Computer generated 3d animation computer science

Computer animation (or CGI animation) is the art of creating moving images with the use of computers. Increasingly it is created by means of 3D computer graphics, though 2D computer graphics are still widely used for stylistic, low bandwidth, and faster real-time rendering needs. It is also referred to as CGI (computer-generated imagery or computer-generated imaging), especially when used in films.

2. PRINCIPLES OF ANIMATION

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. For 3D animations, objects (models) are built on the computer monitor (modeled) and 3D figures are rigged with 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 modeling is complete. For 2D vector animations, the rendering process is the key frame illustration process, while tweened frames are rendered as needed.

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 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.

To trick the eye and brain into thinking they are seeing a smoothly moving object, the pictures should be drawn at around 12 frames per second (frame/s) or faster (a frame is one complete image). With rates above 70 frames/s no improvement in realism or smoothness is perceivable due to the way the eye and brain process images. At rates below 12 frame/s most people can detect jerkiness associated with the drawing of new images which detracts from the illusion of realistic movement. Conventional hand-drawn cartoon animation often uses 15 frames/s in order to save on the number of drawings needed, but this is usually accepted because of the stylized nature of cartoons. Because it produces more realistic imagery computer animation demands higher frame rates to reinforce this realism.

The reason no jerkiness is seen at higher speeds is due to " persistence of vision." From moment to moment, the eye and brain working together actually store whatever one looks at for a fraction of a second, and automatically " smooth out" minor jumps. Movie film seen in theaters in the United States runs at 24 frames per second, which is sufficient to create this illusion of continuous movement.

3. HOW DOES IT WORK

The process of creating 3D animations can be sequentially divided into three basic phases: 3D modeling which describes the process of forming the shape of an object, layout and animation which describes the motion and placement of objects within a scene, and 3D rendering which produces an image of an object.

a)The 3D model describes the process of forming the shape of an object. The two most common sources of 3D models are those originated on the computer by an artist or engineer using some kind of 3D modeling tool, and those scanned into a computer from real-world objects. Models can also be produced procedurally or via physical simulation. 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 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. 3D computer animation combines 3D models of objects and programmed 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 system is set up to deform the 3D mesh (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.

b)Before objects are rendered, they must be placed (laid out) within a scene. This is what defines the spatial relationships between objects in a scene including location and size. Animation refers to the temporal description of an object, how it moves and deforms over time. Popular methods include keyframing, inverse kinematics, and motion capture, though many of these

techniques are used in conjunction with each other. As with modeling, physical simulation is another way of specifying motion.

In most 3D computer animation systems, an animator creates a simplified representation of a character's anatomy, analogous to a skeleton or stick figure. 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 by 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 their 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 behavior and action is required, but the types of characters required exceed what can be done through conventional costuming.

c)Rendering converts a model into an image either by simulating light transport to get photorealistic images, or by applying some kind of style as in non-photorealistic rendering. The two basic operations in realistic rendering are transport (how much light gets from one place to another) and scattering (how surfaces interact with light). This step is usually performed using 3D computer graphics software or a 3D graphics API. The process of altering the scene into a suitable form for rendering also involves 3D projection which allows a three-dimensional image to be viewed in two dimensions.

Let's step through the rendering of a simple image of a room with flat wood walls with a grey pyramid in the center 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 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 colors, where objects blocks the light we darken colors. 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.

4. 3D COMPUTER GRAFICS SOFTWARE

3D computer graphics software refers to programs used to create 3D computer-generated imagery. 3D modelers are used in a wide variety of industries. The medical industry uses them to create detailed models of organs. The movie industry uses them to create and manipulate characters and objects for animated and real-life motion pictures. The video game industry uses them to create assets for video games. The science sector uses them to create highly detailed models of chemical compounds. The architecture industry uses them to create models of proposed buildings and landscapes. The engineering community uses them to design new devices, vehicles and structures as well as a host of other uses. There are typically many stages in the " pipeline" that studios and manufacturers use to create 3D objects for film, games, and production of hard goods and structures.

Many 3D modelers are general-purpose and can be used to produce models of various real-world entities, from plants to automobiles to people. Some are specially designed to model certain objects, such as chemical compounds or internal organs.

3D modelers allow users to create and alter models via their 3D mesh. Users can add, subtract, stretch and otherwise change the mesh to their desire. Models can be viewed from a variety of angles, usually simultaneously. Models can be rotated and the view can be zoomed in and out. 3D modelers can export their models to files, which can then be imported into other applications as long as the metadata is compatible. Many modelers allow importers and exporters to be plugged-in, so they can read and write data in the native formats of other applications.

