ISSN 1754-3657 (Print)
ISSN 1754-3665 (Online)

CS4FN

Computer Science for Fun — **Issue 11**

Computer animation proudly presents...

Films!
Fights!
Filth!
Fireflies!

The animation issue

Computer animation is everywhere. The latest innovations play on cinema screens worldwide. Better technology is making computer animations more and more realistic, and now computers can simulate everything from huge jungles to tiny hairs. In this issue we're going to turn our focus behind the scenes, to tell you how those animations get made.

You might not realise, though, that the connection between animation, computation and technology goes way beyond films. In this issue you'll find out how computer animation fits in with sailboats, light shows, wallpaper and bar fights. Plus we'll reveal why a mechanical duck was a showstopping piece of early computer science. Perfect for a topic that can take you anywhere your imagination leads.

Open your mind with these animation facts!

- In 1979 some computing students at the New York Institute of Technology began making The Works, which would have been the world's first film made entirely from computer animation. However, script and technology problems forced the project to be abandoned and the distinction eventually went to Toy Story, more than fifteen years later.
- Some frames of a typical Pixar film are so complex it can take up to ninety hours for a single computer to translate all the information held in them to a finished image.
- A 5,200-year old bowl found in Iran features an early precursor of animation. Along the bowl's side are five drawings that, when viewed in a sequence, depict a wild goat leaping up to eat leaves off a tree.
- Character animation students at the California Institute of the Arts use classroom number A113. The number appears somewhere in every Pixar film, from a car number plate in Toy Story to a secret computer directive in Wall*E, and a courtroom in Up.

100,000 frames

Ben Stephenson of the University of Calgary gives us a guide to the basics of animation.

Animation isn't a new field – artists have been creating animations for over a hundred years. While the technology used to create those animations has changed immensely during that time, modern computer generated imagery continues to employ some of the same techniques that were used to create the first animations.

The hard work of hand drawing

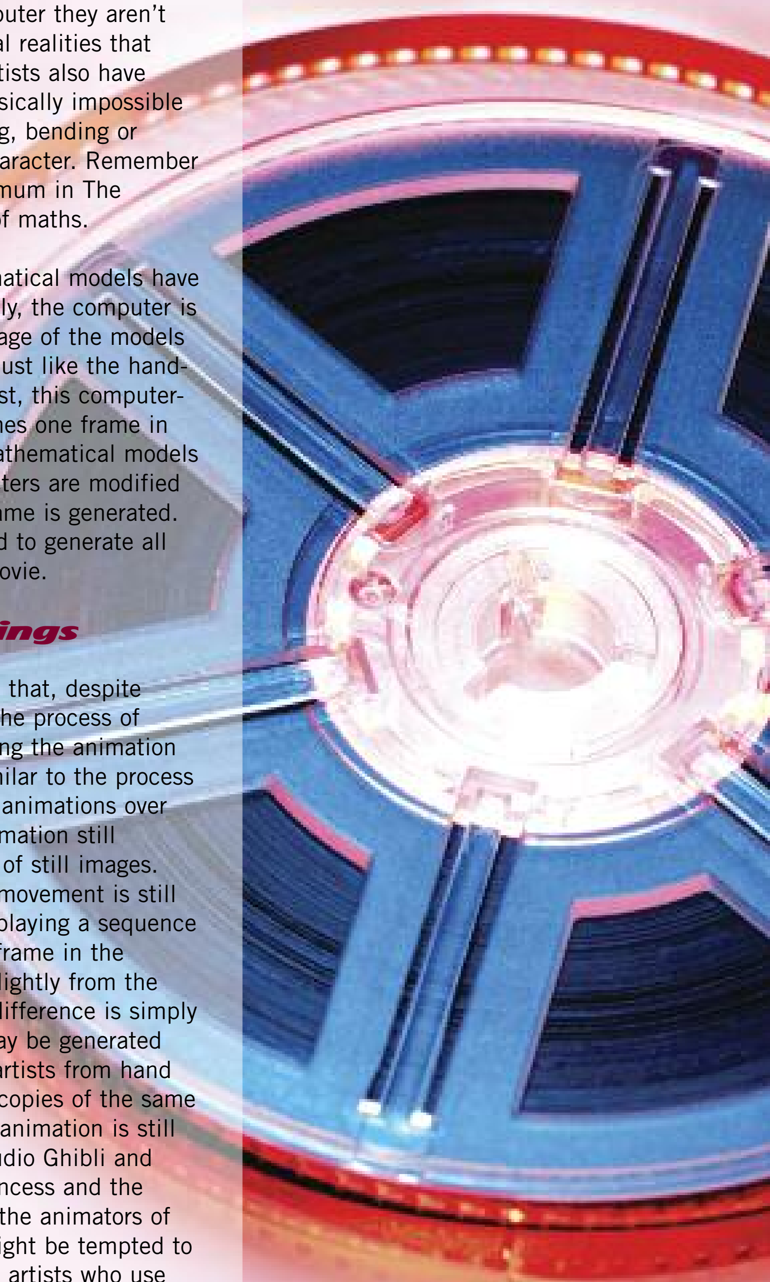
During the early days of animation, moving images were created by rapidly showing a sequence of still images. Each still image, referred to as a frame, was hand drawn by an artist. By making small changes in each new frame, characters were created that appeared to be walking, jumping and talking, or doing anything else that the artist could imagine.

In order for the animation to appear smooth, the frames need to be displayed quickly – typically at around 24 frames each second. This means that one minute of animation required artists to draw over 1400 frames. That means that the first feature-length animated film, a 70-minute Argentinean film called The Apostle, required over 100,000 frames to create. Creating a 90-minute movie, the typical feature length for most animated films, took almost 130,000 hand drawn frames. Despite these daunting numbers, many feature length animated movies have been created using hand-drawn images.

Drawing with data

Today, many animations are created with the assistance of computers. Rather than simply drawing thousands of images of one character using a computer drawing program, artists can create one mathematical model to represent that character, from which all of his or her appearances in individual frames are generated. Artists manipulate the model, changing things like the position of the character's limbs (so that the character can be made to walk, run or jump) and aspects of the character's face (so that it can talk and express emotions). Furthermore, since the models only exist as data on a computer they aren't confined by the physical realities that people are. As such, artists also have the flexibility to do physically impossible things such as shrinking, bending or stretching parts of a character. Remember Elastigirl, the stretchy mum in The Incredibles? All made of maths.

Once all of the mathematical models have been positioned correctly, the computer is used to generate an image of the models from a specific angle. Just like the hand-drawn frames of the past, this computer-generated image becomes one frame in the movie. Then the mathematical models representing the characters are modified slightly, and another frame is generated. This process is repeated to generate all of the frames for the movie.



