changed nearly every aspect of motion picture special effects. Digital compositing allows far more control and creative freedom than optical compositing, and does not degrade the image like
analog (optical) processes. Digital imagery has enabled technicians to create detailed models, matte “paintings,” and even fully realized characters with the malleability of computer software.

Arguably the biggest and most “spectacular” use of CGI is in the creation of photo-realistic images of science-fiction and fantasy characters, settings, and objects. Images can be created in a computer using the techniques of animated cartoons and model animation.

In 1993, stop-motion animators working on the realistic dinosaurs of Steven Spielberg’s *Jurassic Park* were retrained in the use of computer input devices. By 1995, films such as *Toy Story* underscored that the distinction between live-action films and animated films was no longer clear. Other landmark examples include a character made up of broken pieces of a stained-glass window in *Young Sherlock Holmes*, a shapeshifting character in *Willow*, a tentacle of water in *The Abyss*, the T-1000 Terminator in *Terminator 2: Judgment Day*, hordes of armies of robots and fantastic creatures in the *Star Wars prequel trilogy* and *The Lord of the Rings* trilogy and the planet Pandora in *Avatar*.

**PLANNING AND USE**

Although most special effects work is completed during post-production, it must be carefully planned and choreographed in pre-production and production. A Visual effects supervisor is usually involved with the production from an early stage to work closely with the Director and all related personnel to achieve the desired effects.

**Live special effects**

Live special effects are effects that are used in front of a live audience, mostly during sporting events, concerts and corporate shows. Types of effects that are commonly used include: flying effects, laser lighting, Theatrical smoke and fog, CO2 effects, pyrotechnics, confetti and other atmospheric effects such as bubbles and snow.
MINIATURE EFFECT

A miniature effect is a special effect created for motion pictures and television programs using scale models. Scale models are often combined with high speed photography or matte shots to make gravitational and other effects appear convincing to the viewer. The use of miniatures has largely been superseded by computer-generated imagery in the contemporary cinema.

Where a miniature appears in the foreground of a shot, this is often very close to the camera lens — for example when matte painted backgrounds are used. Since the exposure is set to the object being filmed so the actors appear well lit, the miniature must be over-lit in order to balance the exposure and eliminate any depth of field differences that would otherwise be visible. This foreground miniature usage is referred to as forced perspective. Another form of miniature effect uses stop motion animation.

Use of scale models in the creation of visual effects by the entertainment industry dates back to the earliest days of cinema. Models and miniatures are copies of people, animals, buildings, settings and objects. Miniatures or models are used to represent things that do not really exist, or that are too expensive or difficult to film in reality, such as explosions, floods or fires.
FROM 1900 TO THE MID-1960S

French director Georges Méliès incorporated special effects in his 1902 film *Le Voyage dans la Lune (A Trip to the Moon)* — including double-exposure, split screens, miniatures and stop-action.

Some of the most influential visual effects films of these early years such as *Metropolis* (1927), *Citizen Kane* (1941), *Godzilla* (1954) *The Ten Commandments* (1956). The 1933 film *King Kong* made extensive use of miniature effects including scale models and stop-motion animation of miniature elements.

**From the mid-1960s**

The use of miniatures in *2001: A Space Odyssey* was a major development. In production for three years, the film was a significant advancement in creating convincing models.

In the early 1970s, miniatures were often used to depict disasters in such films as *The Poseidon Adventure* (1972), *Earthquake* (1974) and *The Towering Inferno* (1975).

The resurgence of the science fiction genre in film in the late 1970s saw miniature fabrication rise to new heights in such films as *Close Encounters of the Third Kind* (1977), *Star Wars* (also 1977), *Alien* (1979), *Star Trek: The Motion Picture* (1979) and *Blade Runner* (1982). Iconic film sequences such as the tanker truck explosion from *The Terminator* (1984) and the bridge destruction in *True Lies* (1994) were achieved through the use of large-scale miniatures.

**Largely replaced by CGI**

The release of *Jurassic Park* (1993) for many was a turning point in the use of computers to create effects for which physical miniatures would have previously been employed.

While the use of computer generated imagery (CGI) has largely overtaken their use since then, they are still often employed, especially for projects requiring physical interaction with fire, explosions or water.

Techniques

- Carpentry
- Plastic Fabrication
- Vacuum Forming
- Mold Making and Casting
- Fiberglass
- Welding
- Rapid Prototyping
- Laser Cutting
- Acid Etching Metal
- Machining
- Kit-Bashing
- Miniature Lighting and Electronics
- Painting
- Motion Control Photography

Slurpasaur

“Slurpasaur” is a nickname given to optically enlarged reptiles (and occasionally other animals) that are presented as dinosaurs in motion pictures.

Concurrently with Willis O’Brien and others in making stop-motion animated dinosaurs since the early days of cinema, producers have used optically enlarged lizards, often with horns and fins glued on, to represent dinosaurs, to cut costs, and to present a living analog to dinosaurs, despite huge morphological differences between dinosaurs and reptiles. The first film that used reptiles dressed as dinosaurs was D.W. Griffith’s Brute Force. Various slurpasours appeared in the 1929 film version of The
Mysterious Island, the 1933 British film Secret of the Loch, and the 1936 Flash Gordon serial. The first major use of the slurpasaur was in One Million B.C. (1940), which included a pig dressed as a triceratops, with the special effects in this film re-used often, such as in the 1955 movie King Dinosaur.

Other notable films with slurpasuars include Journey to the Center of the Earth (1959) and The Lost World (1960). The former featured reptiles with attached tall spinal fans, simulating Dimetrodons and looked superficially similar to those creatures, as Dimetrodons had a low slung body structure more reminiscent of lizards. The latter is notable for a dinosaur battle wherein a monitor lizard and a young alligatorenengage in an unsimulated, fierce battle. On the 1960 Lost World, O’Brien, who did the stop-motion dinosaurs for the original, was hired as the effects technician, but was disappointed that producer Irwin Allen opted for live animals.

COMPOSITING

Compositing is the combining of visual elements from separate sources into single images, often to create the illusion that all those elements are parts of the same scene. Live-action shooting for compositing is variously called “chroma key”, “blue screen”, “green screen” and other names. Today, most, though not all, compositing is achieved through digital image manipulation. Pre-digital compositing techniques, however, go back as far as the trick films of Georges Méliès in the late 19th century; and some are still in use.

Basic procedure

All compositing involves the replacement of selected parts of an image with other material, usually, but not always, from another image. In the digital method of compositing, software commands designate a narrowly defined color as the part of an image to be replaced. Then the software replaces every pixel within the designated color range with a pixel from another image, aligned to appear as part of the original. For example, one could record
a television weather presenter positioned in front of a plain blue or green background, while compositing software replaces only the designated blue or green color with weather maps.

**Typical applications**

In television studios, blue or green screens may back newsreaders to allow the compositing of stories behind them, before being switched to full-screen display. In other cases, presenters may be completely within compositing backgrounds that are replaced with entire “virtual sets” executed in computer graphics programs. In sophisticated installations, subjects, cameras, or both can move about freely while the computer-generated imagery (CGI) environment changes in real time to maintain correct relationships between the camera angles, subjects, and virtual “backgrounds.”

Virtual sets are also used in motion pictures filmmaking, some of which are photographed entirely in blue or green screen environments; as for example in *Sky Captain and the World of Tomorrow*. More commonly, composited backgrounds are combined with sets – both full-size and models – and vehicles, furniture, and other physical objects that enhance the “reality” of the composited visuals. “Sets” of almost unlimited size can be created digitally because compositing software can take the blue or green color at the edges of a backing screen and extend it to fill the rest of the frame outside it. That way, subjects recorded in modest areas can be placed in large virtual vistas. Most common of all, perhaps, are set extensions: digital additions to actual performing environments. In the film *Gladiator*, for example, the arena and first tier seats of the Roman Colosseum were actually built, while the upper galleries (complete with moving spectators) were computer graphics, composited onto the image above the physical set. For motion pictures originally recorded on film, high-quality video conversions called “digital intermediates” are created to enable compositing and the other operations of computerized post production. Digital compositing is a form of matting, one of four basic compositing methods. The others are physical compositing, multiple exposure, and background projection.
Physical compositing

In physical compositing the separate parts of the image are placed together in the photographic frame and recorded in a single exposure. The components are aligned so that they give the appearance of a single image. The most common physical compositing elements are partial models and glass paintings.

Partial models are typically used as set extensions such as ceilings or the upper stories of buildings. The model, built to match the actual set but on a much smaller scale, is hung in front of the camera, aligned so that it appears to be part of the set. Models are often quite large because they must be placed far enough from the camera so that both they and the set far beyond them are in sharp focus.

Glass shots are made by positioning a large pane of glass so that it fills the camera frame, and is far enough away to be held in focus along with the background visible through it. The entire scene is painted on the glass, except for the area revealing the background where action is to take place. This area is left clear. Photographed through the glass, the live action is composited with the painted area. A classic example of a glass shot is the approach to Ashley Wilkes’ plantation in *Gone with the Wind*. The plantation and fields are all painted, while the road and the moving figures on it are photographed through the glass area left clear.

A variant uses the opposite technique: most of the area is clear, except for individual elements (photo cutouts or paintings) affixed to the glass. For example, a ranch house could be added to an empty valley by placing an appropriately scaled and positioned picture of it between the valley and the camera.

Multiple exposure

An in-camera multiple exposure is made by recording on only one part of each film frame, rewinding the film to exactly the same start point, exposing a second part, and repeating the process as needed. The resulting negative is a composite of all the individual
exposures. (By contrast, a “double exposure” records multiple images on the entire frame area, so that all are partially visible through one another.) Exposing one section at a time is made possible by enclosing the camera lens (or the whole camera) in a light-tight box fitted with maskable openings, each one corresponding to one of the action areas. Only one opening is revealed per exposure, to record just the action positioned in front of it.

The Playhouse compositing using multiple exposures to show nine copies of Buster Keaton on screen at once.

Multiple exposure is difficult because the action in each recording must match that of the others; multiple exposure composites therefore typically contain only two or three elements. However, as early as 1900 Georges Méliès used seven-fold exposure in L’homme-orchestre/The One-man Band; and in the 1921 film The Playhouse, Buster Keaton used multiple exposures to appear simultaneously as nine different actors on a stage, perfectly synchronizing all nine performances.

BACKGROUND PROJECTION

Background projection throws the background image on a screen behind the subjects in the foreground while the camera makes a composite by photographing both at once. The foreground elements conceal the parts of the background image behind them. Sometimes, the background is projected from the front, reflecting
off the screen but not the foreground subjects because the screen is made of highly directional, exceptionally reflective material. (The prehistoric opening of *2001: A Space Odyssey* uses front projection.) However, rear projection has been a far more common technique.

