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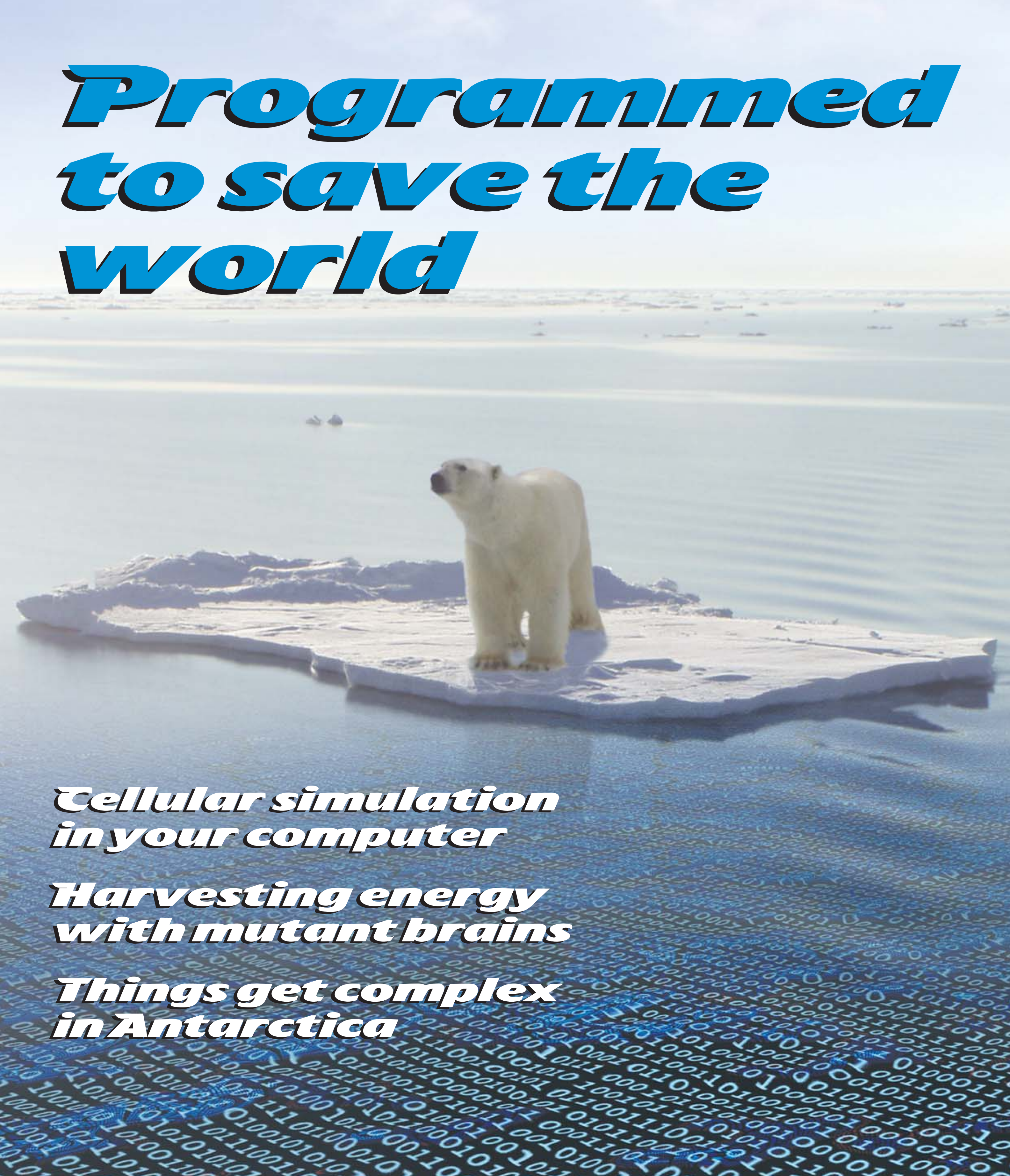
CS4FN