The more things change

You might have noticed that, despite the use of computers, the process of generating and displaying the animation remains remarkably similar to the process used to create the first animations over 100 years ago. The animation still consists of a collection of still images. The illusion of smooth movement is still achieved by rapidly displaying a sequence of frames, where each frame in the sequence differs only slightly from the previous one. The key difference is simply that now the images may be generated by a computer, saving artists from hand drawing over 100,000 copies of the same character. Hand-drawn animation is still alive in the films of Studio Ghibli and Disney's recent The Princess and the Frog, but we wonder if the animators of hand-drawn features might be tempted to look over at their fellow artists who use computers and shake an envious fist. A cramped fist, too, probably.

Read on to find out how things are changing...

Automata: the good, the bad and the cheaters (and a bit of magic too)

Movie animatronics create some breathtaking computer-controlled movie monsters (see p10), but the history of making things come alive and move the way you want them to stretches way beyond the Hollywood hills. Automata, mechanically animated figures and creatures, go way back in history and show just how clever inventors the world over can be. The contraptions they built were the forerunners of today's computers, and if these inventors were at work now, they would be computer scientists. So let's have a look at some of the more interesting and influential characters in automata history.

Boat the beat

The Islamic inventor Al-Jazari really moved things forward in 1206 when he wrote his book the "Book of Knowledge of Ingenious Mechanical Devices". In this he described many of the mechanical devices and designs we still use today, like camshafts, rotary motors, methods for water pumping and so on. He also described ways to build complex programmable humanoid automata, which had real applications to improving people's lives. One of his inventions was a hand washing automaton, which stood by a bowl of water until the lever was pressed. At that point the water drained (using a method similar to today's flushing toilets) and the automaton refilled the bowl. One of his most interesting inventions was a boat with four automatic musicians. This musical group floated on a lake to entertain guests at royal parties. His cunning mechanism had what we would probably think of today as a programmable drum machine. A series of rotating pegs would bump into small levers that would then operate the drums. Moving the pegs around would make the drummer play different drum patterns.

Dinner, music and a duck

In the 1700s automata had become very popular with the rich and famous. They were must-have toys to impress your friends. Frenchman Jacques de Vaucanson, the tenth child of a poor glove maker, hit the scene and became the bad boy of the automaton makers. Through his early ingenuity he managed to get funds to set up a workshop in Lyon where he set about building androids, human-like automata, which would serve dinner and clear the tables for visiting politicians. It wasn't to be: a government official decided his work was "profane", and ordered that the workshop be destroyed.

Poo!

Undaunted, in 1737 Vaucanson built The Flute Player. This was a life-size figure of a shepherd that could play twelve different tunes on the pipes, a bit like a big, flute playing iPod. The mechanics of the shepherd's fingers were poor though, so Vaucanson gave him gloves to cover them. His dad must have been proud. In 1738, he presented his flute player to the French Académie des Sciences. The scientists recognised that Vaucanson's design was more than a toy – it was programmable, and therefore a revolutionary step towards mechanically created life-like machines. He went on to create a tambourine player and, famously, a mechanical duck. Vaucanson even built the world's first flexible rubber tube for the duck, which allowed it to eat and poo. He did cheat a bit on the effects: what went into the duck wasn't the same as what came out of the duck. Vaucanson had stashed a hidden compartment of 'pre digested food' in the duck to make the gross-out joke work. You might not have expected to

learn how to make a fake pooing duck when you started reading this article, but that mechanical feat is nothing compared to what we've got next.

Check mate or cheat?

In 1769 the naughty Hungarian Wolfgang von Kempelen took a chess-playing machine called 'The Turk' round the courts of Europe, making a florin or two on the way. The Turk was, he said, an automaton that could play a blinding game of chess. It fooled many but was eventually exposed as a hoax. Inside the box, rather than a complex chess playing machine, was a real person, good at playing chess, who was actually responsible for the puppet's moves above. Kempelen did redem himself though, by inventing one of the first human operated speaking machines. This proved a real advance in phonetics, the science of studying human speech processes. In fact the Wolfgang von Kempelen Computing Science History Prize was (much) later named in his honour.

Stage struck like clockwork

The use of automata in magicians' stage shows came to be popular in the 19th century. There is something exciting about watching mechanical people do real human things, sometimes even performing magic tricks. The famous magician Robert-Houdin was a popular user of automata. The story goes that as a kid he saved up for books on clockmaking so he could get a decent job, and by mistake he was given books on magic. From there he never looked back. While he worked in a clock shop he also developed automata including a singing bird, a dancer on a tightrope, and an automaton doing the famous conjuring trick the cups and balls. After he became a full time magician, one of his most famous effects, the Marvellous Orange Tree, put an automaton at centre stage.

A Magical Clockwork Orange

This amazing stage illusion involved first vanishing a spectator's handkerchief, then doing various tricks with a lemon where, with each trick, the audience believed the handkerchief would reappear. It never did. Finally assistants would bring onstage a small orange tree planted in a box. The orange tree's branches were bare, until Robert-Houdin magically caused them to sprout orange blossoms. Then from the blossoms grew oranges, which the magician would pick off and throw into the audience to prove they were real. The last orange from the tree would then split open and two butterflies would appear carrying the spectator's handkerchief. The tree and the butterflies were of course exquisite mechanical clockwork automata, programmed by cogs to pull off this amazing trick. Even today magicians the world over cherish and collect automata because of their beauty and their clever programmable craft. Magicians even recreate the timeless effects. So it's perhaps not surprising that one of the largest collections of historical and up-to-date magic automata belongs to a magician and pioneer computer games developer – Richard Garriott from Austin, Texas. (See issues 8 and 9 for more of Richard's adventures.)

Today learns from yesterday

Today's robotics researchers owe a lot to those past pioneers who built automata. From developing fundamental principles on how lifelike movement can be achieved, to entertaining us in magical ways, to helping us begin to understand what's socially acceptable in robot design, we've learnt more than you'd expect from a history that includes chess-playing hoaxes and pooing ducks.

Automaton image courtesy Richard Garriott

Getting there in much less time with a little soap or slime

We all like to get around, but what's the best way? Being able to find the shortest route between a group of train stations, or the least amount of petrol needed to visit twenty different towns are important, but often difficult, questions to answer. The classic Travelling Salesman problem – find the shortest route to visit a set of towns, visiting each only once – has kept many a mathematician and computer scientist up late at night. The problem looks simple, but if you try to work out a general way to solve it for any large number of towns you'll just go berserk. It takes too long to work out the route and no one has yet come up with a way to calculate it that doesn't seem to take forever! (See issue 10 for more about this.)