In rear projection, (often called process shooting) background images (called “plates”, whether they are still pictures or moving) are photographed first. For example, a camera car may drive along streets or roads while photographing the changing scene behind it. In the studio, the resulting “background plate” is loaded into a projector with the film “flipped” (reversed), because it will be projected onto (and through) the back of a translucent screen. A car containing the performers is aligned in front of the screen so that the scenery appears through its rear and/or side windows. A camera in front of the car records both the foreground action and the projected scenery, as the performers pretend to drive.

Like multiple exposure, rear projection is technically difficult. The projector and camera motors must be synchronized to avoid flicker and perfectly aligned behind and before the screen. The foreground must be lit to prevent light spill onto the screen behind it. (For night driving scenes, the foreground lights are usually varied as the car “moves” along.) The projector must use a very strong light source so that the projected background is as bright as the foreground. Color filming presents additional difficulties, but can be quite convincing, as in several shots in the famous crop duster sequence in Alfred Hitchcock’s *North by Northwest*. (Much of the sequence, however, was shot on location.) Because of its complexity, rear projection has been largely replaced by digital compositing with, for example, the car positioned in front of a blue or green screen.

**Matting**

Like its digital successor, traditional matte photography uses a uniformly colored backing – usually (but not always) a special blue or green. Because a matching filter on the camera lens screens
out only the backing color, the background area records as black, which, on the camera’s negative film, will develop clear.

Traditional matting is the process of compositing two different film elements by printing them, one at a time, onto a duplicate strip of film. After one component is printed on the duplicate, the film is rewound and the other component is added. Since the film cannot be exposed twice without creating a double exposure, the blank second area must be masked while the first is printed; then the freshly exposed first area must be masked while the second area is printed. Each masking is performed by a “traveling matte:” a specially altered duplicate shot which lies on top of the copy film stock.

First, a print from the original negative is made on high-contrast film, which records the backing as opaque and the foreground subject as clear. A second high-contrast copy is then made from the first, rendering the backing clear and the foreground opaque.
Next, a three-layer sandwich of film is run through an optical printer. On the bottom is the unexposed copy film. Above it is the first matte, whose opaque backing color masks the background. On top is the negative of the foreground action. On this pass, the foreground is copied while the background is shielded from exposure by the matte.

Then the process is repeated; but this time, the copy film is masked by the reverse matte, which excludes light from the foreground area already exposed. The top layer contains the background scene, which is now exposed only in the areas protected during the previous pass. The result is a positive print of the combined background and foreground. A copy of this composite print yields a “dupe negative” that will replace the original foreground shot in the film’s edited negative.

ADVANTAGES OF DIGITAL MATTES

Digital matting has replaced the traditional approach for two reasons. In the old system, the five separate strips of film (foreground and background originals, positive and negative mattes, and copy stock) could drift slightly out of registration, resulting in halos and other edge artifacts in the result. Done correctly, digital matting is perfect, down to the single-pixel level. Also, the final dupe negative was a “third generation” copy, and film loses quality each time it is copied. Digital images can be copied without quality loss.

This means that multi-layer digital composites can easily be made. For example, models of a space station, a space ship, and a second space ship could be shot separately against blue screen, each “moving” differently. (In such shots, it is the camera that moves, not the model). The individual shots could then be composited with one another, and finally with a star background. With pre-digital matting, the several extra passes through the optical printer would degrade the film quality and increase the probability of edge artifacts. Elements crossing behind or before one another would pose additional problems.
PRACTICAL EFFECT

A practical effect is a special effect produced physically, without computer-generated imagery or other post production techniques. In some contexts, “special effect” is used as a synonym of “practical effect”, in contrast to “visual effects” which are created in post-production through photographic manipulation or computer generation.

Many of the staples of action movies are practical effects. Gunfire, bullet wounds, rain, wind, fire, and explosions can all be produced on a movie set by someone skilled in practical effects. Non-human characters and creatures produced with make-up, prosthetics, masks, and puppets – in contrast to computer-generated images – are also examples of practical effects.

Practical effect techniques

- The use of prosthetic makeup, animatronics, puppetry or suitmation to create the appearance of living creatures.
- Miniature effects, which is the use of scale models which are photographed in a way that they appear full sized.
- Mechanical Effects, such as aerial rigging to simulate flight, stage mounted gimbals to make the ground move, or other mechanical devices to physically manipulate the environment.
- Pyrotechnics for the appearance of fire and explosions.
- Weather effects such as sprinkler systems to create rain and fog machines to create smoke.
- Squibs to create the illusion of gunshot wounds.

VISUAL EFFECTS

In filmmaking, visual effects (abbreviated VFX) are the processes by which imagery is created and/or manipulated outside the context of alive action shot.

Visual effects involve the integration of live-action footage and generated imagery to create environments which look realistic, but would be dangerous, expensive, impractical, or simply
impossible to capture on film. Visual effects using computer generated imagery have recently become accessible to the independent filmmaker with the introduction of affordable and easy-to-use animation and compositing software.

**Timing**

Visual effects are often integral to a movie’s story and appeal. Although most visual effects work is completed during post-production, it usually must be carefully planned and choreographed in pre-production and production. Visual effects primarily executed in Post-Production with the use of multiple tools and technologies such as graphic design, modeling, animation and similar software, while special effects such as explosions and car chases are made on set. A visual effects supervisor is usually involved with the production from an early stage to work closely with production and the film’s director design, guide and lead the teams required to achieve the desired effects.

**Categories**

Visual effects may be divided into at least four categories:

- Matte paintings and stills: digital or traditional paintings or photographs which serve as background plates for keyed or rotoscoped elements.
- Live-action effects: keying actors or models through bluescreening and greenscreening.
- Digital effects (commonly shortened to digital FX or FX) are the various processes by which imagery is created and/or manipulated with or from photographic assets. Digital effects often involve the integration of still photography and computer-generated imagery (CGI) in order to create environments which look realistic but would be dangerous, costly, or simply impossible to capture in camera. FX is usually associated with the still photography world in contrast to visual effects which is associated with motion film production.
Animated Cartoon

Nowadays, animation is a medium of artistic expression which is used by a vast number of professionals, to make conventional cinema and television movies but they are not alone. Each day, thanks to 3D animation and the widening field of multimedia, more and more artists are beginning to see animation as an ideal way of giving expression to their ideas, through image to image sequences.

Today it is not very difficult at all to succeed with such projects, thanks to all of the technological aids we have at our disposal, but the endeavours that have been made up until now (over more than a century) deserve to be known and remembered.

This blog attempts to pay tribute to the pioneers who made possible the birth of animated cartoons, via a chronology which begins with the first and rudimentary optical toys and concludes with the innovations which have made possible the execution of animated cartoons as we know them today.

Seasons will be included, as will retrospectives and all of the animated shorts from those classic creators who, with their inventiveness, advanced the development of animation in each period.

We would be grateful for any kind of comments or information you feel disposed to share with us in this little space. The first animated projection (screening) was created in France, by Charles-
Émile Reynaud, who was a French science teacher. Reynaud created the Praxinoscope in 1877 and the Théâtre Optique in December 1888. On 28 October 1892, he projected the first animation in public, *Pauvre Pierrot*, at the Musée Grévin in Paris. This film is also notable as the first known instance of film perforations being used. His films were not photographed, but drawn directly onto the transparent strip. In 1900, more than 500,000 people had attended these screenings.

The first (photographed) animated projection was *Humorous Phases of Funny Faces* (1906) by newspaper cartoonist J. Stuart Blackton, one of the co-founders of the Vitagraph Company arrived. In the movie, a cartoonist’s line drawings of two faces were ‘animated’ (or came to life) on a blackboard. The two faces smiled and winked, and the cigar-smoking man blew smoke in the lady’s face; also, a circus clown led a small dog to jump through a hoop.

The first animated projection in the traditional sense (i.e., on motion picture film) was *Fantasmagorie* by the French director Émile Cohl in 1908. This was followed by two more films, *Le Cauchemar du fantoche* [The Puppet’s Nightmare, now lost] and *Un Drame chez les fantoches* [A Puppet Drama, called *The Love Affair in Toyland* for American release and *Mystical Love-Making* for British release], all completed in 1908.

One of the very first successful animated cartoons was *Gertie the Dinosaur* (1914) by Winsor McCay. It is considered the first example of true character animation. At first, animated cartoons were black-and-white and silent. Felix the Cat and Oswald the Lucky Rabbit are notable examples.

**HISTORY OF ANIMATION**

Animation refers to the creation of a sequence of images—drawn, painted, or produced by other artistic methods—that change over time to portray the illusion of motion. Before the invention of film, humans depicted motion in static art as far back as the Paleolithic period. In the 1st century, several devices successfully depicted motion in animated images.
EARLY APPROACHES TO MOTION IN ART

An Egyptian burial chamber mural, approximately 4000 years old, showing wrestlers in action.

Sequence of images that minimally differ from each other - from the site of the Burnt City in Iran, late half of 3rd millennium B.C.

One early example is a 5,200-year old pottery bowl discovered in Shahr-e Sukhteh, Iran. The bowl has five images painted around it that show phases of a goat leaping up to nip at a tree.

An Egyptian mural approximately 4000 years old, found in the tomb of Khnumhotep at the Beni Hassan cemetery, features a very long series of images that apparently depict the sequence of events in a wrestling match. Ancient Chinese records contain several mentions of devices, including one made by the inventor Ding Huan, that were said to "give an impression of movement" to a series of human or animal figures on them, but these accounts are unclear and may only refer to the actual movement of the figures through space. Seven drawings by Leonardo da Vinci (c. 1510) extending over two folios in the Windsor Collection,
Anatomical Studies of the Muscles of the Neck, Shoulder, Chest, and Arm, have detailed renderings of the upper body and less-detailed facial features. The sequence shows multiple angles of the figure as it rotates and the arm extends. Because the drawings show only small changes from one image to the next, together they imply the movement of a single figure.

Although some of these early examples may seem similar to a series of animation drawings, the contemporary lack of any means to show them in motion and their extremely low frame rate causes them to fall short of being true animation. Nonetheless, the practice of illustrating movement over time by creating a series of images arranged in chronological order provided a foundation for the development of the art.

**Animation before film**

Numerous devices that successfully displayed animated images were introduced well before the advent of the motion picture. These devices were used to entertain, amaze, and sometimes even frighten people. The majority of these devices didn’t project their images, and accordingly could only be viewed by a single person at any one time. For this reason they were considered toys rather than devices for a large scale entertainment industry like later animation. Many of these devices are still built by and for film students learning the basic principles of animation.

