Computer Animation in the Museum

by Oliver Strimpel

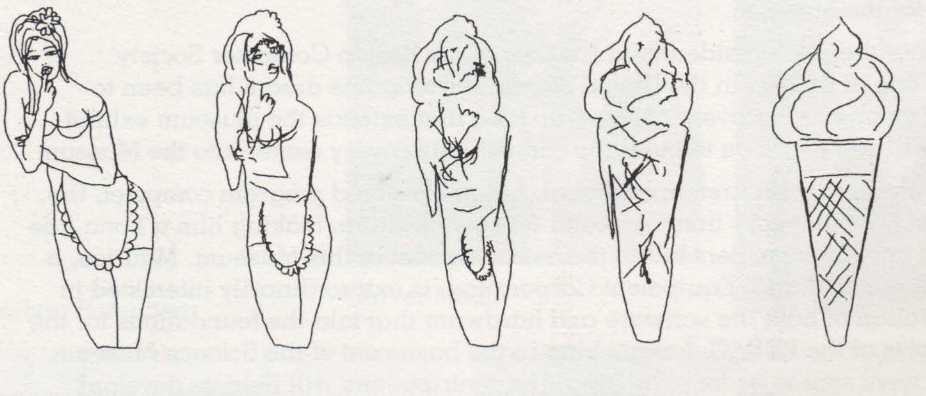
Film and video animated by computer are an important record of hardware and software development. The need to produce large numbers of images and to animate them smoothly absorbs a large amount of computer time and fully exploits all the available spatial and color resolution of computer graphic systems. Makers of film and video have consistently stretched their resources to the limit.

The Museum is building up a collection of computer-animated film and video. An important recent acquisition is a set 12 films donated by Ken Knowlton made at AT&T Bell Laboratories between 1963 and 1976. The computer (an IBM 7094) was used both to draft the images on a microfilm recorder (a Stromberg–Carlson 4020), as well as to calculate what should be drawn. A short piece by Ed Zajac that simulates the oscillations of a communications satellite in the Earth's gravitational field was completed in 1963, making it the earliest computer generated film known to the Museum. Several of the films are educational, visually explaining subjects such as Bell Labs' own movie-making system, programming languages, and Newton's laws of motion and gravitation. Others explore human visual perception using images with random noise, and still others use the medium for its aesthetic possibilities.

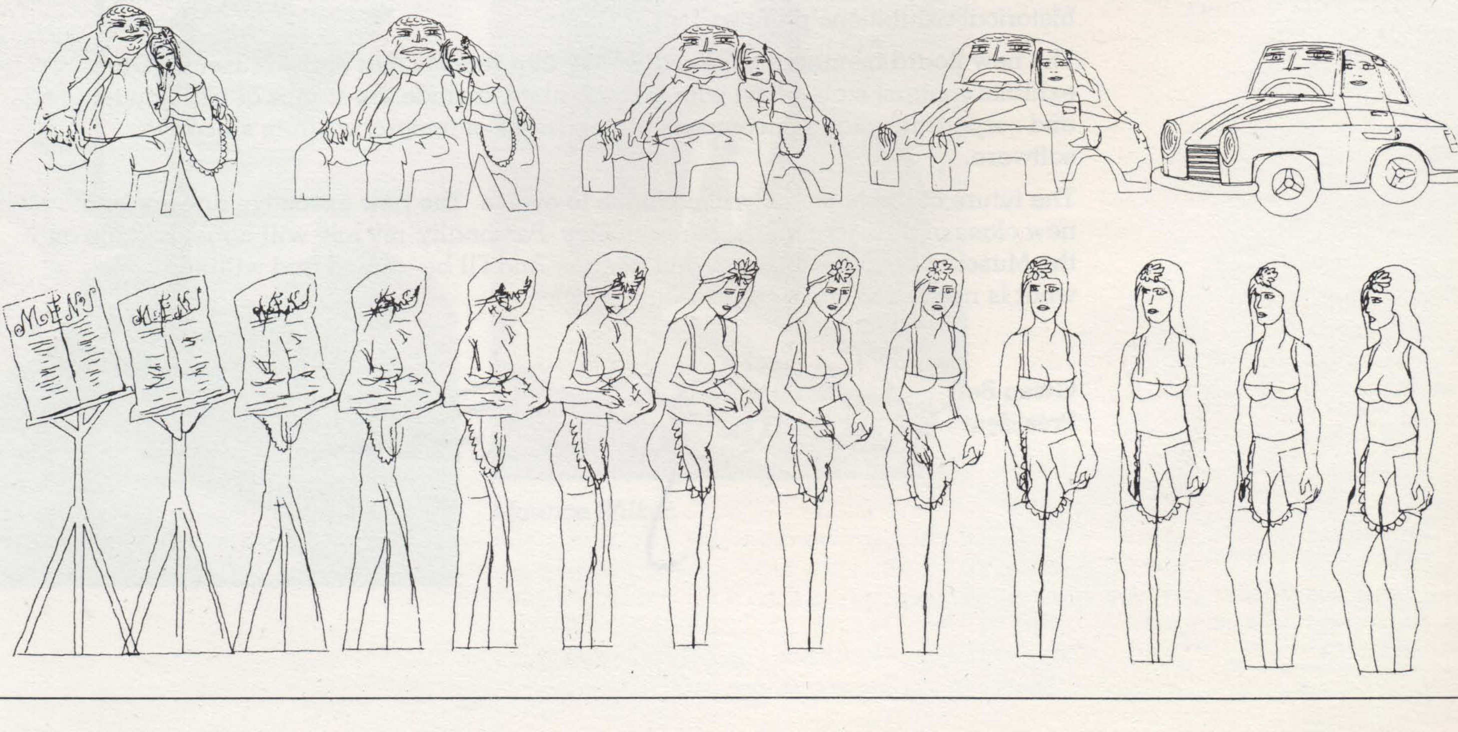
Another significant set of computer-animated films were donated by F R A Hopgood. He led a group who used the Atlas computer at the Rutherford Laboratory in England to develop a convenient high-level computer animation system from 1968 to 1973. The Museum's films explain concepts in computing and physics, but non-technical entertaining films were also made. The system was later developed into a package called ANTICS which continues to be used today, particularly in Japan.