The long way round

It's believed that the first people who started to worry about this were, not surprisingly, travelling salesmen. In 1832 a travelling salesman's handbook was produced, giving useful tips and preferred routes around towns in Germany and Switzerland, but what about those selling stuff in France or Great Britain? There was no mathematical method given to discover the best way. Finding this shortcut to calculating the route is hard because the problem is so complex that the amount of time you need to solve it, depending on the number of cities, just gets too out of hand. So is there another way?

Selling stuff in Germany's 15 largest cities means you need to find the shortest among about 43,000 million possible routes

Physical computing for hard problems

Most of today's computers use millions of electronic switches to do their calculations, but what if today's switches aren't enough? You need a physical computer. Every molecule and every cell in the natural world has rules to follow, so you could think of it as a big computer. The way stuff behaves is like a program we have yet to fully understand. Luckily, we know enough to harness bits of that program to answer questions for us.

One early example of a physical computer solving a tough problem involves a bucket of soapy water. You can try it yourself.

Computing with a little bit of soap

You will need:

1. A big bucket
2. Washing up liquid
3. Water
4. Two clear plastic sheets
5. A small blob of 'poster adhesive putty' (it may be blue and it may tack onto the wall, we couldn't say)

Start by drawing a map of your stations (they could be stations in the real world or ones you made up). To find the shortest route between your train stations take two transparent plastic sheets and stick them together, sandwiching small, same-size blobs of putty as spacers between the sheets at the positions of the stations given by your mini map. Now stand back and have a look. What you have created is a mini model of the world. All you need is to find the shortest distance joining all the stations, solving that rather tricky computational problem.

And the answer is?

Pour plenty of washing up liquid into the bucket and add water to create a very soapy solution. Froth up that bucket of soapy water and dump the plastic sandwich in, swish it around gently and pull it out. In front of you is the perfect solution (pun intended). The soap film left will cling to all the spaces in between your stations, connecting them together. The clever bit is that due to the physical process of surface tension, bubble films must always take up the least surface area they can to minimise the physical forces acting on them. This means that your network of soap bubble tracks are as short as they can possibly be. The soap has effectively solved a problem that the poor old on/off electronic switches find so difficult. You've done some clever physical computing, so have a break and chill.

Capture that actor!

One of the most common ways to create animated characters is with motion capture. The movements of real actors are applied to animated characters, making it possible, for example, for Andy Serkis to play the tiny, thin Gollum in Lord of the Rings, followed by the enormous King Kong in Peter Jackson's remake.

In order to capture the data from Andy's movement, he wore a suit made from Lycra and decorated with markers at important spots on his body. Computers track the movement of the markers and translate that into an animated character. The next step in research, though, is how to capture people's movement without needing to put them in special suits. The suits are expensive and time-consuming, not to mention revealing. Not everyone wants to wear a Lycra uniform to work.

Fortunately, a group at Dundee University is helping to relegate the form-fitting motion capture suit to the past. They've developed a system for getting the actor's motion data straight from a video of their performance. The key to grabbing the data is a search technique called 'particle swarm optimisation'. Imagine you've got a frame of video with your actor in it. To find the body position of your actor, you release a swarm of mathematical particles into the image. Within their programming is a way of finding the actor, and rules on how to follow what their neighbour is doing as well. What this means is that, over time, the particles swarm towards the image of your actor in the frame of video, like bees to a flower.

One of the biggest challenges with this method of motion capture is something you might not think about when you're using software. It's very important for the Dundee team to make their system easy enough for the film crew to use. After all, not many directors are computer scientists too. All of the deep knowledge of algorithms and swarms has to be embedded in the software so it can fine-tune itself to spot any actor, even when they might move in lots of different ways. Whatever weird creature Andy Serkis plays next, the computer has to be sure to capture him.

A jungle with character

What does the army of orcs in The Lord of the Rings have in common with the lush jungle in Avatar? It's hard to imagine that the murderous hordes of Mordor would share anything with the beautiful greenery of James Cameron's imagination, but it's a pretty big thing to have in common. In fact, it's massive. Go to the magazine+ section of our website, **www.cs4fn.org**, to find out more!

A different kind of airbrushing

If you're in a room and the walls look like they're moving, you might think it's time for a trip to the hospital. If you're in a room with Chloe Albert's animated wallpaper, though, it means you're less likely to need the hospital in the future. That's because she's designed some ingenious animated wallpaper with built-in air filters, which respond to pollution in the air around you and help clean it up.

Her project is called Filter the Filth, and she made it as a master's student in Textile Futures at Central Saint Martins College of Art and Design in London. It starts with two wallpaper patterns – one with clouds of pink, green and blue, and another that mixes big slabs of grey with gold tree branches. The colours are nice, but they're not what sets Chloe's wallpaper apart. Her design calls for sensors that take a reading of the pollution inside a room. When the readings get above a certain level, motorised filters poke out of the wallpaper pattern to clean the air, then retract back into the wall when they're done.

Invisible danger

At the business end of the wallpaper, the sensors are sniffing out volatile organic compounds (VOCs), which are chemicals that are often found in aerosols, cleaning products and building materials. Not all VOCs are bad – in fact almost anything you can smell is technically a VOC – but certain ones can damage your health. They can cause complaints ranging from headaches to liver disease. Modern buildings can be particularly rife with VOCs, as they're kept really airtight to ensure heat doesn't escape. Only problem is, neither do the chemicals.

Scrub up

Chloe says Filter the Filth is designed "to create awareness of things that we never really think about but which are affecting us every day". When you're in a room with her wallpaper, as long as the air is clean the wall is motionless. When the sensors begin to detect pollutants, the filters begin to move gently out of the wall, almost like a breeze. But if the VOC levels went up, Chloe explains, "the movement would get more erratic and quicker, which would be like a visual gauge of what's happening invisibly in your air". As the filters did their work and brought the pollution levels down, their movement would die down and eventually stop.

Sense and react

Chloe installed a prototype version of her wallpaper at the final show for her design course, where, she says, "people were very receptive of the idea". Did people find it surprising to be told that they were potentially breathing unsafe air? "I think they were a bit freaked out," says Chloe, "but I think generally they really liked the idea". The wallpaper is designed to alert people to danger, but not in a scary way. "It was designed with fun in mind as well as purpose," says Chloe. But the purpose – raising awareness of our surroundings and invisible dangers – is a good one. No one that Chloe spoke to at her show had heard of VOCs before.