**The magic lantern (c. 1650)**

The magic lantern is an early predecessor of the modern day projector. It consisted of a translucent oil painting, a simple lens and a candle or oil lamp. In a darkened room, the image would appear projected onto an adjacent flat surface. It was often used to project demonic, frightening images in a phantasmagoria that convinced people they were witnessing the supernatural. Some slides for the lanterns contained moving parts, which makes the magic lantern the earliest known example of projected animation. The origin of the magic lantern is debated, but in the 15th century the Venetian inventor Giovanni Fontana published an illustration
of a device that projected the image of a demon in his Liber Instrumentorum. The earliest known actual magic lanterns are usually credited to Christiaan Huygens or Athanasius Kircher.

**Thaumatrope (1824)**

A thaumatrope is a simple toy that was popular in the 19th century. It is a small disk with different pictures on each side, such as a bird and a cage, and is attached to two pieces of string. When the strings are twirled quickly between the fingers, the pictures appear to combine into a single image. This demonstrates the persistence of vision, the fact that the perception of an object by the eyes and brain continues for a small fraction of a second after the view is blocked or the object is removed. The invention of the device is often credited to Sir John Herschel, but John Ayrton Paris popularized it in 1824 when he demonstrated it to the Royal College of Physicians.

**Phenakistoscope (1831)**

The phenakistoscope was an early animation device. It was invented in 1831, simultaneously by the Belgian Joseph Plateau and the Austrian Simon von Stampfer. It consists of a disk with a series of images, drawn on radii evenly spaced around the center of the disk. Slots are cut out of the disk on the same radii as the drawings, but at a different distance from the center. The device would be placed in front of a mirror and spun. As the phenakistoscope spins, a viewer looks through the slots at the reflection of the drawings, are momentarily visible when a slot passes by the viewer’s eye. This created the illusion of animation.

**Zoetrope (1834)**

The zoetrope concept was suggested in 1834 by William George Horner, and from the 1860s marketed as the zoetrope. It operates on the same principle as the phenakistoscope. It was a cylindrical spinning device with several frames of animation printed on a paper strip placed around the interior circumference. The observer looks through vertical slits around the sides to view the moving
images on the opposite side as the cylinder spins. As it spins, the material between the viewing slits moves in the opposite direction of the images on the other side and in doing so serves as a rudimentary shutter. The zoetrope had several advantages over the basic phenakistoscope. It did not require the use of a mirror to view the illusion, and because of its cylindrical shape it could be viewed by several people at once.

In ancient China, people used a device that one 20th century historian categorized as “a variety of zoetrope.” It had a series of translucent paper or mica panels and was operated by being hung over a lamp so that vanes at the top would cause it to rotate as heated air rose from the lamp. It has been claimed that this rotation, if it reached the ideal speed, caused the same illusion of animation as the later zoetrope, but because there was no shutter (the slits in a zoetrope) or other provision for intermittence, the effect was in fact simply a series of horizontally drifting figures, with no true animation.

**Flip book (1868)**

John Barnes Linnett patented the first flip book in 1868 as the *kineograph*. A flip book is a small book with relatively springy pages, each having one in a series of animation images located near its unbound edge. The user bends all of the pages back, normally with the thumb, then by a gradual motion of the hand allows them to spring free one at a time. As with the phenakistoscope, zoetrope and praxinoscope, the illusion of motion is created by the apparent sudden replacement of each image by the next in the series, but unlike those other inventions no view-interrupting shutter or assembly of mirrors is required and no viewing device other than the user’s hand is absolutely necessary. Early film animators cited flip books as their inspiration more often than the earlier devices, which did not reach as wide an audience.

The older devices by their nature severely limit the number of images that can be included in a sequence without making the
device very large or the images impractically small. The book format still imposes a physical limit, but many dozens of images of ample size can easily be accommodated. Inventors stretched even that limit with the mutoscope, patented in 1894 and sometimes still found in amusement arcades. It consists of a large circularly-bound flip book in a housing, with a viewing lens and a crank handle that drives a mechanism that slowly rotates the assembly of images past a catch, size to match the running time of an entire reel of film.

**Praxinoscope (1877)**

The first known animated projection on a screen was created in France by Charles-Émile Reynaud, who was a French science teacher. Reynaud created the Praxinoscope in 1877 and the Théâtre Optique in December 1888. On 28 October 1892, he projected the first animation in public, *Pauvre Pierrot*, at the Musée Grévin in Paris. This film is also notable as the first known instance of film perforations being used. His films were not photographed, but drawn directly onto the transparent strip. In 1900, more than 500,000 people attended these screenings.

**TRADITIONAL ANIMATION**

The first film recorded on standard picture film that included animated sequences was the 1900 Enchanted Drawing, which was followed by the first entirely animated film, the 1906 *Humorous Phases of Funny Faces* by J. Stuart Blackton—who is, for this reason, considered the father of American animation.

In Europe, the French artist, Émile Cohl, created the first animated film using what came to be known as traditional animation creation methods—the 1908 *Fantasmagorie*. The film largely consisted of a stick figure moving about and encountering all manner of morphing objects, such as a wine bottle that transforms into a flower. There were also sections of live action where the animator’s hands would enter the scene. The film was created by drawing each frame on paper and then shooting each
frame onto negative film, which gave the picture a blackboard look.

The more detailed hand-drawn animations, requiring a team of animators drawing each frame manually with detailed backgrounds and characters, were those directed by Winsor McCay, a successful newspaper cartoonist, including the 1911 *Little Nemo*, the 1914 *Gertie the Dinosaur*, and the 1918 *The Sinking of the Lusitania*.

During the 1910s, the production of animated short films, typically referred to as “cartoons”, became an industry of its own and cartoon shorts were produced for showing in movie theaters. The most successful producer at the time was John Randolph Bray, who, along with animator Earl Hurd, patented the cel animation process that dominated the animation industry for the rest of the decade.

**The silent era**

Charles-Émile Reynaud’s Théâtre Optique is the earliest known example of projected animation. It predates even photographic motion picture devices such as Thomas Edison’s 1893 invention, the Kinetoscope, and the Lumière brothers’ 1894 invention, the cinematograph. Reynaud exhibited three of his animations on October 28, 1892 at Musée Grévin in Paris, France. The only surviving example of these three is *Pauvre Pierrot*, which was 500 frames long.

After the cinematograph popularized the motion picture, producers began to explore the endless possibilities of animation in greater depth. A short stop-motion animation was produced in 1908 by Albert E. Smith and J. Stuart Blackton called *The Humpty Dumpty Circus*. Stop motion is a technique in which real objects are moved around in the time between their images being recorded, so that when the images are viewed at a normal frame rate the objects appear to move by some invisible force. It directly descends from various early trick film techniques that created the illusion of impossible actions.
A few other films that featured stop motion technique were released afterward, but the first to receive wide scale appreciation was Blackton’s *Haunted Mansion*, which baffled viewers and inspired much further development. In 1906, Blackton also made the first drawn work of animation on standard film, *Humorous Phases of Funny Faces*. It features faces that are drawn on a chalkboard and then suddenly move autonomously.

*Fantasmagorie*, by the French director Émile Cohl (also called Émile Courtet), is also noteworthy. It was screened for the first time on August 17, 1908 at Théâtre du Gymnase in Paris. Cohl later went to Fort Lee, New Jersey near New York City in 1912, where he worked for French studio Éclair and spread its animation technique to the US.

*Katsudô Shashin*, from an unknown creator, was discovered in 2005 and is speculated to be the oldest work of animation in Japan, with Natsuki Matsumoto, an expert in iconography at the Osaka University of Arts and animation historian Nobuyuki Tsugata determining the film was most likely made between 1907 and 1911. The film consists of a series of cartoon images on fifty frames of a celluloid strip and lasts three seconds at sixteen frames per second. It depicts a young boy in a sailor suit who writes the kanji characters “;mÔR™Qw” (*katsudô shashin*, or “moving picture”), then turns towards the viewer, removes his hat, and offers a salute. Evidence suggests it was mass-produced to be sold to wealthy owners of home projectors. To Matsumoto, the relatively poor quality and low-tech printing technique indicate it was likely from a smaller film company.

Influenced by Émile Cohl, the author of the first puppet-animated film (i.e., *The Beautiful Lukanda* (1912)), Russian-born (ethnically Polish) director Wladyslaw Starewicz, known as Ladislas Starevich, started to create stop motion films using dead insects with wire limbs and later, in France, with complex and really expressive puppets. In 1911, he created *The Cameraman’s Revenge*, a complex tale of treason, and violence between several different insects. It is a pioneer work of puppet animation, and
the oldest animated film of such dramatic complexity, with characters filled with motivation, desire and feelings.

In 1914, American cartoonist Winsor McCay released *Gertie the Dinosaur*, an early example of character development in drawn animation. The film was made for McCay’s vaudeville act and as it played McCay would speak to Gertie who would respond with a series of gestures. There was a scene at the end of the film where McCay walked behind the projection screen and a view of him appears on the screen showing him getting on the cartoon dinosaur’s back and riding out of frame. This scene made *Gertie the Dinosaur* the first film to combine live action footage with hand drawn animation. McCay hand-drew almost every one of the 10,000 drawings he used for the film.

Also in 1914, John Bray opened John Bray Studios, which revolutionized the way animation was created. Earl Hurd, one of Bray’s employees patented the cel technique. This involved animating moving objects on transparent celluloid sheets. Animators photographed the sheets over a stationary background image to generate the sequence of images. This, as well as Bray’s innovative use of the assembly line method, allowed John Bray Studios to create Colonel Heeza Liar, the first animated series.

In 1915, Max and Dave Fleischer invented rotoscoping, the process of using film as a reference point for animation and their studios went on to later release such animated classics as *Ko-Ko the Clown, Betty Boop, Popeye the Sailor Man*, and *Superman*. In 1918 McCay released *The Sinking of the Lusitania*, a wartime propaganda film. McCay did use some of the newer animation techniques, such as cels over paintings—but because he did all of his animation by himself, the project wasn’t actually released until just shortly before the end of the war. At this point the larger scale animation studios were becoming the industrial norm and artists such as McCay faded from the public eye.

The first known animated feature film was *El Apóstol*, made in 1917 by Quirino Cristiani from Argentina. He also directed two other animated feature films, including 1931’s *Peludópolis*, the first
feature length animation to use synchronized sound. None of these, however, survived.

In 1920, Otto Messmer of Pat Sullivan Studios created Felix the Cat. Pat Sullivan, the studio head took all of the credit for Felix, a common practice in the early days of studio animation. Felix the Cat was distributed by Paramount Studios, and it attracted a large audience. Felix was the first cartoon to be merchandised. He soon became a household name.