Most 3D modelers contain a number of related features, such as ray tracers and other rendering alternatives and texture mapping facilities. Some also contain features that support or allow animation of models. Some may be able to generate full-motion video of a series of rendered scenes .

Computer animation development equipment

Computer animation can be created with a computer and 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, 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 . 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. Pixar's Renderman is rendering software which is widely used as the movie animation industry standard, in competition with Mental Ray. It can be bought at the official Pixar website for about $3, 500. It will work on Linux, Mac OS X, and Microsoft Windows based graphics workstations along with an animation program such as Maya and Softimage XSI. Professionals also use digital movie cameras, motion capture or performance capture, bluescreens, film editing software, props, and other tools for movie animation.

Major software packages

3ds Max (Autodesk), originally called 3D Studio MAX, is a comprehensive and versatile 3D application used in film, television, video games and architecture for Windows. It can be extended and customized through its SDK or scripting using a Maxscript. It can use third party rendering options such as Brazil R/S, finalRender and V-Ray.

Maya (Autodesk) is currently used in the film and television industry. Maya has developed over the years into an application platform in and of itself through extendability via its MEL programming language. It is available for Windows, Linux and Mac OS X.

Softimage (Autodesk) Softimage (formerly Softimage| XSI) is a 3D modeling and animation package that integrates with mental ray rendering. It is feature-similar to Maya and 3DS Max and is used in the production of professional films, commercials, video games, and other media.

LightWave 3D (NewTek), first developed for the Amiga, was originally bundled as part of the Video Toaster package and entered the market as a low cost way for TV production companies to create quality CGI for their programming. It first gained public attention with its use in the TV series Babylon 5 and is used in several contemporary TV series. Lightwave is also used in film production. It is available for both Windows and Mac OS X.

ZBrush (Pixologic) is a digital sculpting tool that combines 3D/2. 5D modeling, texturing and painting tool available for Mac OS X and Windows. It is used to create normal maps for low resolution models to make them look more detailed.

Cinema 4D (MAXON) is a light package in its basic configuration. The software is for lay users. It has a lower initial entry cost due to a modular a-la-carte design for purchasing additional functions as users need them. Originally developed for the Amiga, it is also available for Mac OS X, Windows and Linux.

4. ANIMATION ALONG TIME

CGI was first used in movies in 1973's Westworld, a science-fiction film about a society in which robots live and work among humans, though the first use of 3D Wireframe imagery was in its sequel, Futureworld (1976), which featured a computer-generated hand and face created by then University of Southern California graduate students Edwin Catmull and Fred Parke. The third movie to use this technology was Star Wars (1977) for the scenes with the wireframe Death Star plans and the targeting computers in the X-wings and the Millennium Falcon. The Black Hole (1979) used raster wire-frame model rendering to depict a black hole. The science fiction-horror film Alien of that same year also used a raster wire-frame model, in this case to render the image of navigation monitors in the sequence where a spaceship follows a beacon to a land on an unfamiliar planet.

In 1978, graduate students at the New York Institute of Technology Computer Graphics Lab began work on what would have been the first full-length CGI film, The Works, and a trailer for it was shown at SIGGRAPH 1982, but the film was never completed. Star Trek II: The Wrath of Khan premiered a short CGI sequence called The Genesis Wave in June 1982. The first two films to make heavy investments in Solid 3D CGI, Tron (1982) and The Last Starfighter (1984), were commercial failures, causing most directors to relegate CGI to images that were supposed to look like they were created by a computer.

It was the 1993 film Jurassic Park, however, in which dinosaurs created with CGI were seamlessly integrated into live action scenes, that revolutionized

the movie industry. It marked Hollywood's transition from stop-motion animation and conventional optical effects to digital techniques. The following year, CGI was used to create the special effects for Forrest Gump. The most noteworthy effects shots were those that featured the digital removal of actor Gary Sinise's legs. Other effects included a napalm strike, the fast-moving Ping-Pong balls, and the digital insertion of Tom Hanks into several scenes of historical footage.

Two-dimensional CGI increasingly appeared in traditionally animated films, where it supplemented the use of hand-illustrated cels. Its uses ranged from digital tweening motion between frames, to eye-catching quasi-3D effects, such as the ballroom scene in Beauty and the Beast. In 1993, Babylon 5 became the first television series to use CGI as the primary method for its visual effects (rather than using hand-built models). It also marked the first TV use of virtual sets. That same year, Insektors became the first full-length completely computer animated TV series. Soon after, in 1994, the hit Canadian CGI show ReBoot aired.