The future

Filter the Filth was good enough to win Chloe the Apple Digital Innovation award at her show. To take her project into the real world, she'll need to partner with an engineer to see how to turn Filter the Filth into a product. She imagines it could be installed in homes, hotels, hospitals – any building where having clean air is especially important. But already she's succeeded in bringing a bit of smart technology and 3D movement to traditional wallpaper. So in the future, if you walk into a room where the walls are moving you won't have to worry you're hallucinating. You'll know that your wallpaper is hard at work cleaning the nasty stuff out of your air.

Images courtesy of Chloe Albert

The virtual Jedi

A virtual reality animation is giving users an experience that was previously only available a long time ago in a galaxy far, far away. Josh Holtrop, a graduate of Calvin College in the USA, has constructed a Jedi training environment inspired by the scene from Star Wars in which Luke Skywalker goes up against a hovering droid that shoots laser beams at him. Fortunately you don't have to be blindfolded in the virtual reality version, like Luke was in the movie. All you need to wear over your eyes is a pair of goggles with screens inside.

When you're wearing the goggles, it's as though you're encased in a cylinder with rough metal walls. A bumpy metallic sphere floats in front of the glowing blade of your lightsabre – which in the real world is a toy version with a blue light and whooshy sound effects. The sphere in your goggles spins around, shooting yellow pellets of light toward you as it does. It's up to you to bring your weapon around and deflect each menacing pulse away before it hits you. If you do, you get a point. If you don't, your vision fills with yellow and you lose one of your ten lives.

Tracking movement with magnetism

It takes more than just some fancy goggles to make the Jedi trainer work, though. A computer tracks your movement in order to translate your position into the game. How does it know where you are? Because the whole time you're playing the game, you're also wandering through a magnetic field. The field comes from a small box on the ceiling above you and stretches for about a metre and a half in all directions. Sixty times every second, sensors attached to the headset and lightsabre check their position in the magnetic field and send that information to the computer. As you move your head and your sabre the sensors relay their position, and the view in your goggles changes. What's more, each of your eyes receives a slightly different view, just like in real life, creating the feeling of a 3D environment.

Once the sensors have gathered all the information, it's up to the software to create and animate the virtual 3D world – from the big cylinder you're standing in to the tiny spheres the droid shoots at you. It controls the behaviour of the droid, too, making it move semi-randomly and become a tougher opponent as you go through the levels. Most users seem to get the hang of it pretty quickly. "Most of them take about two minutes to get used to the environment. Once they start using it, they get better at the game. Everybody's bad at it the first sixty seconds," Josh says. "My mother actually has the highest score for a beginner."

The atom smasher

Much as every Jedi apprentice needs to find a way to train, there are uses for Josh's system beyond gaming too. Another student, Jess Vriesma, wrote a program for the system that he calls the "atom smasher". Instead of a helmet and lightsabre, each sensor represents a virtual atom. If the user guides the two atoms together, a bond forms between them. Two new atoms then appear, which the user can then add to the existing structure. By doing this over and over, you can build virtual molecules. Eventually, the researchers at Calvin College hope to build a system that lets you 'zoom in' to the molecule to the point where you could actually walk round inside it.

The team have also just bought themselves a shiny new magnetic field generator, one that lets them generate a field that's almost nine metres across. That's big enough for two scientists to walk round the same molecule together. Or, of course, two budding Jedi to spar against one another.

The 10p napkin scam

You take a napkin and fold it into a perfect square. Pop it on the table and dump a load of 10p pieces on the table beside it. Challenge your friend to a dynamic game of wits and cunning. One by one each of you will place a 10p onto the napkin. The first person who can't place their 10p piece on the napkin without going over the edge loses. Simple game, simple rules, and a simple way to always win this animated game of strategy. Find out how in the magazine + section of **www.cs4fn.org**

The art of animatronics

or how to build a believable dinosaur

How do you create a full-sized dinosaur without a hint of computer graphics? The answer is through the amazing art of animatronics. Animatronics is a field of special effects that uses sculpture, mechanics, electronics and computer engineering to create life-size moving creatures for films and theme parks. They're like puppets only much bigger, much smarter and much scarier. While today many film creatures are created using computer graphics in post production, some filmmakers prefer to have their creatures 'live' on the set so the human actors have a real co-star to act along with. In a theme park, animatronics can put a weird creature, like a zombie pirate or a great white shark, right there and in your face. Famous movie animatronics stars include the shark in Jaws, the gigantic Spinosaurus in Jurassic Park III and the lovable alien in ET. How are these amazing effects created? Let's get primeval with some state-of-the-art computer science.

On and off the drawing board

An animatronic creature starts out in life as a sketch on the drawing board. In some cases it's a new creature-tastic idea thought up by the designer. In the case of dinosaurs, the sketches are created with the help of expert paleontologists. The sketches are then converted into a scale model, called a maquette. This scale model allows the designers to examine and correct their design plans before the big money is spent bringing the creature to full size 'life'.

Growing up

Here's where the model goes from the small to the large. The mini maquette is laser scanned, capturing all the detail of the model sculpture and feeding it into a computer aided design (CAD) software package. From this data whirring, computer-controlled blades automatically sculpt a full sized model using blocks of polyurethane foam. The blocks are assembled like a big 3D jigsaw, and sculptors add the extra fine detail. Now it's big, it's real and it's ready for its screen test!

Pouring in the skin

If the full-sized version shows that star quality, it gets molded. Using the life-size model a set of moulds are made to allow the outside skin of the creature to be created. With the outside finished, now you have to think about the insides – namely, the skeleton, the mechanics of which depend on how the creature will be expected to move. Using a rough shape corresponding to the form of the core skeleton innards, the outer foam rubber skin can be poured in so that it only fills the negative space between the outside creature shape and in the inside skeleton. This reduces the weight of the skin and allows more believable, flexible movements.

More than just the bare bones

Skin done, now the technology really kicks in. The animatronics skeleton inside the creature is where all the smart stuff happens. It's clever and custom made. It has to be – it's the part that moves the outside skin to make it look believable. Attached around the main skeleton frame, which is often built with strong-but-light graphite and looks a lot like the real creature's skeleton, we find the actuators. These are little clumps of clever computing that move the pieces around to make the creature look alive. Computer science abounds here, along with other state-of-the-art techniques. Mechanical and electronic engineering combined with computer-controlled motors are used to move small expressive bits like eyes, or to control the more heavy-duty hydraulic systems that move limbs. The systems may be pre-programmed for characteristic behaviours like blinking or swiping a claw. In essence the animatronics under the skin produce a gigantic remote controlled lifelike puppet for the director to play with.

Does my bum look big in this?