In Germany, during the 1920s the abstract animation was invented by Walter Ruttmann, Hans Richter, and Oskar Fischinger, however, the Nazis censorship against so-called “degenerate art” prevented the abstract animation from developing after 1933.

The earliest surviving animated feature film is the 1926 silhouette-animated *Adventures of Prince Achmed*, which used colour-tinted film. It was directed by German Lotte Reiniger and French/Hungarian Berthold Bartosch.

**Walt Disney & Warner Bros.**

In 1923, a studio called Laugh-O-Grams went bankrupt and its owner, Walt Disney, opened a new studio in Los Angeles. Disney’s first project was the *Alice Comedies* series, which featured a live action girl interacting with numerous cartoon characters. Disney’s first notable breakthrough was 1928’s *Steamboat Willie*, the third of the Mickey Mouse series. It was the first cartoon that included a fully post-produced soundtrack, featuring voice and sound effects printed on the film itself (“sound-on-film”). The short film showed an anthropomorphic mouse named Mickey neglecting his work on a steamboat to instead make music using the animals aboard the boat.

In 1933, Warner Brothers Cartoons was founded. While Disney’s studio was known for its releases being strictly controlled by Walt Disney himself, Warner brothers allowed its animators more freedom, which allowed for their animators to develop more recognizable personal styles.
The first animation to use the full, three-color Technicolor method was *Flowers and Trees*, made in 1932 by Disney Studios, which won an Academy Award for the work. Color animation soon became the industry standard, and in 1934, Warner Brothers released *Honeymoon Hotel* of the Merrie Melodies series, their first color films. Meanwhile, Disney had realized that the success of animated films depended upon telling emotionally gripping stories; he developed an innovation called a “story department” where storyboard artists separate from the animators would focus on story development alone, which proved its worth when the Disney studio released in 1933 the first-ever animated short to feature well-developed characters, *Three Little Pigs*. In 1935, Tex Avery released his first film with Warner Brothers. Avery’s style was notably fast paced, violent, and satirical, with a slapstick sensibility.

**Snow White and the Seven Dwarfs**

Many consider Walt Disney’s 1937 *Snow White and the Seven Dwarfs* the first animated feature film, though at least seven films were released earlier. However, Disney’s film was the first one completely made using hand-drawn animation. The previous seven films, of which only four survive, were made using cutout, silhouette or stop motion, except for one—also made by Disney seven months prior to Snow White’s release—*Academy Award Review of Walt Disney Cartoons*. This was an anthology film to promote the upcoming release of Snow White. However, many do not consider this a genuine feature film because it is a package film. In addition, at approximately 41 minutes, the film does not seem to fulfill today’s expectations for a feature film. However, the official BFI, AMPAS and AFI definitions of a feature film require that it be over 40 minutes long, which, in theory, should make it the first animated feature film using traditional animation.

But as Snow White was also the first one to become successful and well-known within the English-speaking world, people tend to disregard the seven films. Following Snow White’s release, Disney began to focus much of its productive force on feature-
length films. Though Disney did continue to produce shorts throughout the century, Warner Brothers continued to focus on features.

The television era

Color television was introduced to the US Market in 1951. In 1958, Hanna-Barbera released *Huckleberry Hound*, the first half-hour television program to feature only animation. Terrytoons released *Tom Terrific* the same year. In 1960, Hanna-Barbera released another monumental animated television show, *The Flintstones*, which was the first animated series on prime time television. Television significantly decreased public attention to the animated shorts being shown in theatres.

ANIMATION TECHNIQUES

Innumerable approaches to creating animation have arisen throughout the years. Here is a brief account of some of the non traditional techniques commonly incorporated.

Stop motion

This process is used for many productions, for example, the most common types of puppets are clay puppets, as used in *The California Raisins*, *Wallace and Gromit* and *Shaun the Sheep* by Aardman, and figures made of various rubbers, cloths and plastic resins, such as *The Nightmare Before Christmas* and *James and the Giant Peach*. Sometimes even objects are used, such as with the films of Jan Švankmajer.

Stop motion animation was also commonly used for special effects work in many live-action films, such as the 1933 version of *King Kong* and *The 7th Voyage of Sinbad*.

CGI animation

Computer-generated imagery (CGI) revolutionized animation. The first fully computer-animated feature film was Pixar’s *Toy Story* (1995). The process of CGI animation is still very tedious and
similar in that sense to traditional animation, and it still adheres to many of the same principles.

A principal difference of CGI animation compared to traditional animation is that drawing is replaced by 3D modeling, almost like a virtual version of stop-motion. A form of animation that combines the two and uses 2D computer drawing can be considered computer aided animation.

Most CGI created films are based on animal characters, monsters, machines, or cartoon-like humans. Animation studios are now trying to develop ways to create realistic-looking humans. Films that have attempted this include Final Fantasy: The Spirits Within in 2001, Final Fantasy: Advent Children in 2005, The Polar Express in 2004, Beowulf in 2007 and Resident Evil: Degeneration in 2009. However, due to the complexity of human body functions, emotions and interactions, this method of animation is rarely used. The more realistic a CG character becomes, the more difficult it is to create the nuances and details of a living person, and the greater the likelihood of the character falling into the uncanny valley. The creation of hair and clothing that move convincingly with the animated human character is another area of difficulty. The Incredibles and Up both have humans as protagonists, while films like Avatar combine animation with live action to create humanoid creatures.

Cel-shading is a type of non-photorealistic rendering intended to make computer graphics appear hand-drawn. It is often used to mimic the style of a comic book or cartoon. It is a somewhat recent addition to computer graphics, most commonly turning up in console video games. Though the end result of cel-shading has a very simplistic feel like that of hand-drawn animation, the process is complex. The name comes from the clear sheets of acetate (originally, celluloid), called cels, that are painted on for use in traditional 2D animation. It may be considered a “2.5D” form of animation. True real-time cel-shading was first introduced in 2000 by Sega’s Jet Set Radio for their Dreamcast console. Besides video games, a number of anime have also used this style of animation,
such as Freedom Project in 2006. Machinima is the use of real-time 3D computer graphics rendering engines to create a cinematic production. Most often, video games are used to generate the computer animation. Machinima-based artists, sometimes called machinimists or machinimators, are often fan laborers, by virtue of their re-use of copyrighted materials.

ASIA

History of Chinese animation
- 1922: first animation in a commercial Shuzhendong Chinese Typewriter
- 1926: first animation to showcase technology Uproar in the Studio and acknowledge Wan Laiming and Wan Guchan as pioneers.
- 1935: The Camel’s Dance - first chinese animation with sound.
- 1941: Princess Iron Fan
- 1980: Three Monks

History of Indian animation
- 1974: Ek Anek Aur Ekta
- 1978: The Hunt
- 1986: Ghayab Aaya
- 1992: Ramayana: The Legend of Prince Rama

History of Iranian animation

Iran’s animation owes largely to the animator Noureddin Zarrinkelk. Zarrinkelk was instrumental in founding the Institute for Intellectual Development of Children and Young Adults (IIDCYA) in Tehran in collaboration with the late father of Iranian graphics Morteza Momayez and other fellow artists like Farshid Mesghali, Ali Akbar Sadeghi, and Arapik Baghdasarian.
- Circa 3000 BCE: Zoopraxiscope-style animated pottery is produced. This is considered one of the oldest forms of animation in the world.
• 1970: Duty, First
• 1971: A Playground for Baboush
• 1971: Philipo and a Train from Hong Kong
• 1971: Seven Cities
• 1972: Shower of Flowers
• 1973: Association Of Ideas
• 1973: I Am He Who…
• 1974: Atal-Matal
• 1974: The Castle
• 1975: The Mad, Mad, Mad World
• 1975: The Sun King

History of Japanese animation (Anime)
• Circa 1915: Discovered in Kyoto in 2005, the earliest known Japanese animated film is *Katsudō Shashin (Moving Picture)*, which depicts a boy wearing a sailor uniform performing a salute. The undated film is considered among the earliest examples of Japanese animation. The discoverer speculates that it is from as early as 1907. It is composed of 50 frames assembled on 35mm Celluloid with paste.
• 1917: *Imokawa Mukuzo Genkanban no Maki*
• 1917: *Namakura Gatana*
• 1918: *Urashima Tarō*
• 1921: *Kiatsu to Mizuage Ponpu*
• 1922: *Shokubutsu Seiri: Seishoku no Maki*
• 1924: *Usagi to Kame*
• 1945: *Momotaro’s Divine Sea Warriors*
• 1958: *The Tale of the White Serpent*
• 1963: *Astro Boy*
• 1968: *Hols: Prince of the Sun*
• 1970: *Ashita no Joe*
• 1974: *Space Battleship Yamato*
• 1979: *Mobile Suit Gundam*
• 1979: *The Castle of Cagliostro*
• 1984: *Nausicaä of the Valley of the Wind*
Aspects of Animation: Steps to Learn Animated Cartoons

- 1984: Lensman: Secret of The Lens
- 1987: Wicked City
- 1988: The Adventures of Lolo the Penguin
- 1988: My Neighbor Totoro
- 1988: Grave of the Fireflies
- 1988: Akira
- 1993: Ninja Scroll
- 1995: Neon Genesis Evangelion
- 1995: Ghost in the Shell
- 1997: Princess Mononoke
- 1998: Hunter x Hunter
- 2000: Vampire Hunter D: Bloodlust
- 2001: Spirited Away
- 2001: Millennium Actress
- 2004: Howl’s Moving Castle
- 2006: Paprika
- 2008: Ponyo
- 2011: Hunter x Hunter
- 2013: The Wind Rises
- 2014: The Tale of the Princess Kaguya

EUROPE

History of British animation

- 1899: Arthur Melbourne-Cooper’s “Matches Appeal”
- 1954: Animal Farm
- 1978: Watership Down
- 1982: Plague Dogs
- 1982: SuperTed
- 1990: The Dreamstone
- 1999: Watership Down

History of Czech animation

The roots of Czech puppet animation began in the mid-1940s when puppet theater operators, Eduard Hofman and Jiří Trnka
founded the Poetic animation school, Bratøí v Triku. Since that
time animation has expanded and flourished.

- 1945: Dídek zasadil øepu ("My grandfather planted a beet")
- 1946: Zvíøátka to petrovstí ("Animals and bandits")
- 1946: Pérak SS ("The jumper and the men of the SS")
- 1946: Dárek ("The Gift")
- 1949: Román s basou ("Story of a bass")
- 1949: Èertuv mlýn ("The Devil's Mill")
- 1949: Arie prerie ("Song of the Prairie")
- 1949: Císaøùv Slavík ("The Emperor's Nightingale")

History of Estonian animation

Estonian animation began in the 1930s and has carried on into
the modern day.

