Computer Science

COMPSCI 111 SC - Lecture 33

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Computer Graphics

Introduction

Computer Graphics have become extremely common in modern society. The ability of the computer to manipulate images, and to create new images has allowed artists to explore an entirely new artistic domain. The high visual impact has encouraged the use of computer graphics in advertising, where it is seen most commonly. Hollywood has been quick to embrace computer graphics, which have developed into a cheap way of creating special effects. The funding provided by movies has encouraged research and has frequently pushed the boundaries of current technology. Computer Graphics have become so effective in recent years that it is no longer possible to distinguish between reality and computer generated images.

Standards

As in any aspect of computer science, standards are important in computer graphics. A picture has to be stored in a way that other computers can recognise. The use of images on the WWW has forced industry to settle on some standard ways of encoding pictures (such as JPEG, and GIF). Although these standards are developing slowly, they provide some common ground by which different computer systems may interact. The MPEG-2 Standard has now moved from computer science to becoming the new standard for digital moving pictures, and will be used for High Definition TV, CD-Roms, Digital Video etc.

Colours:

The number of colours available on a computer depend upon the screen and the graphics capacity of the computer (specifically the power of the video card). The greater the range of colours required, the higher quality the screen is required to be (and therefore the greater the cost). If the computer can display more colours, then it will use much more of the processing power just dealing with the colours. Note that the amount of memory used increases significantly with a larger number of colours (A full size screen of 1024 x 1024 in black and white requires 128KB, but in photographic quality colour will use 3 MB).

1 bit	2 colours (Black and White)
2 bits	4 colours
3 bits	8 colours
4 bits	16 colours
8 bits	256 colours
16 bits	65536 colours
24 bits	16, 777, 216 colours (True Colour)

Figure 1: Table showing how the number of colours depends upon number of bits used.

Image Processing

Computer Graphics can be broadly divided into two categories (although there is some overlap): the analysis of images, and the synthesis (or creation) of images.

Image processing is concerned with the analysis and alteration of existing images. Typically, an image is "cleaned up" to remove distortion, or enhanced to show desired objects more effectively. There are many examples of image processing in the technical, and scientific community. Some of these include:

- Hospitals using computer enhanced images from x-rays, CAT scans, ultra-sound etc.
- Weather reports which show computer enhanced satellite images; etc.
- Police enhancing photographs to recognise people or license plate numbers

It is also possible to alter aspects of an image (eg; morphing an image, changing its colour, proportions etc). Some examples include:

- Photo developers who alter the colours/ contrast of your photos;
- Hair salons which take a photo of your hair and recolour it;
- Removal of parts of an image (legs of Lieutenant Dan in Forrest Gump)
- Combining two images (Forrest Gump meeting JFK, people falling off the Titanic) Morphing which occurs in Terminator II

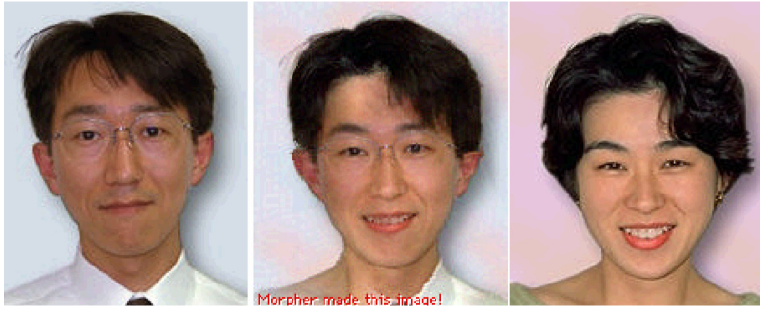

Figure 2: Combining two images to form a third image.

Graphics Rendering

Generating (or creating) computer images is perhaps the most easily recognised aspect of computer graphics. In order to generate computer graphics, a model of the object must be created within the computer, and then a representation of the object is displayed on the screen. The process of converting the computer model to a visible image is known as *rendering.* These rendered images are used primarily as artwork (eg; company logos, pretty pictures, special effects, etc.), although they are also used to help visualise technical information (such as the flow of air around an object in fluid dynamics, a house drawn from plans, chemical interactions, educational recreations, etc.)