Putting the skin over the animatronics isn't always easy. As each of the sections of foam rubber skin are added to the skeleton the construction team needs to check that the new bit of skin added doesn't look too stretched, or too baggy with lots of unsightly flabby folds. One cunning way to help the image conscious creature is to use elastic bungee cords to connect areas of the skin to the frame. These act like tendons under the skin, stretching and bunching when it moves, and making the whole effect more relaxed and natural. Once the skin is on, it's a quick paint job and the creature is ready for its close up. Action – grrrr — shriek! Computer science takes centre stage.

Stirring up virtual trouble

What would you do if you saw someone getting beaten up? Would you jump in? Call for help? Is it possible you wouldn't do anything? Social scientists have found that people don't always help others, even if they realise someone's in trouble. The only way to figure out why this happens, and what makes a difference whether bystanders help someone, is to study situations like it. But how? Scientists can't just go around beating people up to see how others will react.

A team of computer scientists may have the answer: use virtual reality. The team includes researchers in the UK and Spain, one of whom is Richard Southern at Bournemouth University. Richard explains that by donning 3D glasses and stepping into a room with animations projected on the walls and floor, subjects can test their reactions without anyone getting hurt. "While people know it's not real," Richard says, "they behave as if it is real."

You lookin' at me?

When you step into the illusion, you step into a pub. The team has designed an experiment in which the user is hanging around in a virtual pub when a character approaches him or her and begins talking about football. After a short conversation the character goes away, but soon he gets himself into trouble. Another character goes up to the friendly one and tries to stir up a fight. The user doesn't know it, but this is the part the scientists are watching. What does the user do? Will he or she intervene?

It turns out that almost half do, but most don't. Eleven out of twenty-five bystanders in the experiment so far have intervened. Some people in the virtual room reach out to try and touch the characters, while others try speaking to the tough guy to try and calm him down. Still others try looking around the room, to see whether the barman will catch on or if there's someone else they can get to help. Many, though, just try and stay out of the way.

Friendly with Arsenal

Scientists are trying to figure out what makes the difference between whether people try and help, or decide to mind their own business. One of their theories is that it can depend on how much togetherness the subject feels with the character in trouble. Richard explains some studies have shown that "being a member of a particular group – generally groupiness – is a factor in determining the likelihood of intervention in violent emergencies." If the person feels like they share a bond, that feeling might prompt him or her to step in. That's why one of the elements of the experiment was about togetherness. Sometimes when the user went into the virtual pub, the friendly character wore an Arsenal shirt, and sometimes he didn't. The idea is that if the experimental subject is an Arsenal supporter, they might have a better chance of stepping in.

The unreal world

The illusion of reality might make the difference between helping and not helping too. That's the bit Richard and his group at Bournemouth are particularly interested in. He explains that people will generally believe the illusion until they're given a reason not to – say, if the user finds out they can walk through another character. In the bar fight, some of the users said they didn't intervene because they didn't think the virtual setting would let them. But even small issues with the realism of the animation might affect whether people intervene. Richard explains that the original experiment featured pretty basic animations, "and there were complaints about it from several of the bystanders – they said the animations were unrealistic." But Richard's team doesn't actually know if that changes the results of the experiment, or, if they do, by how much. So they're going to try improving the animations and seeing if people react differently.

Helping out

There are a few good things that could come out of all this research. For one, Richard explains, their results could help in dangerous situations in the real world because "it might benefit the emergency services to know what to look for on CCTV cameras, for example", or finding out ways to help make it more likely that bystanders will intervene when something unpleasant happens.

Of course one big benefit of this research is that with every experiment done in a virtual environment, Richard explains that scientists have a chance to confirm that virtual experiments get good results. Plus, he says, "you can avoid the ethical issues of exposing people to violence and other dangerous situations". Which means that it's possible to do experiments that couldn't have been done without virtual reality. And you can rest easy knowing that there won't be any wandering gangs of scientists on the street looking to start a fight. Not that you were worried about that before, of course.

Character images courtesy Gavin Lewis

From creepy to credible

If you saw Up last year, you'll know that the animation isn't designed to look completely realistic – you'd never mistake Carl and Russell for real humans. Ultra-realism isn't exactly Pixar's style, fortunately, because it's still very difficult for CGI animators to make people look realistic. They usually end up looking creepy instead.

Animated or re-animated?

The problem is the face – people's facial movements are incredibly subtle, and we're all very good at picking up on them. If anything is amiss, an animated human looks kind of zombie-ish. That's exactly what went wrong in 2004, when the Tom Hanks film The Polar Express came out. It was meant to be a charming Christmas film, but instead it got a reputation for creepiness – one CNN critic said it should have been subtitled 'The Night of the Living Dead'.

What went wrong? Well, the performances in The Polar Express came from real actors wearing motion-capture suits (Gollum in the Lord of the Rings films is the most famous example, but see page 7 for more on motion-capture). The problem came because there were two crucial bits of the actors where the Polar Express animators couldn't put sensors: the inside of the mouth and the eyes. Those areas had to be created from scratch by computer animation, and at the time, the technology just wasn't good enough to get it right. The same CNN critic said that when the characters spoke, their tongues looked "like slabs of meat". Eww.

But there is hope. In 2008 the University of Southern California's Graphics Lab partnered up with an animation company, Image Metrics, to try to produce a completely photorealistic animated face. They were going to try to break through the creepiness barrier.

Right in the face

First they chose an actor – Emily O'Brien, a soap opera star – to deliver a monologue about computer animation. Once they had their actor, they needed to gather all the information they could about her. Well, her face anyway. To do this, they put Emily into what's called a light stage. It's a huge spherical rig, with lights all around it. By turning various combinations of lights on and off, the lab researchers can record how an actor's face looks under different lighting conditions. They can eliminate the natural reflection of the skin, so that the team were able to see Emily as evenly lit as you could possibly get.

Using the data from the light scans, the USC team could also build 3D maps of Emily's face. One was a low-resolution map that showed her basic bone structure, and another was in such high detail that they could see the individual pores of Emily's face. Next, the lab team took photos of Emily with 33 different facial expressions, which allowed them to capture the movement of her entire face, especially the trickiest parts to get right, her eyes and mouth.

Then the team analysed the pictures. With resolution that went down below a millimetre, they could even see how Emily's pores got longer and shallower when she stretched her cheek. They also gathered information about the colour of her face at every point, and they even took exact models of her teeth! All of that data would be used to create the most realistic picture of a moving face they could get. All that was left was to animate the picture.

Making Emily move

The USC lab team handed their scans over to their partners the animators at Image Metrics, and within a few months they had made a fully movable model. It was so detailed that, unlike the Polar Express characters, the digital Emily even had fully modelled, moveable skin around her eyes. The next step was for the animators to record a video of the real Emily speaking the lines of her monologue. Then they pulled, stretched and shifted the muscles of Emily's digital double so that they matched the real movement exactly. In the final video of the monologue, the animators replaced Emily's real face with the digital version. They did an amazing job: it's practically impossible to tell the difference, and many people can't even tell after they watch the video many times.