- 1931 - The Adventures of Juku the Dog, first Estonian animated
  short film
- 1950s - founding of puppet animation division of
  Tallinnfilm by Elbert Tuganov
- 1970s - founding of drawn animation division, Joonisfilm,
  by Rein Raamat

History of French animation

- 1908-1925, The work of animation pioneer Émile Cohl
  produces a number of firsts in animation and animation
techniques.
- 1908: The first animated cartoon
- 1909: First use of morphing
- 1910: First use of puppet animation and first color-animated
cartoon
- 1911: First use of pixilation
- 1916: La journée de Flambeau becomes the first animated
  series. (Also known as Flambeau, chien perdu)

History of Hungarian animation

- 1914: István Kató Kiszly first becomes involved in cut-out
  promotional animations for use during newsreels.
Aspects of Animation: Steps to Learn Animated Cartoons

- 1932: Gyula Macskássy and János Halász establish Hungary's first animation studio, Coloriton.
- 1930-1940: Hungarian animators such as Jean Image, George Pal, and John Halas emigrate from Hungary due to political instability and settle abroad.
- 1948: All film-making is nationalized by the Hungarian Communist Party under Magyar Szinkronfilmgyártó Vállalat (later rechristened as Pannónia Film Stúdió).
- 1962: Gyula Macskássy and György Várnai create Hungary's first animated serial, the *Petti* series.
- 1981: Ferenc Rofusz wins the 1981 Academy Award for Best Animated Short Film with *A Légy*.
- 1985 - Hungary holds its first Hungarian Animated Cartoon Festival in Kecskemét.
- 1990 - Communism ends, and with it state support for Pannónia Film Stúdió. Independent studios like Varga Studio and Digic Pictures emerge.

History of Italian animation

- 1949: The first two Italian animated movies are released: *La rosa di Bagdad* directed by Anton Gino Domeneghini and *I Fratelli Dinamite* directed by Nino Pagot.
- 1970: The Italian animated cartoon art and industry (La Linea (cartoon), Caliméro...) is born.
- 1977: The animated Italian classic, *Allegro non troppo*, is both a parody of and homage to Disney’s *Fantasia*. This is director Bruno Bozetto’s most ambitious work and his only feature-length animation, although he also directed several notable shorter works including *West and Soda*, an animated spaghetti western.
History of Russian animation

- 1910-1913: Ladislas Starevich creates puppet animations
- 1935: Soyuzmultfilm Studio is created.
- Late 1930s to 1950s: Socialist Realism in cartoons:
  - 1947: The Humpbacked Horse
  - 1952: The Scarlet Flower
  - 1955: The Enchanted Boy
  - 1956: The Twelve Months
  - 1957: The Snow Queen
- 1969: Gena the Crocodile, the first Cheburashka short is made.
- 1973: The Nutcracker
- 1975: Hedgehog in the Fog
- 1978: Three from Prostokvashino
- 1979: Tale of Tales
- 1981: The Mystery of the Third Planet
- 1982: Once Upon a Dog
- 1987: The Adventures of Lolo the Penguin
- 1990s: government subsidies shrink dramatically, while the number of studios grow.
- 1999: The Old Man and the Sea
- Since 2001: Internet era in the Russian independent animation: Masyanya, Mr. Freeman and the others.
- 2004-2012: Kikoriki (Smeshariki) series.
- Since 2009: Masha and the Bear series.

History of animation in Croatia (in former Yugoslavia)

- 1953: Zagreb Film inaugurates the Zagreb school of animation.
1975: Škola Animiranog Filma Šakovec (ŠAF) inaugurates the Šakovec school of animation.

AMERICAS

History of Argentinian animation

The world’s first two feature-length animated films and the first film with sound were developed in Argentina by Quirino Cristiani;
- 1917: El Apóstol
- 1918: Sin dejar rastros

History of Brazilian animation

- 1917: Álvaro Marins produces Kaiser, Brazil's first animated short film
- 1953: Anélio Lattini Filho produces Amazon Symphony, Brazil’s first animated feature-length film
- 1996: NDR Filmes produces Cassiopéia, considered for some as the first CG movie in the world.

History of Canadian animation

- 1914: Raoul Barré of Barré Studio produces animated segments for Animated Grouch Chaser
- 1916: Raoul Barré produces Mutt and Jeff
- 1926: Raoul Barré works as guest animator for Felix the Cat
- 1941: The National Film Board of Canada’s animation department is founded with the addition of Norman McLaren to the organization.

History of Cuban animation

- 1970: Juan Padrón creates the character of Elpidio Valdés, star of a long-running series of shorts and two motion pictures.
- 1985: Juan Padrón’s ¡Vampiros en la Habana!
- 1992: An animation category is added to the Festival Internacional del Nuevo Cine Latinoamericano
History of Mexican animation

• 1935: Alfonso Vergara produces Paco Perico en premier, animated short film.
• 1974: Fernando Ruiz produces Los tres reyes magos, Mexico’s first animated feature-length film.
• 1977: ANUAR BADIN creates the film, Los supersabios. Based on the comic.
• 1983: Roy del espacio

History of United States animation

Beginning of industrial production of animated cartoon.

The history of Hollywood animation as an art form has undergone many changes in its hundred-year history, the following lists four separate chapters in the development of its animation:

Animation in the United States during the silent era (1900s through 1920s)

• The beginnings of theatrical, the earliest animated cartoons in the era of silent film, ranging from the works of Winsor McCay through Koko the Clown and Felix the Cat
• The Bray Studios was the first and foremost cartoon studio, housed in New York City. Many aspiring cartoonists started their careers at Bray, including Paul Terry of “Mighty Mouse” fame, Max Fleischer of “Betty Boop” fame, as well as Walter Lantz of “Woody Woodpecker” fame. The cartoon studio operated from c. 1915 until 1928. Some of the first cartoon stars from the Bray studios were Farmer Alfalfa (by Paul Terry) and Bobby Bumps (by Earl Hurd).
• Max and Dave Fleischer formed their own studio Fleischer Studios, and created the Koko the Clown, Out of the Inkwell, and Sound Car-Tunes series.

Golden Age of American animation (1930s through 1950s)

• The dominance of Walt Disney throughout the 1930s, through revolutionary cartoons Silly Symphonies, Mickey Mouse, and Donald Duck.
• The rise of Warner Bros. and MGM
Aspects of Animation: Steps to Learn Animated Cartoons

- The Fleischer Studios creation of Betty Boop and Popeye the Sailor
- Disney’s Snow White and The Seven Dwarfs marks the start of the “Golden Age” at Disney.
- The departure from realism, and UPA

Animation in the United States in the television era (1960s through Mid-1980s)
- 1938: Chad Grothkopf’s eight-minute experimental Willie the Worm, cited as the first animated film created for TV, was shown on NBC.
- The decline of theatrical cartoons and feature films
- The rise of Saturday morning cartoons
- The attempts at reviving animated features through the 1960s
- The rise of adult animation in the early 1970s
- The onslaught of commercial cartoons in the 1980s

Modern animation in the United States (Late-1980s through present)
- Who Framed Roger Rabbit and the Disney Renaissance
- Steven Spielberg’s collaborations with Warner Bros.
- The Simpsons marks the resurgence of adult-oriented animation.
- The rise of computer animation, for both 2D and 3D (CGI) animation
- The decline of traditional animation
- The decline of Saturday morning cartoons, the rise of Nickelodeon, Disney Channel and Cartoon Network
- The Anime Explosion: mainstream popularization of Japanese animation, known as anime. Toonami/Cartoon Network contributes largely to the success.
- “South Park” mimicks cut-out animation by using computer animation.
- Cartoon Network's late-night animation block Adult Swim becomes immensely popular and leads to a resurgence in short, adult animation.
INTRODUCTION

An animation database is a database which stores fragments of animations or human movements and which can be accessed, analyzed and queried to develop and assemble new animations. Given that the manual generation of a large amount of animation can be time consuming and expensive, an animation database can assist users in building animations by using existing components, and sharing animation fragments.

A dancer’s movements, captured via optical motion capture can be stored in an animation database, then analyzed and reused.
Early examples of animation databases include the system MOVE which used an object oriented database. Modern animation databases can be populated via the extraction of skeletal animations from motion capture data.

Other examples include crowd simulation in which a number of people are simulated as a crowd. Given that in some applications the people need to be walking at different speeds, say on a sidewalk, the animation database can be used to retrieve and merge different animated figures. The method is mainly known as “motion graphs”.

Animation databases can also be used for “interactive storytelling” in which fragments of animations are retrieved from the animation database and are recycled to combine into new stories. For instance, the animation database called Animebase is used within the system Words Anime to help generate animations using recycled components. In this approach, the user may input words which form parts of a story and queries against the database help select suitable animation fragments. This type of system may indeed use two databases: an animation database, as well as a story knowledge database. The story knowledge database may use subjects, predicates and objects to refer to story fragments. The system then assists the user in matching between story fragments and animation fragments.

Animation databases can also be used for the generation of visual scenes using humanoid models. An example application has been the development of an animated humanoid-based sign language system to help the disabled.

Another application of an animation database is in the synthesis of idle motion for human characters. Human beings move all the time and in unique ways, and the presentation of a consistent and realistic set of idle motions for each character between different animation segments has been a challenge, e.g. each person has a unique way of standing and this needs to be represented in a realistic way throughout an animation. One of the problems is that idle motion affects all joints and simply showing statistical
movements at each joint results in less than realistic portrayals. One approach to solving this problem is to use an animation database with a large set of pre-recorded human movements, and obtain the suitable patterns of motion from the database through statistical analysis.

**DATABASE DESIGN**

Database design is the process of producing a detailed data model of a database. This data model contains all the needed logical and physical design choices and physical storage parameters needed to generate a design in a data definition language, which can then be used to create a database. A fully attributed data model contains detailed attributes for each entity.

The term database design can be used to describe many different parts of the design of an overall database system. Principally, and most correctly, it can be thought of as the logical design of the base data structures used to store the data. In the relational model these are the tables and views. In an object database the entities and relationships map directly to object classes and named relationships. However, the term database design could also be used to apply to the overall process of designing, not just the base data structures, but also the forms and queries used as part of the overall database application within the database management system (DBMS).

The process of doing database design generally consists of a number of steps which will be carried out by the database designer. Usually, the designer must:

- Determine the data to be stored in the database.
- Determine the relationships between the different data elements.
- Superimpose a logical structure upon the data on the basis of these relationships.