Also in the collection is a record of the first real time animation, a simulated flight of the Apollo LEM. This was filmed from the screen of an Adage Graphics Terminal in 1967.

The Museum has created a mini-theater in "The Computer and the Image" gallery to screen some of the more recent pieces in the computer animation collection for the public. Five pieces spanning the development of the art were selected for a 20 minute program which shows continuously. Each piece demonstrates creative and original use of the techniques of computer animation.



Computer key frame inbetweening is the process whereby the artist only draws the frames that represent the end of a movement or the completion of a metamorphosis. The computer automatically computes and draws the intermediate frames. Here, the artist drew the first and last pictures of the series using a tablet connected to a computer, and the machine generated the frames in between. When seen as moving film, the metamorphosis appears continuous.



Hunger (1975)
by Peter Foldes
National Research Council, Ottawa, Canada and National Film Board of Canada

Hunger is the first film to use the computer to animate hand-drawn images. It shows a man with an insatiable appetite devouring a huge quantity of food. He is then tormented by nightmares in which hordes of starving people devour his own body. The freedom offered by computer animation is used to its fullest extent to convey the film's disturbing message. For example, as he eats, the man's body steadily becomes more inflated and numerous mouths appear to help him eat faster. His visions are graphically portrayed, as in the woman metamorphosing into an ice cream cone.

The technique used is known as "key frame inbetweening." In traditional animation, the animator draws key frames while assistants laboriously draw intervening frames to make motion appear smooth. But in this film, the 'tweens' were drawn by computer. The machine works out the intermediate frames by taking averages of the initial key frame and the final one. In *Hunger* the interpolation is linear, which means that the motion starts off jerkily and progresses smoothly till the end-point is reached. Naturally, animators wish to control motion. Contemporary 'tweening systems now allow many types of movement to be simulated. The most common requirement is to start off slowly, accelerating gradually, and then slow down to a stop. Real living characters generally follow this type of motion.

Vol Libre (1980)
by Loren Carpenter

In *Hunger*, all the key frames are line drawings created by the artist. The computer smooths the passage between these frames. In *Vol Libre*, the computer is used to generate all the images—indeed the images are so complex that they could not be drawn by hand. The film shows a flight through an imaginary landscape of mountains, valleys and lakes. As the landscape is synthetic, the viewpoint can be moved freely, simulating truly free flight.

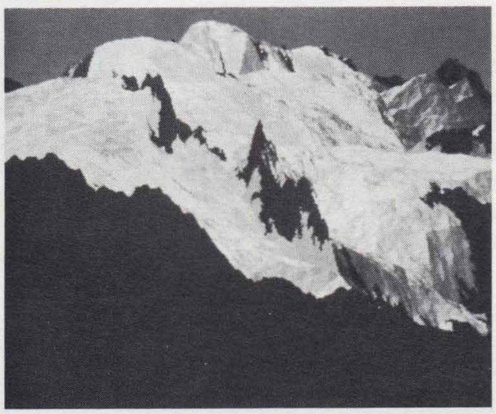
The landscapes were simulated using a class of mathematical objects termed fractals by their discoverer, Benoit Mandelbrot. Many natural phenomena, such as clouds, rivers, coastlines, turbulent flow, and capillary networks can be modelled as fractals. *Vol Libre* is the first film that used fractals to simulate a landscape. It also showed that such an artificial landscape could be viewed from several angles and still appear self-consistent. This is not obvious, as the landscape surface is not a real entity, and only the visible portion in the 'camera' is calculated for each frame.