Ray Casting

Ray-casting is a rendering technique that calculates an image of a scene by shooting rays into the scene. The scene is built from shapes, materials, light sources, a camera, and other special features such as fog and atmospheric effects. Once the three dimensional objects have been placed, and a camera and light sources positioned, the internal representation is complete.

In order to draw the image, a viewing window must be positioned in the scene. The image which is rendered is the image that the camera would see when looking through the viewing window.

The rendering software divides up the viewing window into a grid, where the number of cells in the grid are equal to the number of pixels in the final image. It is then possible to work out the colour of each cell in the viewing window, and set the corresponding pixel in the final picture to display that colour.

To work out the colour of each cell, a viewing ray is shot from the camera through each cell and into the scene. This ray is tested for intersection with any of the objects in the scene. Every time an object is hit, the colour of the surface at that point is calculated. This calculation is based upon the angle between the camera and the light source at that point. The surface material of the object is also taken into consideration in the calculation (a hard shiny surface reflects more light than a soft dull surface).

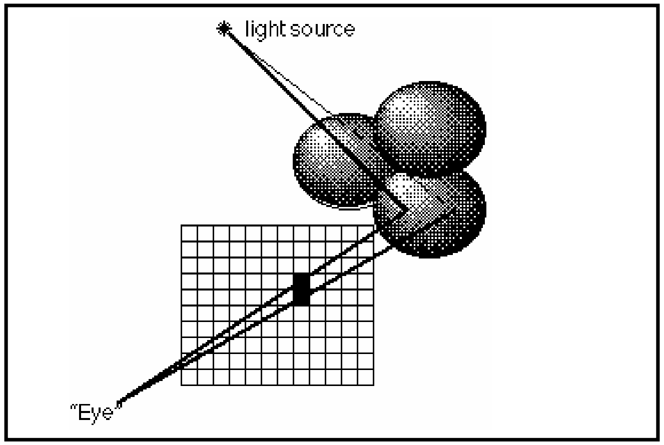

Figure 3: The process of ray casting

Ray Tracing

Ray Tracing produces photo-realistic images by using the same approach as ray casting, but involving more complex methods of calculating the colour of the surface. If the surface is reflective or translucent, then the ray tracing technique generates secondary rays from the point of intersection between the object and the viewing ray. These secondary rays are known as reflection rays, and are generated in order to work out the contribution to the colour of the surface which comes from light reflected from other objects. The colour of this reflected light alters the colour at the point of intersection on the original object. This complex process allows ray tracing to produce images which have reflections, transparent surfaces and complex lighting models involving such effects as halos.

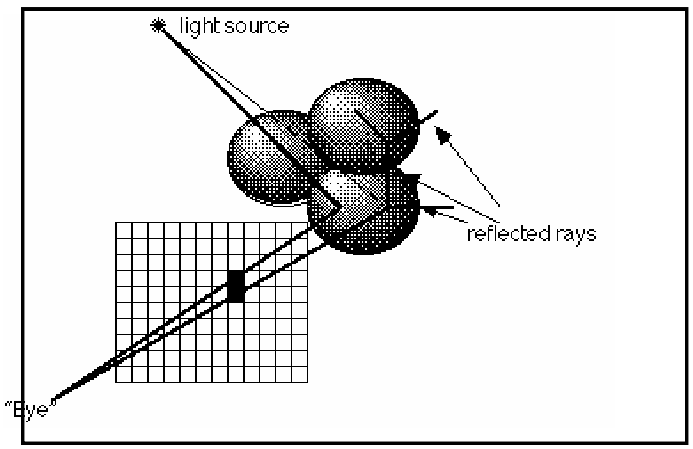

Figure 4: The technique of ray tracing works out the colour of a surface by calculations involving angle between light source and camera, surface of object, and colour or reflected light

Computer Animation

Animation was traditionally achieved by an artist hand-drawing each frame in the animated sequence. Computers have been used for some time to speed up this time consuming process. It is easy to scan the outline of the hand-drawn images into the computer, and then simply use a painting program to fill the interior with colours. A more sophisticated approach is to draw "key frames" by hand, and then allow a computer program to automatically draw the intermediate frames.