Within the relational model the final step above can generally be broken down into two further steps, that of determining the
grouping of information within the system, generally determining what are the basic objects about which information is being stored, and then determining the relationships between these groups of information, or objects. This step is not necessary with an Object database.

**Determining data to be stored**

In a majority of cases, a person who is doing the design of a database is a person with expertise in the area of database design, rather than expertise in the domain from which the data to be stored is drawn e.g. financial information, biological information etc. Therefore, the data to be stored in the database must be determined in cooperation with a person who does have expertise in that domain, and who is aware of what data must be stored within the system.

This process is one which is generally considered part of requirements analysis, and requires skill on the part of the database designer to elicit the needed information from those with the domain knowledge. This is because those with the necessary domain knowledge frequently cannot express clearly what their system requirements for the database are as they are unaccustomed to thinking in terms of the discrete data elements which must be stored. Data to be stored can be determined by Requirement Specification.

**Determining data relationships**

Once a database designer is aware of the data which is to be stored within the database, they must then determine where dependency is within the data. Sometimes when data is changed you can be changing other data that is not visible. For example, in a list of names and addresses, assuming a situation where multiple people can have the same address, but one person cannot have more than one address, the address is dependent upon the name. When provided a name and the list the address can be uniquely determined; however, the inverse does not hold - when given an address and the list, a name cannot be uniquely
determined because multiple people can reside at an address. Because an address is determined by a name, an address is considered dependent on a name.

**Logically structuring data**

Once the relationships and dependencies amongst the various pieces of information have been determined, it is possible to arrange the data into a logical structure which can then be mapped into the storage objects supported by the database management system. In the case of relational databases the storage objects are tables which store data in rows and columns. In an Object database the storage objects correspond directly to the objects used by the Object-oriented programming language used to write the applications that will manage and access the data. The relationships may be defined as attributes of the object classes involved or as methods that operate on the object classes.

The way this mapping is generally performed is such that each set of related data which depends upon a single object, whether real or abstract, is placed in a table. Relationships between these dependent objects is then stored as links between the various objects.

Each table may represent an implementation of either a logical object or a relationship joining one or more instances of one or more logical objects. Relationships between tables may then be stored as links connecting child tables with parents. Since complex logical relationships are themselves tables they will probably have links to more than one parent.

**ER DIAGRAM (ENTITY-RELATIONSHIP MODEL)**

Database designs also include ER (entity-relationship model) diagrams. An ER diagram is a diagram that helps to design databases in an efficient way.

Attributes in ER diagrams are usually modeled as an oval with the name of the attribute, linked to the entity or relationship that contains the attribute.
A design process suggestion for Microsoft Access

1. Determine the purpose of the database - This helps prepare for the remaining steps.

2. Find and organize the information required - Gather all of the types of information to record in the database, such as product name and order number.

3. Divide the information into tables - Divide information items into major entities or subjects, such as Products or Orders. Each subject then becomes a table.

4. Turn information items into columns - Decide what information needs to be stored in each table. Each item becomes a field, and is displayed as a column in the table. For example, an Employees table might include fields such as Last Name and Hire Date.

5. Specify primary keys - Choose each table’s primary key. The primary key is a column, or a set of columns, that is used to uniquely identify each row. An example might be Product ID or Order ID.

6. Set up the table relationships - Look at each table and decide how the data in one table is related to the data in other tables. Add fields to tables or create new tables to clarify the relationships, as necessary.

7. Refine the design - Analyze the design for errors. Create tables and add a few records of sample data. Check if results come from the tables as expected. Make adjustments to the design, as needed.

8. Apply the normalization rules - Apply the data normalization rules to see if tables are structured correctly. Make adjustments to the tables.

NORMALIZATION

In the field of relational database design, normalization is a systematic way of ensuring that a database structure is suitable for general-purpose querying and free of certain undesirable characteristics—insertion, update, and deletion—that could lead to loss of data integrity. A standard piece of database design
guidance is that the designer should create a fully normalized design; selective denormalization can subsequently be performed, but only for performance reasons. However, some modeling disciplines, such as the dimensional modeling approach to data warehouse design, explicitly recommend non-normalized designs, i.e. designs that in large part do not adhere to 3NF. Normalization consists of normal forms that are 1NF, 2NF, 3NF, BOYCE-CODD NF (3.5NF), 4NF and 5NF

**Conceptual schema**

**Schema refinement**

Schema refinement of the database specifies that the data is normalized to reduce data insufficiency and conflicts.

**Physical design**

The physical design of the database specifies the physical configuration of the database on the storage media. This includes detailed specification of data elements, data types, indexing options and other parameters residing in the DBMS data dictionary. It is the detailed design of a system that includes modules & the database’s hardware & software specifications of the system.

**SKELETAL ANIMATION**

'Bones' (in green) used to pose a hand. In practice, the 'bones' themselves are often hidden and replaced by more user-friendly objects. In this example from the open source project Blender, these 'handles' (in blue) have been scaled down to bend the fingers. The bones are still controlling the deformation, but the animator only sees the 'handles'.
Skeletal animation is a technique in computer animation in which a character is represented in two parts: a surface representation used to draw the character (called skin or mesh) and a hierarchical set of interconnected bones (called the skeleton or rig) used to animate (pose and keyframe) the mesh.

While this technique is often used to animate humans or more generally for organic modeling, it only serves to make the animation process more intuitive and the same technique can be used to control the deformation of any object—a door, a spoon, a building, or a galaxy.

When the animated object is more general than for example a humanoid character the set of bones may not be hierarchical or interconnected, but it just represents a higher level description of the motion of the part of mesh or skin it is influencing.

This technique is used in virtually all animation systems where simplified user interfaces allows animators to control often complex algorithms and a huge amount of geometry; most notably through inverse kinematics and other “goal-oriented” techniques. In principle, however, the intention of the technique is never to imitate real anatomy or physical processes, but only to control the deformation of the mesh data.

**TECHNIQUE**

“Rigging is making our characters able to move. The process of rigging is we take that digital sculpture, and we start building the skeleton, the muscles, and we attach the skin to the character, and we also create a set of animation controls, which our animators use to push and pull the body around.”

— Frank Hanner, character CG supervisor of the Walt Disney Animation Studios, provided a basic understanding on the technique of character rigging.

This technique is used by constructing a series of ‘bones,’ sometimes referred to as rigging. Each bone has a three-dimensional transformation (which includes its position, scale and orientation),
and an optional parent bone. The bones therefore form a hierarchy. The full transform of a child node is the product of its parent transform and its own transform.

So moving a thigh-bone will move the lower leg too. As the character is animated, the bones change their transformation over time, under the influence of some animation controller.

A rig is generally composed of both forward kinematics and inverse kinematics parts that may interact with each other. Skeletal animation is referring to the forward kinematics part of the rig, where a complete set of bones configurations identifies a unique pose.

Each bone in the skeleton is associated with some portion of the character’s visual representation. Skinning is the process of creating this association.

In the most common case of a polygonal mesh character, the bone is associated with a group of vertices; for example, in a model of a human being, the ‘thigh’ bone would be associated with the vertices making up the polygons in the model’s thigh. Portions of the character’s skin can normally be associated with multiple bones, each one having a scaling factors called vertex weights, or blend weights.

The movement of skin near the joints of two bones, can therefore be influenced by both bones. In most state-of-the-art graphical engines, the skinning process is done on the GPU thanks to a shader program.

For a polygonal mesh, each vertex can have a blend weight for each bone. To calculate the final position of the vertex, a transformation matrix is created for each bone which, when applied to the vertex, first puts the vertex in bone space then puts it back into mesh space, the vertex. After applying a matrix to the vertex, it is scaled by its corresponding weight. This algorithm is called matrix palette skinning, because the set of bone transformations (stored as transform matrices) form a palette for the skin vertex to choose from.
Benefits and drawbacks

Strengths

- Bone represents a set of vertices (or some other objects, which represent for example a leg).
- Animator controls fewer characteristics of the model
- Animator can focus on the large scale motion.
- Bones are independently movable.

An animation can be defined by simple movements of the bones, instead of vertex by vertex (in the case of a polygonal mesh).

Weaknesses

- Bone represents a set of vertices (or some other object).
- Does not provide realistic muscle movement and skin motion
- Possible solutions to this problem:
  - Special muscle controllers attached to the bones
  - Consultation with physiology experts (increase accuracy of musculoskeletal realism with more thorough virtual anatomysimulations)

Applications

Skeletal animation is the standard way to animate characters or mechanical objects for a prolonged period of time (usually over 100 frames). It is commonly used by video game artists and in the movie industry, and can also be applied to mechanical objects and any other object made up of rigid elements and joints.

Performance capture (or motion capture) can speed up development time of skeletal animation, as well as increasing the level of realism.

For motion that is too dangerous for performance capture, there are computer simulations that automatically calculate physics of motion and resistance with skeletal frames. Virtual anatomy properties such as weight of limbs, muscle reaction, bone strength
and joint constraints may be added for realistic bouncing, buckling, fracture and tumbling effects known as virtual stunts. However, there are other applications of virtual anatomy simulations such as military and emergency response.

Virtual soldiers, rescue workers, patients, passengers and pedestrians can be used for training, virtual engineering and virtual testing of equipment. Virtual anatomy technology may be combined with artificial intelligence for further enhancement of animation and simulation technology.
INTRODUCTION

Computer-generated imagery (CGI for short) is the application of computer graphics to create or contribute to images in art, printed media, video games, films, television programs, shorts, commercials, videos, and simulators. The visual scenes may be dynamic or static, and may be two-dimensional (2D), though the term “CGI” is most commonly used to refer to 3D computer graphics used for creating scenes or special effects in films and television. Additionally, the use of 2D CGI is often mistakenly referred to as “traditional animation”, most often in the case when dedicated animation software such as Adobe Flash or Toon Boom is not used and/or the CGI is hand drawn using (a) tablet(s) and/or mouse.

The term ‘CGI animation’ refers to dynamic CGI rendered as a movie. The term virtual world refers to agent-based, interactive environments. Computer graphics software is used to make computer-generated imagery for films, etc. Availability of CGI software and increased computer speeds have allowed individual artists and small companies to produce professional-grade films, games, and fine art from their home computers. This has brought about an Internet subculture with its own set of global celebrities,
clichés, and technical vocabulary. The evolution of CGI led to the emergence of virtual cinematography in the 1990s where runs of the simulated camera are not constrained by the laws of physics.