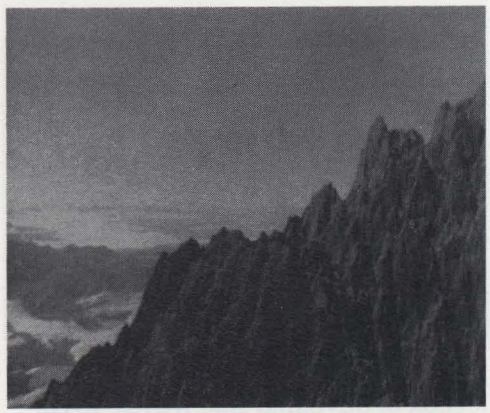
The film received a standing ovation when it was first shown at the ACM SIGGRAPH conference in 1980. Despite images that are crude in comparison to today's, the film is true to its name, conveying an exhilating sense of liberation from the shackles of gravity and inertia.

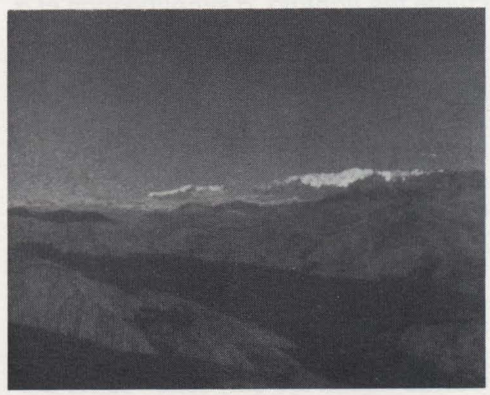
Carla's Island (1980)
by Nelson Max,
Lawrence Livermore National Laboratory

Nelson Max made the first attempt to model the appearance of moving water for the film *Carla's Island*. A range of simulated lighting is shown on the water surface, from broad daylight to moonlight.

Ray-tracing, modified by some time-saving short cuts, was used to render the play of light on the rippling water surface. During the sunset and rising and setting of the moon, a single cycle of water wave motion was repeated many times, but the colors were changed by altering the color table. This meant that there was no need to recalculate all the reflections. The results worked out for one set of colors were

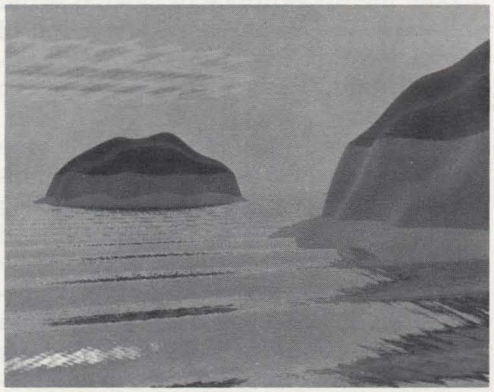


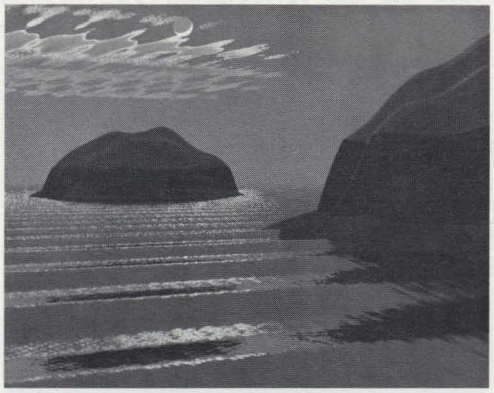




View of mountains in a fractal landscape. To create the landscape, Loren Carpenter started off by entering 180 altitude points. These points were connected, giving an initial database of 300 triangles to represent the landscape. The computer then used a random process to assign a midpoint for each triangle, either above or below the plane of the triangle, and connected the edges with the new midpoint to make three new, smaller triangles. The process was repeated until the triangles were only a couple of pixels across. The splitting was carried out afresh for each viewpoint.

reused for a different set, chosen to shift towards the colors of sunset and then moonlight. The effect is convincing, and only required a very small amount of extra computer time for a considerable extension in the length of film.