Computer Science for Fun

Issue 9

Programmed to save the world



Cellular simulation in your computer

Harvesting energy with mutant brains

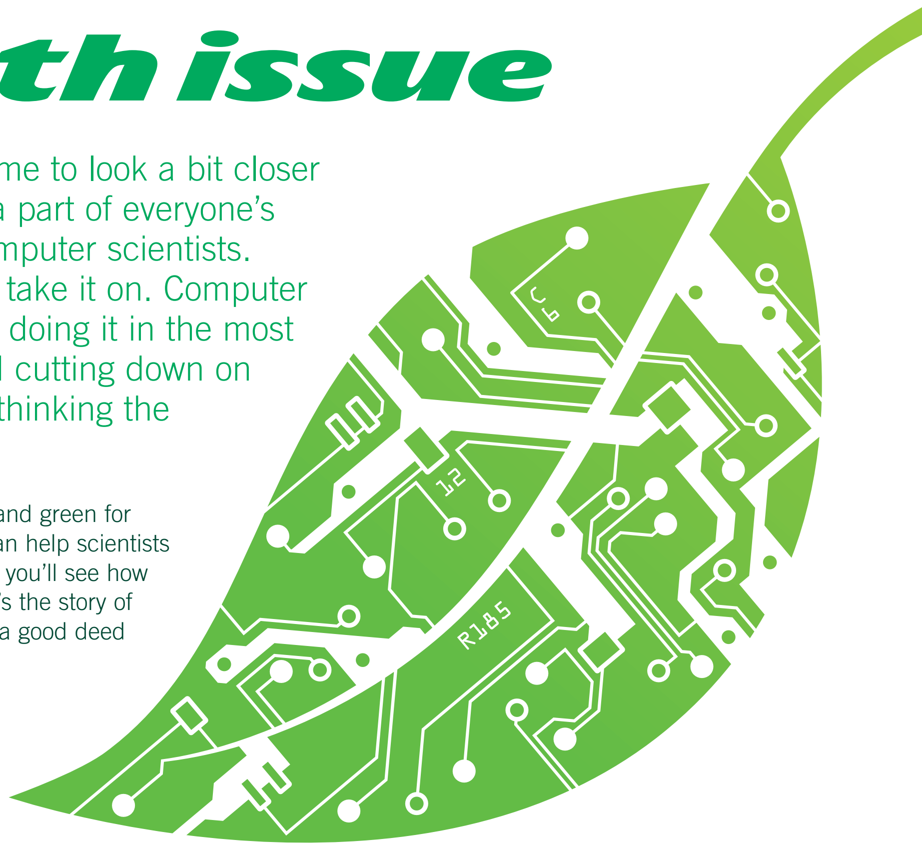
Things get complex in Antarctica

The Earth issue

After last issue's flight into space, it's time to look a bit closer to home. Protecting our planet is now a part of everyone's life, and that responsibility includes computer scientists. Fortunately, they're more than ready to take it on. Computer science is about solving problems, and doing it in the most efficient way possible. Helping out, and cutting down on waste: does that sound like the sort of thinking the Earth needs?

That's not the only thing that computer science is good and green for though. In this issue you'll read about how computers can help scientists figure out what our climate will be like in the future, and you'll see how robots are helping to clean up nuclear waste. Plus there's the story of how technology brought together a mob of people to do a good deed for the Earth.

Explore this issue and find out how computer scientists can help our planet. Have fun.