STATIC IMAGES AND LANDSCAPES

Not only do animated images form part of computer-generated imagery, natural looking landscapes (such as fractal landscapes) are also generated via computer algorithms. A simple way to generate fractal surfaces is to use an extension of the triangular mesh method, relying on the construction of some special case of a de Rham curve, e.g. midpoint displacement. For instance, the algorithm may start with a large triangle, then recursively zoom in by dividing it into four smaller Sierpinski triangles, then interpolate the height of each point from its nearest neighbors. The creation of a Brownian surface may be achieved not only by adding noise as new nodes are created, but by adding additional noise at multiple levels of the mesh. Thus a topographical map with varying levels of height can be created using relatively straightforward fractal algorithms. Some typical, easy-to-program fractals used in CGI are the plasma fractal and the more dramatic fault fractal.

The large number of specific techniques have been researched and developed to produce highly focused computer-generated effects — e.g. the use of specific models to represent the chemical weathering of stones to model erosion and produce an “aged appearance” for a given stone-based surface.

Architectural scenes

Modern architects use services from computer graphic firms to create 3-dimensional models for both customers and builders. These computer generated models can be more accurate than traditional drawings. Architectural animation (which provides animated movies of buildings, rather than interactive images) can also be used to see the possible relationship a building will have in relation to the environment and its surrounding buildings. The
rendering of architectural spaces without the use of paper and pencil tools is now a widely accepted practice with a number of computer-assisted architectural design systems.

Architectural modelling tools allow an architect to visualize a space and perform “walk-throughs” in an interactive manner, thus providing “interactive environments” both at the urban and building levels. Specific applications in architecture not only include the specification of building structures (such as walls and windows) and walk-throughs, but the effects of light and how sunlight will affect a specific design at different times of the day.

Architectural modelling tools have now become increasingly internet-based. However, the quality of internet-based systems still lags behind those of sophisticated inhouse modelling systems.

In some applications, computer-generated images are used to “reverse engineer” historical buildings. For instance, a computer-generated reconstruction of the monastery at Georgenthal in Germany was derived from the ruins of the monastery, yet provides the viewer with a “look and feel” of what the building would have looked like in its day.

ANATOMICAL MODELS

Computer generated models used in skeletal animation are not always anatomically correct. However, organizations such as the Scientific Computing and Imaging Institute have developed anatomically correct computer-based models. Computer generated anatomical models can be used both for instructional and operational purposes. To date, a large body of artist produced medical images continue to be used by medical students, such as images by Frank Netter, e.g. Cardiac images. However, a number of online anatomical models are becoming available.

A single patient X-ray is not a computer generated image, even if digitized. However, in applications which involve CT scans a three dimensional model is automatically produced from a large number of single slice x-rays, producing “computer
generated image”. Applications involving magnetic resonance imaging also bring together a number of “snapshots” (in this case via magnetic pulses) to produce a composite, internal image.

In modern medical applications, patient specific models are constructed in ‘computer assisted surgery’. For instance, in total knee replacement, the construction of a detailed patient specific model can be used to carefully plan the surgery. These three dimensional models are usually extracted from multiple CT scans of the appropriate parts of the patient’s own anatomy. Such models can also be used for planning aortic valve implantations, one of the common procedures for treating heart disease. Given that the shape, diameter and position of the coronary openings can vary greatly from patient to patient, the extraction (from CT scans) of a model that closely resembles a patient’s valve anatomy can be highly beneficial in planning the procedure.

**GENERATING CLOTH AND SKIN IMAGES**

Models of cloth generally fall into three groups:
- The geometric-mechanical structure at yarn crossing
- The mechanics of continuous elastic sheets
- The geometric macroscopic features of cloth.

To date, making the clothing of a digital character automatically fold in a natural way remains a challenge for many animators.

In addition to their use in film, advertising and other modes of public display, computer generated images of clothing are now routinely used by top fashion design firms.

The challenge in rendering human skin images involves three levels of realism:
- Photo realism in resembling real skin at the static level
- Physical realism in resembling its movements
- Function realism in resembling its response to actions.

The finest visible features such as fine wrinkles and skin pores are size of about 100 µm or 0.1 millimetres. Skin can be modelled
as a 7-dimensional bidirectional texture function (BTF) or a collection of bidirectional scattering distribution function (BSDF) over the target’s surfaces.

**INTERACTIVE SIMULATION AND VISUALIZATION**

Interactive visualization is a general term that applies to the rendering of data that may vary dynamically and allowing a user to view the data from multiple perspectives. The applications areas may vary significantly, ranging from the visualization of the flow patterns in fluid dynamics to specific computer aided design applications. The data rendered may correspond to specific visual scenes that change as the user interacts with the system — e.g. simulators, such as flight simulators, make extensive use of CGI techniques for representing the world.

At the abstract level an interactive visualization process involves a “data pipeline” in which the raw data is managed and filtered to a form that makes it suitable for rendering. This is often called the “visualization data”. The visualization data is then mapped to a “visualization representation” that can be fed to a rendering system. This is usually called a “renderable representation”. This representation is then rendered as a displayable image. As the user interacts with the system (e.g. by using joystick controls to change their position within the virtual world) the raw data is fed through the pipeline to create a new rendered image, often making real-time computational efficiency a key consideration in such applications.

**COMPUTER ANIMATION**

While computer generated images of landscapes may be static, the term computer animation only applies to dynamic images that resemble a movie. However, in general the term computer animation refers to dynamic images that do not allow user interaction, and the term virtual world is used for the interactive animated environments.
Computer animation is essentially a digital successor to the art of stop motion animation of 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 screen and repeatedly replaced by a new image which is similar to the previous image, but advanced slightly in the time domain (usually at a rate of 24 or 30 frames/second). This technique is identical to how the illusion of movement is achieved with television and motion pictures.

Virtual worlds

A yellow submarine in Second Life.

Metallic balls

A virtual world is a simulated environment, which allows user to interact with animated characters, or interact with other
users through the use of animated characters known as avatars. Virtual worlds are intended for its users to inhabit and interact, and the term today has become largely synonymous with interactive 3D virtual environments, where the users take the form of avatars visible to others graphically. These avatars are usually depicted as textual, two-dimensional, or three-dimensional graphical representations, although other forms are possible (auditory and touch sensations for example). Some, but not all, virtual worlds allow for multiple users.

In Courtrooms

Computer-generated imagery has been used in courtrooms, primarily since the early 2000s. However, some experts have argued that it is prejudicial. They are used to help judges or the jury to better visualize the sequence of events, evidence or hypothesis. However, a 1997 study showed that people are poor intuitive physicists and easily influenced by computer generated images. Thus it is important that jurors and other legal decision-makers be made aware that such exhibits are merely a representation of one potential sequence of events.

FRACTAL LANDSCAPE

A fractal landscape is a surface generated using a stochastic algorithm designed to produce fractal behaviour that mimics the appearance of natural terrain. In other words, the result of the procedure is not a deterministic fractal surface, but rather a random surface that exhibits fractal behaviour.

Many natural phenomena exhibit some form of statistical self-similarity that can be modeled by fractal surfaces. Moreover, variations in surface texture provide important visual cues to the orientation and slopes of surfaces, and the use of almost self-similar fractal patterns can help create natural looking visual effects. The modeling of the Earth’s rough surfaces via fractional Brownian motion was first proposed by Benoît Mandelbrot. Because the intended result of the process is to produce a landscape, rather
than a mathematical function, processes are frequently applied to such landscapes that may affect the stationarity and even the overall fractal behavior of such a surface, in the interests of producing a more convincing landscape.

According to R. R. Shearer, the generation of natural looking surfaces and landscapes was a major turning point in art history, where the distinction between geometric, computer generated images and natural, man made art became blurred. The first use of a fractal-generated landscape in a film was in 1982 for the movie *Star Trek II: The Wrath of Khan*. Loren Carpenter refined the techniques of Mandelbrot to create an alien landscape.

**Behaviour of natural landscapes**

Whether or not natural landscapes behave in a generally fractal manner has been the subject of some research. Technically speaking, any surface in three-dimensional space has a topological dimension of 2, and therefore any fractal surface in three-dimensional space has a Hausdorff dimension between 2 and 3. Real landscapes however, have varying behaviour at different scales. This means that an attempt to calculate the ‘overall’ fractal dimension of a real landscape can result in measures of negative fractal dimension, or of fractal dimension above 3. In particular, many studies of natural phenomena, even those commonly thought to exhibit fractal behaviour, do not in fact do so over more than a few orders of magnitude. For instance, Richardson’s examination of the western coastline of Britain showed fractal behaviour of the coastline over only two orders of magnitude. In general, there is no reason to suppose that the geological processes that shape terrain on large scales (for example plate tectonics) exhibit the same mathematical behaviour as those that shape terrain on smaller scales (for instance soil creep).

Real landscapes also have varying statistical behaviour from place to place, so for example sandy beaches don’t exhibit the same fractal properties as mountain ranges. A fractal function, however, is statistically stationary, meaning that its bulk statistical
properties are the same everywhere. Thus, any real approach to modeling landscapes requires the ability to modulate fractal behaviour spatially. Additionally real landscapes have very few natural minima (most of these are lakes), whereas a fractal function has as many minima as maxima, on average. Real landscapes also have features originating with the flow of water and ice over their surface, which simple fractals cannot model.

It is because of these considerations that the simple fractal functions are often inappropriate for modeling landscapes. More sophisticated techniques (known as ‘multifractal’ techniques) use different fractal dimensions for different scales, and thus can better model the frequency spectrum behaviour of real landscapes.

**GENERATION OF FRACTAL LANDSCAPES**

A way to make such a landscape is to employ the random midpoint displacement algorithm, in which a square is subdivided into four smaller equal squares and the center point is vertically offset by some random amount. The process is repeated on the four new squares, and so on, until the desired level of detail is reached. There are many fractal procedures (such as combining multiple octaves of Simplex noise) capable of creating terrain data, however, the term “fractal landscape” has become more generic.

**SCENERY GENERATOR**

A scenery generator refers to software used to create landscape images, 3D models, and animations. These programs often use procedural generation to generate the landscapes. Basic elements of landscapes created by scenery generators include terrain, water, foliage, and clouds.

**Common features**

Most scenery generators are able to create basic heightmaps in order to simulate the variation of elevation in basic terrain. Common techniques include Simplex noise, fractals, or the Diamond-Square Algorithm, which are able to generate 2-
dimensional heightmaps. However, cliffs and caves, due to their 3-dimensional nature, cannot be created using basic heightmap techniques, and are created by a variety of alternative methods. Bodies of water have their own distinct behavior, and form lakes, rivers, and oceans. They are either created separately as a unique aspect of the scenery, or are computed from existing elevations in the heightmap. Vegetation may also be simulated on top of the generated terrain, with the goal of achieving a natural landscape. Features such as trees or bushes are typically generated using L-systems or fractals, due to featuring a generic structure. Clouds and other atmospheric effects are featured in scenery generators less often, and are created using different applications of fractals and noise.