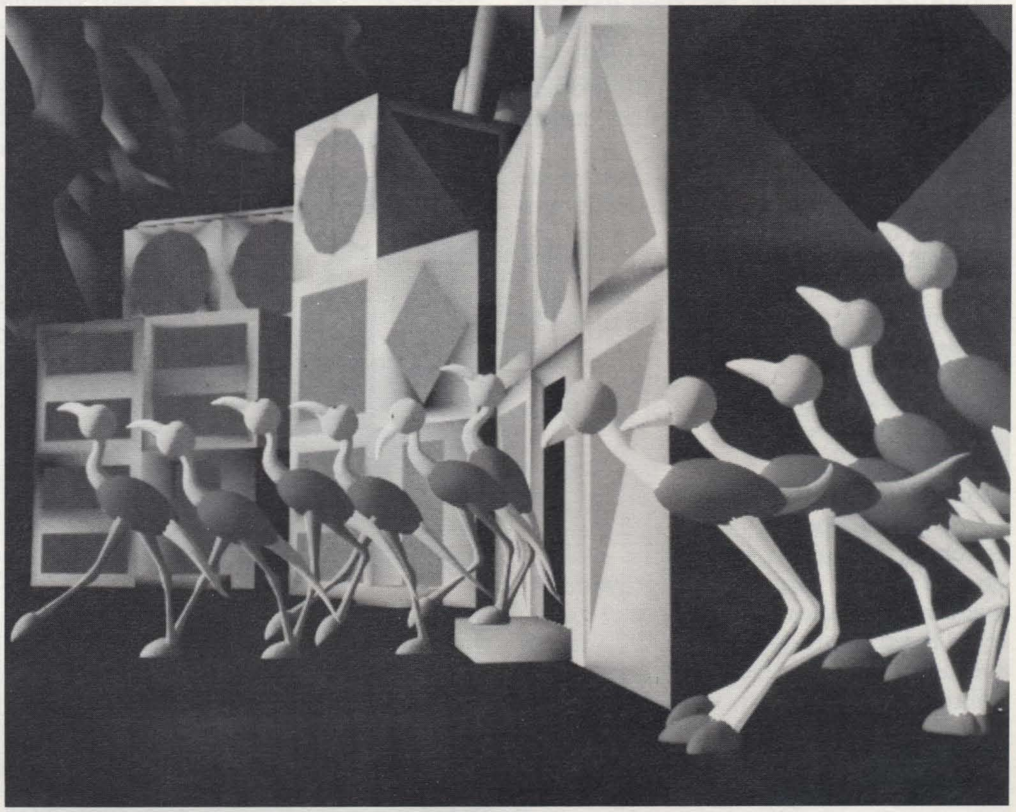
The water surface is modelled by a collection of travelling sine waves. To calculate the lighting, a simplification of a rendering technique known as ray-tracing is used. In ray tracing, the computer follows individual light rays backwards from the viewpoint, reflecting or refracting them off objects in the artificial scene until they hit a light source, matte surface or fade. The destination of the ray is used to work out the ray's contribution to the image. As a ray has to be followed for each pixel of the image, ray tracing is very demanding of computer time. As a short cut, the rays in Carla's Island are only followed for a maximum of 2 reflections on the water, and then assumed to originate from whatever they point to. It still took a Cray-1 supercomputer 7 seconds to compute each 512 by 384 frame.

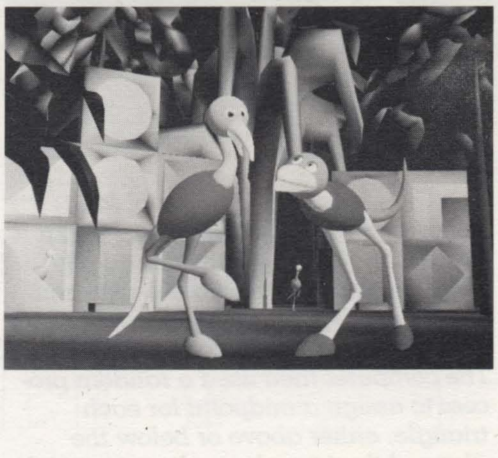
Snoot and Muttly (1984)
by Susan Van Baerle and
Douglas Kingsbury,
Ohio State University

Snoot and Muttly are two bird-like creatures who play together in a rainbow colored world under trees and floating bubbles. Three types of animation are used. The tails, necks and legs of the animals not only move but change shape as they walk. Taking the legs, for example, the animator input the positions of the hip, knee and ankle for five key positions during a step. The computer then interpolated between these positions.