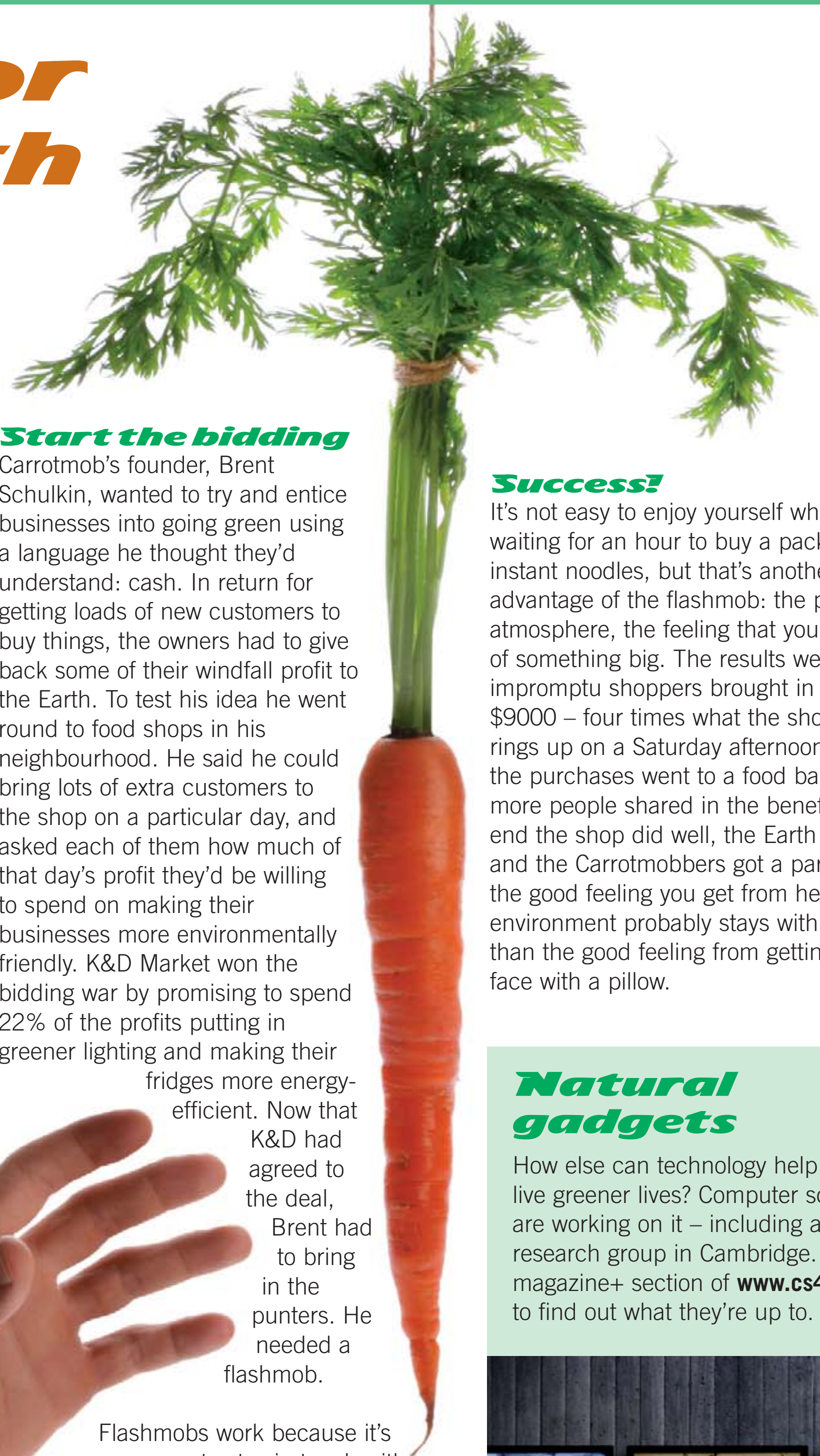


Brain power

Human brains are pretty impressive computing beasts – they are still more powerful than any computer on the planet. Despite that they are pretty energy efficient too. Your brain uses only 12W of power (compare that say with a normal 60W lightbulb – it's pretty eco-good). Modern compute-servers, used by search engines to store all the data they use to make web searches fast, have about as many basic computing components as there are neurons in the brain. They ought to be able to be similarly efficient you might think. In fact they use megawatts of power – that's getting on for a million times more power hungry.