In addition to procedural methods, scenery generators such as Grome may also allow for users to manually edit terrain features, often according to sets of rules. A small number of software packages that do not generate terrain are often specialized to create specific aspects of it. Speed Tree, for example, is used to create only vegetation, while CityEngine specializes in creating realistic buildings and infrastructure.

Applications
Scenery generators are commonly used in movies, animations and video games. For example, Industrial Light & Magic used E-on Vue to create the fictional environments for Pirates of the Caribbean: Dead Man’s Chest. In such live-action cases, a 3D model of the generated environment is rendered and blended with live-action footage. Scenery generated by the software may also be used to create completely computer-generated scenes. In the case of animated movies such as Kung-Fu Panda, the raw generation is assisted by hand-painting to accentuate subtle details. Environment elements not commonly associated with landscapes, such as or ocean waves have also been handled by the software.

Scenery generators in video games give a variety of benefits, due to their procedural nature. Large environments can be created
for players to explore, while using little space to store the data. Certain games are also able to offer different kinds of landscapes that are constantly changing, allowing players a different experience between sessions.

Alternatively, the content created by a scenery generator can replace scenery elements that would otherwise need to be manually created. Time and resources in the game’s development cycle can be conserved by automating repetitive tasks, such as the generation of varied foliage. Virtual simulations such as non-commercial versions of America’s Army also benefit from the use of scenery generators due to their need to provide realistic, predictable settings with emergent properties. Due to the role that scenery generation plays in many present-day video games, game engines such as OGRE or Unreal Engine 3 often include a means to generate scenery within their own packages.

Software

- Artifex Terra 3D, freeware 3D terrain editor and painter based on the Ogre3D engine, brush-centric editing, triplanar texturing, able to import and export heightmaps.
- Bryce, 3D editing software famous for landscape creation.
- Grome, able to generate terrain, roads, water and additional decoration both manually and procedurally.
- Houdini, 3D editing software completely centered on procedural generation.
- Outerra, specializes in planetary generation.
- Speed Tree, software used for generating foliage for video games.
- Terragen, freeware for Microsoft Windows and Apple Macintosh which specializes in landscapes and planets.
- Terra Vista from Presagis is a terrain generation software tool for the rapid development of correlated visual, sensor, SAF/CGF, maps, and analytical 3D databases.
- SEGen Server from Presagis is a procedural modeling-based software tool for the low-cost development of large-area synthetic environments from minimal source data.
• VistaPro, which is able to use images of Mars and Earth in the generation process.
• Vue, a scenery generator that specializes in outdoor landscapes and animation.
• World Machine, a node-based generated terrain software with a plugin system to write user-defined nodes.

INTERACTIVE VISUALIZATION

Interactive visualization or interactive visualisation is a branch of graphic visualization in computer science that involves studying how humans interact with computers to create graphic illustrations of information and how this process can be made more efficient.

For a visualization to be considered interactive it must satisfy two criteria:

• Human input: control of some aspect of the visual representation of information, or of the information being represented, must be available to a human, and
• Response time: changes made by the human must be incorporated into the visualization in a timely manner. In general, interactive visualization is considered a soft real-time task.

One particular type of interactive visualization is virtual reality (VR), where the visual representation of information is presented using an immersive display device such as a stereo projector. VR is also characterized by the use of a spatial metaphor, where some aspect of the information is represented in three dimensions so that humans can explore the information as if it were present (where instead it was remote), sized appropriately (where instead it was on a much smaller or larger scale than humans can sense directly), or had shape (where instead it might be completely abstract).

Another type of interactive visualization is collaborative visualization, in which multiple people interact with the same computer visualization to communicate their ideas to each other or to explore information cooperatively. Frequently, collaborative
visualization is used when people are physically separated. Using several networked computers, the same visualization can be presented to each person simultaneously. The people then make annotations to the visualization as well as communicate via audio (i.e., telephone), video (i.e., a video-conference), or text (i.e., IRC) messages.

**Human control of visualization**

The Programmer’s Hierarchical Interactive Graphics System (PHIGS) was one of the first programmatic efforts at interactive visualization and provided an enumeration of the types of input humans provide. People can:

- *Pick* some part of an existing visual representation;
- *Locate* a point of interest (which may not have an existing representation);
- *Stroke* a path;
- *Choose* an option from a list of options;
- *Valuate* by inputting a number; and
- *Write* by inputting text.

All of these actions require a physical device. Input devices range from the common – keyboards, mice, graphics tablets, trackballs, and touchpads – to the esoteric – wired gloves, boom arms, and even omnidirectional treadmills.

These input actions can be used to control both the information being represented or the way that the information is presented. When the information being presented is altered, the visualization is usually part of a feedback loop. For example, consider an aircraft avionics system where the pilot inputs roll, pitch, and yaw and the visualization system provides a rendering of the aircraft’s new attitude. Another example would be a scientist who changes a simulation while it is running in response to a visualization of its current progress. This is called *computational steering*.

More frequently, the representation of the information is changed rather than the information itself.
Rapid response to human input

Experiments have shown that a delay of more than 20 ms between when input is provided and a visual representation is updated is noticeable by most people. Thus it is desirable for an interactive visualization to provide a rendering based on human input within this time frame. However, when large amounts of data must be processed to create a visualization, this becomes hard or even impossible with current technology. Thus the term "interactive visualization" is usually applied to systems that provide feedback to users within several seconds of input. The term *interactive framerate* is often used to measure how interactive a visualization is. Framerates measure the frequency with which an image (a frame) can be generated by a visualization system. A framerate of 50 frames per second (frame/s) is considered good while 0.1 frame/s would be considered poor. The use of framerates to characterize interactivity is slightly misleading however, since framerate is a measure of bandwidth while humans are more sensitive to latency. Specifically, it is possible to achieve a good framerate of 50 frame/s but if the images generated refer to changes to the visualization that a person made more than 1 second ago, it will not feel interactive to a person.

The rapid response time required for interactive visualization is a difficult constraint to meet and there are several approaches that have been explored to provide people with rapid visual feedback based on their input. Some include

- *Parallel rendering* – where more than one computer or video card is used simultaneously to render an image. Multiple frames can be rendered at the same time by different computers and the results transferred over the network for display on a single monitor. This requires each computer to hold a copy of all the information to be rendered and increases bandwidth, but also increases latency. Also, each computer can render a different region of a single frame and send the results over a network for display. This again requires each computer to hold all of the data and can lead
to a load imbalance when one computer is responsible for rendering a region of the screen with more information than other computers. Finally, each computer can render an entire frame containing a subset of the information. The resulting images plus the associated depth buffer can then be sent across the network and merged with the images from other computers. The result is a single frame containing all the information to be rendered, even though no single computer’s memory held all of the information. This is called parallel depth compositing and is used when large amounts of information must be rendered interactively.

- **Progressive rendering** – where a framerate is guaranteed by rendering some subset of the information to be presented and providing incremental (progressive) improvements to the rendering once the visualization is no longer changing.

- **Level-of-detail (LOD) rendering** – where simplified representations of information are rendered to achieve a desired framerate while a person is providing input and then the full representation is used to generate a still image once the person is through manipulating the visualization. One common variant of LOD rendering is subsampling. When the information being represented is stored in a topologically rectangular array (as is common with digital photos, MRI scans, and finite difference simulations), a lower resolution version can easily be generated by skipping \( n \) points for each 1 point rendered. Subsampling can also be used to accelerate rendering techniques such as volume visualization that require more than twice the computations for an image twice the size. By rendering a smaller image and then scaling the image to fill the requested screen space, much less time is required to render the same data.

- **Frameless rendering** – where the visualization is no longer presented as a time series of images, but as a single image where different regions are updated over time.


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Aspects of Animation
Steps to Learn Animated Cartoons
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The animated cartoons and their evolution have been described in a historical perspective. Animation precedes the invention of photography and the cine camera by several decades. It is an art form in which a world of dynamic image and sound may be synthesised completely out of nothing but a thought.

Animation is the most nimble of mediums. It has survived the mechanical ‘persistence of vision’ toys popular in the 19th century; found expression as an art form in cinema; it was the means by which to experiment with time-based art and cinematic forms to present new visual vocabularies; it was brilliantly positioned to pioneer the use of computers to create moving images from numbers; it has demystified complex processes; visualised scientific phenomena and provided simulation models to help us understand the world; it has become an essential ingredient in multimedia content; it is imbedded in the control interface display of multi-million dollar jet fighter planes, it is integral to the computer games industry; it increasingly underpins all special effects in motion picture production; and it has provided content in an ideal form to distribute across a bandwidth poor networked environment.

Animation can be described as the creation of the illusion of motion through a rapid sequence of still images. Although the quality of the original images is important, equally important is the quality of the sequence through which action, character, and story development are portrayed. There must be a coherent pattern to the action. A common story structure introduces characters, a source of conflict, the development of this conflict, a climax, and finally a resolution. But an animated story can also be more fluid, including the creation of forms or simple images, some interaction.
of them, and then a transformation or transmutation, such as a smiley face turning into a frown or dissolving into the background.

Animatronics entails the use of computer-controlled models that can be actuated in real-time. These models have electronic and mechanical parts including motion-enabling armatures covered with a synthetic skin. These models, often used in conjunction with live actors, form the foundation for animation sequences. Films featuring animatronics include Jaws, Star Wars, and Jurassic Park.

The book helps you to learn various multimedia and animation designing applications and explore career opportunities present in the field of Animation.

—Author
ABOUT THE BOOK

An introduction to the science and arts of animation technology and design is provided with a global perspective, focusing particularly on developments in Europe, America and Asia. The animated cartoons and their evolution have been described in a historical perspective. An animation is the illusion of movement created by showing a series of still pictures in rapid succession. In the world of computers, graphic software used to create this effect. Simple animation may be as basic as an animated gif file like the image shown on this page. A more complex animation could be of a human or alien face in a computer software game or animation of a space battle in a movie. The book helps you to learn various multimedia and animation designing applications and explore career opportunities present in the field of Animation. This publication is designed to serve the purpose of a reference book on the said subject areas of animation, cartoon and multimedia. Each chapter includes step-by step instructions and screenshots, self-quizzes and hands-on projects. This book teaches how to master the building blocks of multimedia, including text, images, audio, video, and animation.

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The Uses of Animation; Analysing Animated Cartoons and their Evolution; Computer Animation; Limited Animation; Motion Capture; Machinima; Animatronics; Computer Graphic and Animation; Multimedia and Animation; Flash Animation; Special Effect; Animated Cartoon; Animation Database; Computer-generated Imagery