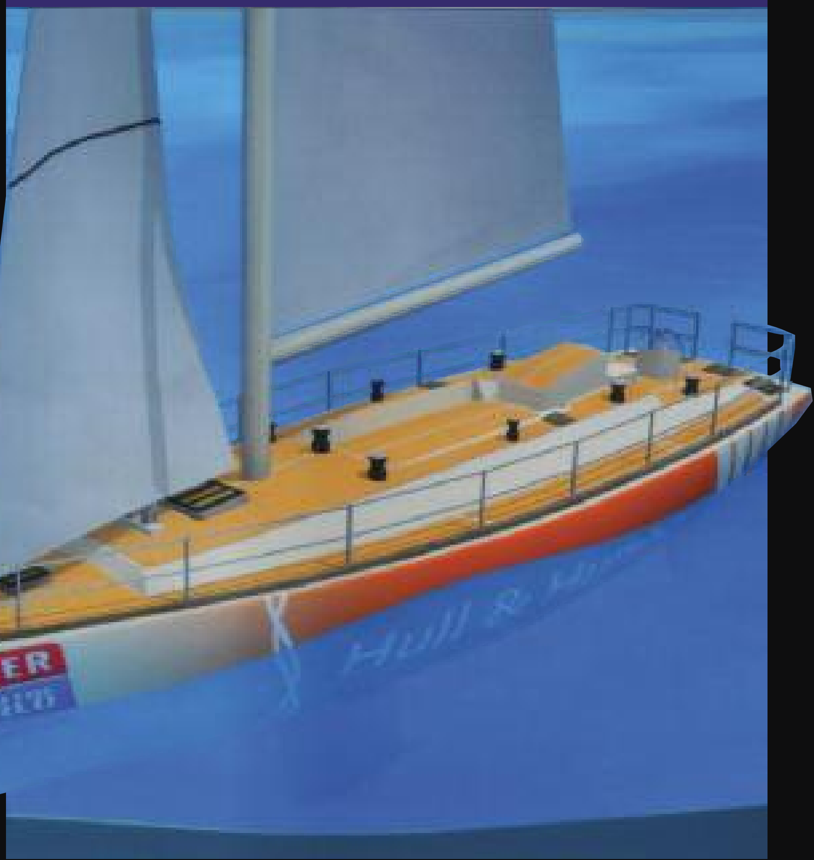
It may not be long until we see realistic digital humans in the movies. When we do, it's entirely possible that animators will look back to Emily as the beginning of a new era: the first time animation left creepy, zombie-like humans back in the horror films in which they belong.

The virtual way around the world

The sailing clipper Hull & Humber is, right now, coming to the end of a monumental voyage. Since September 2009 it's been taking part in a round-the-world sailing race that has taken it over 35,000 miles. But at least one version of the Hull & Humber hasn't gone anywhere at all. Researchers at the University of Hull have made a virtual 3D version of the boat, which lives in a special immersive environment on their campus. Visitors can put on special goggles that let them walk round the vessel in virtual reality.

The 3D model was made by scanning the entire boat with a laser, then turning the geometric data contained in the scan into a virtual copy. Having a digitised version of the Hull & Humber comes in handy, as it lets visitors do lots of things they wouldn't be able to do to the boat in real life, like give it a personalised paint job and sails, and even captain it in a virtual clipper race!

Want to know how the real Hull & Humber is getting on in its round-the-world adventure? Follow the links from our magazine + section on **www.cs4fn.org**.



Firefly

Imagine. Imagine sitting with a laptop on the bank of a river as it flows through the city centre. Both sides of the river are lined with trees decorated with lights. Now imagine all the lights make up a giant computer screen that can display pictures or messages in 3D. And you control them.

This was an idea someone floated in one of those random what-if discussions inventive people tend to have when sitting around chatting over a drink. With most groups such up-in-the-clouds ideas wouldn't go much further, but this group of people were computer scientists from Lancaster University, and they were intrigued. So they decided to make it happen.

The result they came up with is called Firefly. One of the team, Alan Dix, has been telling us about how it works.

Christmas tree lights can of course flash in different patterns, but those patterns are pre-set before the lights leave the factory. The different patterns are a result of the way the lights are physically wired together. Using physical wiring has two problems. First it's not very flexible. To change the lighting effect you may have to rebuild it from scratch. Secondly it uses a lot of wire and wire is expensive.

What the Lancaster team were thinking of was something different. What if you made every individual light a networked computer? It would be like connecting them into a mini-internet. If each light is a computer then it can be programmed to do clever things, rather than putting the cleverness in the physical structure.

Each firefly light is made of a single LED, its own personal microprocessor, a capacitor and a diode. Nothing more. Thousands of these can then be strung together in long lines using a pair of wires, with a computer that acts as a network controller at the end. This is how the computers in a school or office are often networked together. By sending instructions over the network from the network controller to all the microprocessors, the lights can then be switched individually.

Wait a minute though. Aren't computers a bit expensive to be putting them into thousands or even millions of individual lights? That's the surprising thing. No! Computer chips are very, very cheap. In fact, the most expensive part of each Firefly light is the LED not the microprocessor. Remember too that Firefly saves money by doing away with the expensive wiring other lights depend on. Less wiring makes Firefly greener than other lights too.

OK, so you have strung together lots of computer-controlled lights. How does that get you any closer to your riverside vision of controlling a 3D display in fairy lights? Well, now for the really clever bit. You pretend each light is a tiny part of a massive computer screen.

A normal computer screen is made up of thousands of individual lights, or pixels. Each can be switched between different colours. The pixels can be combined into images because they are positioned in a regular grid, and the computer knows the location of each one. That makes it easy for a computer to know which pixel to switch on to show the desired image.

Trees aren't exactly as smooth and regular as a flat screen, though. If we string our Firefly lights around a tree (or any solid object for that matter), their actual positions are hard to control. To turn them into a display we need the network controller to know exactly where each one ends up.

So, how do we do that? Easy. Just position three cameras round them, and instruct each light to flash its own unique pattern. A computer vision program can then use the three camera images and some simple geometry to spot each pattern and figure out exactly where it's coming from.

Actually there is still a slightly tricky problem to overcome. To make the microprocessors as cheap as possible they all have to be identical. That means there is no way of telling them apart once they are strung together. They would all hold the same program and all flash the same pattern! To get round this each microprocessor needs to be allocated an identity number to tell it apart from the rest. These numbers can also identify which ones are being told to switch on at any time. Assigning a number from the central, controlling computer isn't easy. Instead, it turns out to be easier to get each microprocessor to just pick a number itself. In a perfect world, as all the chips are identical, they would all pick the same number. Luckily the world, and particularly chip manufacture, isn't perfect. The speed that different chips do things is very, very slightly different. If each picks a number based on that timing they will mainly end up picking different ones.