Toy Story(1995) was the first fully computer-generated feature film.

In 1995, the first fully computer-generated feature film, Disney-Pixar's Toy Story, was a resounding commercial success. Additional digital animation studios such as Blue Sky Studios (20th Century Fox), DNA Productions (Paramount Pictures and Warner Bros.), Omation Studios (Paramount Pictures), Sony Pictures Animation (Columbia Pictures), Vanguard Animation (Walt Disney Pictures, Lions Gate Entertainment and 20th Century Fox), Big Idea Productions (Universal Pictures and FHE Pictures), Animal Logic (Warner

Bros.) and Pacific Data Images (Dreamworks SKG) went into production, and existing animation companies, such as The Walt Disney Company, began to make a transition from traditional animation to CGI. Between 1995 and 2005 the average effects budget for a wide-release feature film skyrocketed from $5 million to $40 million. According to one studio executive, as of 2005[update], more than half of feature films have significant effects. However, CGI has made up for the expenditures by grossing over 20% more than their real-life counterparts.

In the early 2000s, computer-generated imagery became the dominant form of special effects. 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. Virtual sets, in which part or all of the background of a shot is digitally generated, also became commonplace. The timeline of CGI in film and television shows a detailed list of pioneering uses of computer-generated imagery in film and television.

CGI for films is usually rendered at about 1. 4-6 megapixels. Toy Story, for example, was rendered at 1536A A?-A 922 (1. 42MP). The time to render one frame is typically around 2-3 hours, with ten times that for the most complex scenes. This time hasn't changed much in the last decade, as image quality has progressed at the same rate as improvements in hardware, since with faster machines, more and more complexity becomes feasible. Exponential increases in GPUs processing power, as well as massive increases in parallel

CPU power, storage and memory speed and size have greatly increased CGI's potential.

In 2001, Square Pictures created the CGI film Final Fantasy: The Spirits Within, which made headlines for attempting to create photo-realistic human actors. 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. Square Pictures produced only two more films using a similar visual style Final Flight of the Osiris, a short film which served as a prologue to The Matrix Reloaded and Final Fantasy VII: Advent Children, based on their extremely popular video game series.

Developments in CGI technologies are reported each year at SIGGRAPH, an annual conference on computer graphics and interactive techniques, attended each year by tens of thousands of computer professionals. 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. This art form is called machinima.

This is a chronological list of films and television programs that have been recognised as being pioneering in their use of computer-generated imagery.

5. THE FUTURE OF ANIMATION

One open challenge in computer animation is a photorealistic animation of humans. Currently, most computer-animated movies show animal

characters, fantasy characters, anthropomorphic machines or cartoon-like humans. The movie Final Fantasy: The Spirits Within is often cited as the first computer-generated movie to attempt to show realistic-looking humans. However, due to the enormous complexity of the human body, human motion, and human biomechanics, realistic simulation of humans remains largely an open problem. Another problem is the distasteful psychological response to viewing nearly perfect animation of humans, known as " the uncanny valley." It is one of the " holy grails" of computer animation. Eventually, the goal is to create software where the animator can generate a movie sequence showing a photorealistic human character, undergoing physically-plausible motion, together with clothes, photorealistic hair, a complicated natural background, and possibly interacting with other simulated human characters. This could be done in a way that the viewer is no longer able to tell if a particular movie sequence is computer-generated, or created using real actors in front of movie cameras. Complete human realism is not likely to happen very soon, and when it does it may have major repercussions for the film industry.

For the moment it looks like three dimensional computer animation can be divided into two main directions; photorealistic and non-photorealistic rendering. Photorealistic computer animation can itself be divided into two subcategories; real photorealism (where performance capture is used in the creation of the virtual human characters) and stylized photorealism. Real photorealism is what Final Fantasy tried to achieve and will in the future most likely have the ability to give us live action fantasy features as The Dark Crystal without having to use advanced puppetry and animatronics,

while Antz is an example on stylistic photorealism . None of them mentioned are perfected as of yet, but the progress continues.

The non-photorealistic/cartoonish direction is more like an extension of traditional animation, an attempt to make the animation look like a three dimensional version of a cartoon, still using and perfecting the main principles of animation articulated by the Nine Old Men, such as squash and stretch.

While a single frame from a photorealistic computer-animated feature will look like a photo if done right, a single frame vector from a cartoonish computer-animated feature will look like a painting (not to be confused with cel shading, which produces an even simpler look).