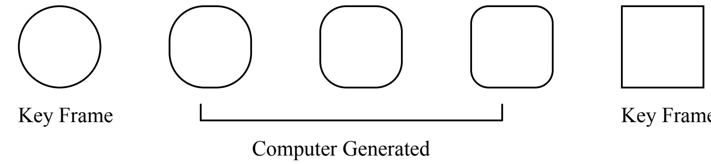

Figure 5: Computers are used to automatically draw flat 2d animation cells.

Three Dimensional Animation

Today, some animations (such as Toy Story) are generated by a computer, based upon a description of the scene which is required. In addition to specifying the physical look of the object, it is possible to describe movement through three dimensional space using a computer model. The computer can generate multiple frames of an animation given a simple description of the scene. In order to make the movement of physical objects look realistic, the computer model needs to take account of physical laws such as gravity and friction. The more realistic the scene is required to be, the more realistic the computer model has to be.

Modelling and Simulation

A recent trend in computer graphics research is to attempt to make the model as close to reality as possible. The distinction between simulation and computer graphics is blurred in this area. Computer graphics are far more realistic if they appear like the real world, and to achieve this, they need to accurately model the real world. This requires the computer model to account for the laws of physics, in order for the objects to behave more realistically. This simulation of reality has been closely linked to research in other fields of study, such as weather prediction, stresses of objects in engineering, chaos theory and quantum physics models. The partnership formed with these alternate disciplines is a symbiotic one, with both sides working towards a closer understanding of the physical universe.

Limits of Computer Graphics

The traditional problems associated with the production of computer are the physical limits imposed by the quality of the screen, and the speed of computation. Advances are being made in both of these areas, and many of the classical limitations have been defeated. The limits of computer graphics today are due to the difficulty in programming a computer to represent reality in a realistic way. Hardware is no longer such a major concern, but software techniques are a popular topic for research. Traditionally, computer graphics has been poor at modelling small particles such as those which make up clouds and fire. Recent developments (shown in movies such as Twister) have proven that both of these effects are achievable.

It is also difficult to model anything that is irregular, or uneven. This is because computers use mathematical models to create the objects which are represented. The natural result of this approach is for everything to appear regular, or to follow a pattern. Anything which is not regular is more difficult. This is because the computer must model *everything* that you see. Every minor blemish or imperfection must be deliberately placed. This makes scratches, dirt, and other imperfections difficult, and can often seem out of place.

The creation of realistic living creatures is still the most difficult task for computer graphics. Biological entities tend to be very complex, and highly irregular. Because people are so good at recognising small details about body language and emotion, the discrepancies between the computer representation of a human and reality are noticed easily.

The Future of Computer Graphics

Computer graphics techniques will continue to improve. Currently, it is possible to create cars, planes, clouds, fire, and explosions which cannot be distinguished from reality. Movies in the future will be heavily influenced by computer graphics as a way to escape the constraints of reality and provide freedom of expression (e.g. Jurassic Park, Titanic). Computers will be able to generate human images indistinguishable from a real actor.

In Star Wars Episode 1: The Phantom Menace. one of the central characters (and most of the supporting character along with many fight scenes) are entirely computer generated. A human actor is normally recorded as they go through the physical motions, and then a computer-generated shell will be mapped onto the recorded movements. Using this technique, any type of creature or personality can be created, including the ability to recreate real human faces. It is inevitable that great movie stars of the past (like Marilyn Monroe) will be recreated using computer generated models.

Lord of the Rings has more than 200,000 computer generated figures in a single scene. These characters have been given general rules about how to move and react to events, then the computer controls their appearance in an autonomous fashion, without the need for the animator to manipulate each movement individually. Movies such as Final Fantasy have shown that computer graphics are now almost indistinguishable from real footage in many situations. Another huge advantage is that once the models have been created once, they can be digitally stored and used for future movies easily.

The future of computer graphics is assured. The graphics will quickly become indistinguishable from reality. Current research attempts to combine artificial intelligence (autonomous reasoning) with computer graphics. Eventually a designer will be able to create a virtual world, and inhabit it with many individual characters, each having motives, desires, intentions and the capacity to make decisions. The animator will take the role of director, choosing ways to record the virtual world, and making minor changes to the motivations of the characters so they produce more interesting interactions. Given the amount of research currently engaged in the area, it may not be long before computer generated actors are as common as real ones.

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