The network controller then just needs to know if any two chips did pick the same number by chance, and get them to pick a new one. The Lancaster team came up with a clever way to do that too. They realised that there is a noticeably large drop in power when more than one light switches on. The controller can watch for that happening.

How does the controller do that? First it sends a command to all the lights saying that any chip that picked number 1 should flash its light. Next tell those that picked number 2 to do so, and so on. Each time the controller watches the power drop to see if more than one light came on. If that happens, the offending chips receive a message telling them to choose new unallocated numbers. The result is that eventually every light has a unique identity and the programmers can go back to creating their 3D map. Because each light has a unique number, it will flash a unique pattern at the three cameras, waiting to create a three-dimensional map of the sea of pixels.

With this 'calibration' process done, the tough part is out of the way. Now you just use a 3D drawing program to draw pictures in virtual 3D space on your computer. The controller can switch on the lights in the equivalent places out in the real world. You could program this in advance or control it interactively – draw in the 3D space and see your pictures immediately appear out there in the trees. The pictures you create don't need to be still of course. You could create a 3D animation, with words or pictures snaking around the trees along that riverbank.

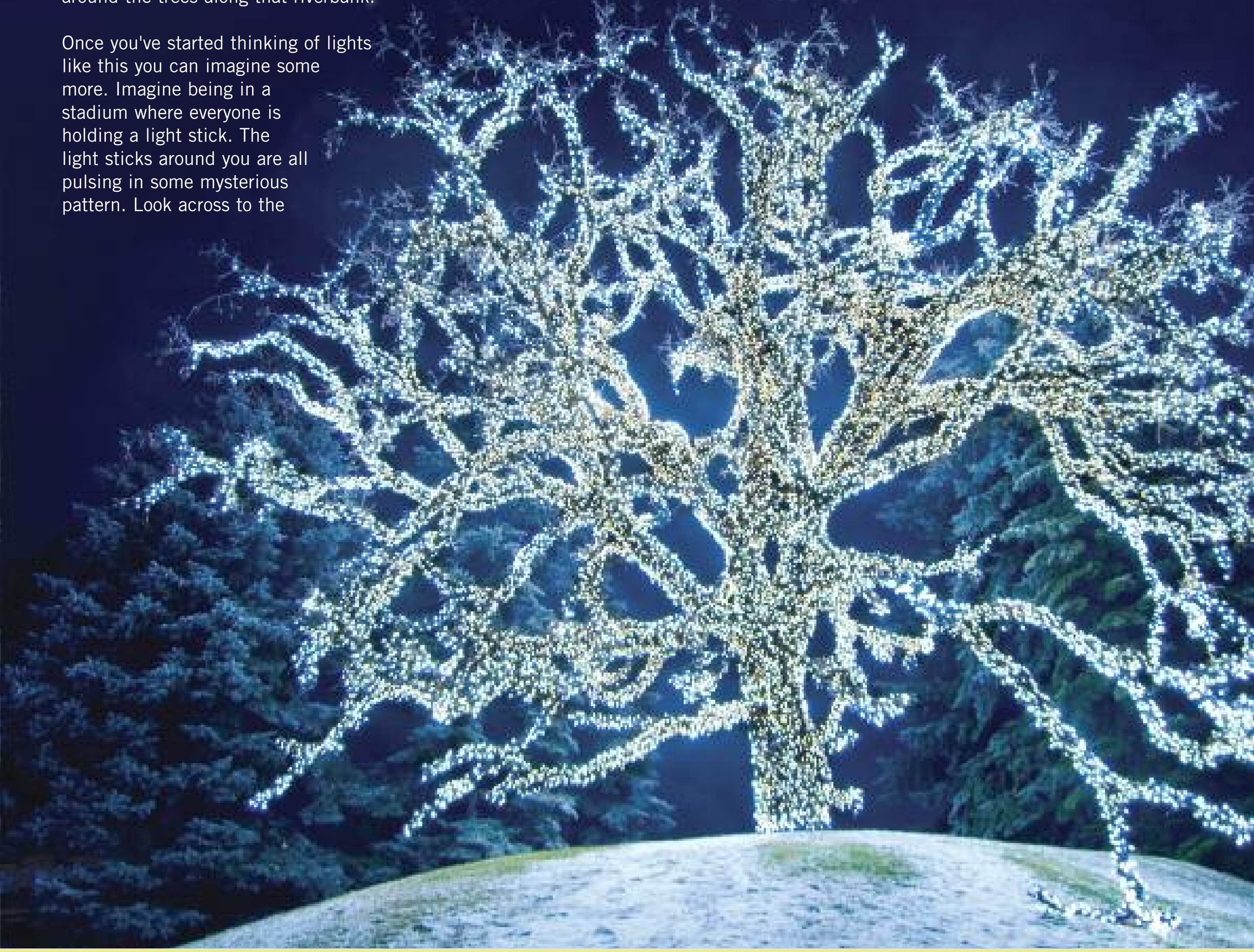
Once you've started thinking of lights like this you can imagine some more. Imagine being in a stadium where everyone is holding a light stick. The light sticks around you are all pulsing in some mysterious pattern. Look across to the other side of the stadium and you see the ones there are showing a gigantic image of the action on the pitch. You are too close to see, but that's what yours are doing too!

Imagine instead that that you are in a concert hall, the audience behind and an orchestra in front. As the conductor conducts the orchestra you conduct the light show. Every gesture is picked up by cameras and turned into changes in images that fill the auditorium.

Imagine now controlling lights on roofs across a city. As planes circle above, waiting to land, the passengers looking out the windows see more than just the lights, they see city-sized images as the city itself welcomes them.

Think bigger still. Imagine looking out of the space station at the lights of the continent passing below...

Perhaps the sky isn't the limit for good ideas after all.



Grabbing attention, saving lives

Computer science is clearly helping animators do their jobs more easily. It is less obvious how the animators might teach computer scientists a thing or two, but Rachid Hourizi of the University of Bath thought maybe they could.

He was studying how to improve the design of airline cockpits and was particularly interested in what is called situation awareness. If a pilot loses track of the current state that the autopilot is in, for example, then they might crash the plane.