The heads, feet, eyes and beaks are animated by normal key frame animation, following a smooth rotation without changing shape between the key positions. Finally, the bubbles were placed randomly on a grid and were then moved both systematically to simulate a wind or natural buoyancy, as well randomly between themselves. The computer smoothed the movement between the grid points.

Snoot, Muttly, the bubbles and the trees are rendered with a smooth-shading model simulating sunlight.





Snoot and Muttly are constructed using simple shapes: the bodies are ellipsoids, the necks, tails and legs are tubes, and the head and eyes are spheres. Despite this crudeness, the creatures are convincing and full of character owing to their movement. Successive key frames are shown in these pictures.

André & Wally B. (1984)
by Steven Baraniuk, Loren Carpenter, Ed Catmull, Rob Cook, Tom Duff, Craig Good, John Lasseter, Sam Leffler, Eben Ostby, Tom Porter, William Reeves, David Salesin and Alvy Ray Smith of the Computer Graphics Project, Lucasfilm Limited

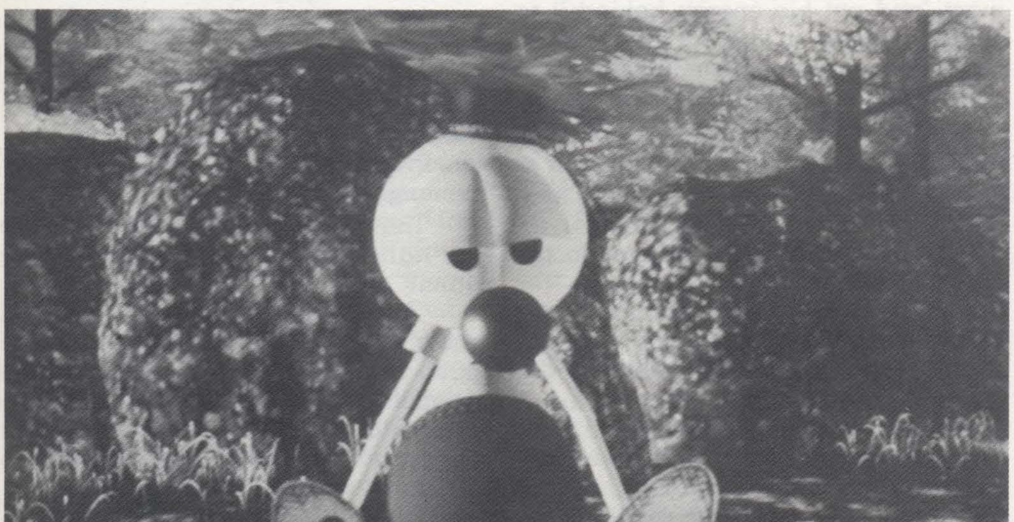
This 1.8 minute film is presently the most sophisticated piece of computer animation. It opens with a sunrise shot of a magnificent forest, zooming in to reveal an android, André, waking up and stretching. Soon he is confronted with an aggressive-looking bee, Wally B. In classic Disney cartoon style, André momentarily diverts the bee's attention and then flees with Wally in hot pursuit.

André and Wally B. were created on a computer by a Disney-trained animator. Using a tablet and a vector display, he input the characters by hand and then used the computer to animate them. In order to give him the necessary freedom, 547 independent controls were needed for the model of André, 252 for Wally B. Careful attention was given to the interface so that the animator could make use of the available flexibility without becoming aware of the complexity of the computing task.

Once the vector version was complete, the characters were rendered with color and texture and added to the forest backgrounds. For the first time in computer animation, motion blur was added. Without motion blur, sharp edges of animated characters tend to 'strobe', or double up. By deliberately blurring moving objects as if they were moving with the camera shutter open, the strobing disappears and the motion looks more realistic.

To create even this short clip occupied many months of the entire computer graphics research team at Lucasfilm. The huge computer processing needs were met by 10 VAX 11/750's, including those of Project Athena at MIT, and Cray XMP-2 and XMP-4 supercomputers of Cray Research.

The Museum is continually collecting computer animation. The Computer Animation Theater is a showcase of the collection, changing each year to display new pieces. Acquisitions include early work going back to the 1960's, as well as very recent material selected from the film show at each year's ACM SIGGRAPH conference, the prime forum for this medium. This year's selection will be on show at the Museum by this fall.



André waking up in the forest. André is a full three-dimensional model. He and Wally B. move in a forest background generated from a 3-dimensional database of 46,254 trees. These were made using particle systems which, rather like fractals, have the property that with a simple starting set of data, complex natural-looking shapes can be generated by repeatedly applying a simple set of rules.