In modern planes, the computers do most of the flying. You might think that makes things easier for the pilot, but if at some point the pilot has to take over, then he or she has to rapidly understand the current state of the plane. If not things can go badly wrong. For example, in 1992, an Airbus A320 coming in to land at Strasbourg crashed because the pilot, who wanted to enter an angle of descent into the computer, didn't realise that the autopilot was in a mode that treated the number he entered not as an angle but as fast speed to ascend. He flew the plane into a hillside killing all on board. Similarly, if the autopilot makes adjustments to the course it is important that the pilot realises it, so he knows where they are heading on taking over. A person's attention can only be in one place at a time, so how do you best focus a pilot's attention to the place it needs to be to take in vital information in situations like this?

Having been on a course on animation for fun, Rachid realised that the animators might be able to help. Throughout the 1900s, the Disney animation studios were worrying about a similar issue. How do you grab the audience's attention so they don't miss any of the action, even though important things might happen on different parts of the screen? The solution they came up with was to have the characters do what is called a 'predictive' movement. Before Mickey Mouse starts to run forwards he will take a single step backwards. That movement draws everyone's attention to Mickey so that when he does start to run everyone sees it. Rachid suggested the same might work in cockpits if we can find ways for the autopilot to make similar anticipatory actions. More work is needed to find out if the approach really does help, but if it does then one day this Mickey Mouse technology could just save lives.

Gaming together

The rise and rise of social gaming

Computer games are getting all sociable these days. Loads of popular games live on social networking sites like Facebook, where they are easy to get started with, and even free to play. What's more, many of these games are brilliant ideas turned into reality by just a few creative programmers.

Their games are loved and played by millions, and yes, there are millions of pounds to be made, just like in the heyday of the early games industry. But what's the psychology behind the biggest money-spinning social games? Find out in the magazine+ section of our website, **www.cs4fn.org**!

Calling all animators!

Toby Howard of The University of Manchester gives you some animation start-up tips.

Now that you've seen what other people are doing with computer animation, why not try making your own? It's easy to get started, and there's lots of free software for PCs and Macs that you can use.

Two programs that many schools use to teach the basics of animation are Scratch (**www.scratch.mit.edu**) and Alice (**www.alice.org**), both of which are freely available from their websites, along with step-by-step guides that take you through the whole process of making an animated film. Scratch is for making flat, 2D animations like traditional cartoons, while Alice lets you create 3D worlds with objects and characters. With both systems you can add sound and music to your animations.

There's also stop-frame animation, where you build your film out of hundreds (sometimes thousands!) of photographs, with the positions and shapes of objects changed very slightly from one frame to the next. When you watch the frames at the rate of about 20 every second, the still images come to life. There's lots of stop-frame animation software around, such as I Can Animate and iStopMotion.

Once you've got some experience with the basics, you might want to move onto Adobe Flash. Flash isn't free, but many schools already have it available, so ask your ICT teacher. With Flash you can produce results that look very cool and very professional! If you want your animations to be interactive, and to learn a serious programming language at the same time, try Greenfoot.

When you've made a great animation, why not enter it in the UK Schools Computer Animation Competition, held each year by The University of Manchester? There are always great prizes to be won, and an even bigger audience will see your impressive work.

Want to be an animator? Start right away! Simples!

See for yourself!

For links to all the brilliant animation stuff mentioned in this article, see the version on the magazine+ page on **www.cs4fn.org**.

Back (page) on the big screen

What do James Cameron's Avatar, Tim Burton's Alice in Wonderland and a cinema advert for Doctor Who featuring Matt Smith as the travelling timelord have in common? They are screened in three dimensions. 3D movies are currently making a comeback, and computer science is helping to add that extra dimension of depth.

The mysterious floating sausage illusion

Make two fists, and then stick out your index fingers. Keeping the rest of your fingers clenched bring your hands up in front of your face and touch your two extended index fingers together. If you focus your eyes on the other side of the room and observe where your index fingers join a fleshy sausage appears. Moving your hands forwards and back will make this illusory floating breakfast product change size. It happens because each of your eyes has a slightly different view of the world and your brain computes like mad to combine these views together to give you a sense of depth. In the case of the sausage, there is enough similarity in the two out-of-focus views of your index fingers that your brain mistakenly matches them, and 3D sausage magic occurs.

The tagline: In a world divided by left and right, only a sausage could unite them.

Let there be red and blue light

The first wave of 3D movies used a method called anaglyptic stereo. The film was shot using two slightly separated but synchronised cameras, each camera recording a one eye view of the action. The two films were then developed and were tinted either red or blue. The audience had to wear special 3D glasses, one with a red lens the other with a blue lens. What this produces, as well as a grievous fashion nightmare, is the effect that the red covered eye only sees the red parts of the image and the blue parts get blocked, and vice versa for the blue filter covered eye. The brain then does the sums to fuse these two images together, assuming the differences are caused by different distances, and 3D happens. This method was also used to make 3D comics because it was cheap and easy to do, but it really messed with the colours in the pictures.

The tagline: I see red, people.

Build a better pair of glasses

Polaroid sunglasses work because they block polarised light. The next wave of 3D technologies used this method. A two-lens camera system meant that the two separate images were squashed side by side on the same film frame. When played back through a single projector each of the squashed images was expanded by two special lenses, each lens having a different polarising filter on them. The projection had to be onto a special thin metal screen to keep the reflected polarisations perfect. Each audience member wore special Polaroid glasses, where one polarisation was blocked from one eye, and the other polarisation was blocked from the second eye. This once again produced two different images, now in their proper colour, that the brain blended together to deliver that 3D experience. But the screens were expensive, seats at the side of the cinema couldn't see the pictures properly, and your eyes and brain hurt after a while. So the second wave of 3D washed away until the large screen IMAX systems arrived and new computer technology made it possible to manipulate the images to be projected to reduce the viewers' eyestrain

The tagline: I'll make them an offset they can't eye fuse.

In future forget the glasses

Computer technology will open up whole new possibilities in 3D displays in the future. Methods include having lenticular arrays – a sheet of two types of tiny thin lenses which bend the light coming through them left or right. The 3D image is created by taking the two pictures and slashing them into tiny strips. You then switch on all the strips under left bending lenses, followed by all the strips under right bending lenses, and back again. If you switch between them quickly enough the brain doesn't notice this flicker, but instead gets two different views through the left and right eyes, creating 3D. Technology like this is being developed for TV and mobile phones, so in the future depth will be as common as today's breadth and height.

The tagline: In the future, every 3D film will be a slasher film.

cs4fn is supported by industry including **Google**, **Microsoft** and **ARM**.

The Higher Education Academy Information and Computer Sciences

bcs The Chartered Institute for IT

EPSRC Engineering and Physical Sciences Research Council

For a full list of our university partners see www.cs4fn.org

Queen Mary University of London

www.cs4fn.org