There are clearly still some tricks that computer designers could learn from evolution about making machines super-efficient!

A mob for the Earth



One Saturday afternoon last spring in San Francisco, a queue of people stretched down the pavement from a neighbourhood market. There was no shortage of other food shops nearby, so why were hundreds of people waiting to buy everything from crisps to cat litter at this one place? Because that shop had pledged to donate more than a fifth of that day's profits to improving its environmental footprint.

Pillow fights and parties

The organisation behind the busy shopping day is called Carrotmob. The tactics they used to summon so many people to the tiny market in San Francisco had already been working all over the world for less serious stuff. From a huge pillow fight in New York's Times Square to a mass disco at Victoria Station in London where people danced along to their MP3 players, the concept of the flashmob can seem to create a party out of thin air. From a simple idea, word can spread over social networking sites, email and word of mouth until a few people have turned into a huge crowd.

Start the bidding

Carrotmob's founder, Brent Schulkin, wanted to try and entice businesses into going green using a language he thought they'd understand: cash. In return for getting loads of new customers to buy things, the owners had to give back some of their windfall profit to the Earth. To test his idea he went round to food shops in his neighbourhood. He said he could bring lots of extra customers to the shop on a particular day, and asked each of them how much of that day's profit they'd be willing to spend on making their businesses more environmentally friendly. K&D Market won the bidding war by promising to spend 22% of the profits putting in greener lighting and making their fridges more energy-efficient. Now that K&D had agreed to the deal, Brent had to bring in the punters. He needed a flashmob.

Flashmobs work because it's now so easy to stay in touch with large numbers of people. If we find out about a cool event we can share it with all our friends just by making one post on sites like Facebook or Twitter. We can make plans to do something as a group just by sending a few texts. When lots of people spread word around like this, suddenly a small idea like Carrotmob, armed with only a website and a few videos, can drop an hour-long queue on the doorstep of a market in San Francisco.

Success!

It's not easy to enjoy yourself when you're waiting for an hour to buy a packet of instant noodles, but that's another advantage of the flashmob: the party atmosphere, the feeling that you're part of something big. The results were big: the impromptu shoppers brought in more than $9000 – four times what the shop ordinarily rings up on a Saturday afternoon. Lots of the purchases went to a food bank, so even more people shared in the benefits. In the end the shop did well, the Earth did well, and the Carrotmobbers got a party. Plus the good feeling you get from helping the environment probably stays with you longer than the good feeling from getting hit in the face with a pillow.

Natural gadgets

How else can technology help people live greener lives? Computer scientists are working on it – including an entire research group in Cambridge. Visit the magazine+ section of **www.cs4fn.org** to find out what they're up to.

Do not enter!

Humans have many great qualities, but we often tend to leave a bit of a mess. In the recent Pixar film, WALL-E, we meet a robot who helps to clean up after humans, but lots of robots already have WALL-E's job for real.

Robots in Scotland

In Scotland a swarm of robots are helping to clean up the radioactive leftovers from a nuclear power station. Dounreay was an experimental fast breeder reactor. It used neutrons to turn uranium into plutonium, and the discoveries made there gave us new ways to produce electricity without burning fossil fuels. But, like most things in life, it came at a cost. At the end there were thousands of stainless steel tubes filled with radioactive uranium that needed to be moved to a special building to be examined, cleaned up, and even in some cases recycled. This is where the robots came in, because people wouldn't want to be getting too close to the nuclear leftovers. The robot gang is made up of simple robots that are controlled by people at a distance, and some smarter robots that can do things for themselves. Robots that have some ability to act independently are called autonomous. Though autonomous robots aren't yet able to decide everything they want to do, they can work out some things for themselves.

Reach out and touch me

Imagine you want your robot's gripper to move to a nuclear rod and pick it up. You could watch how the gripper moves in real time by camera link and move the gripper with a joystick every bit of the way. Alternatively, you could just tell the robot to move its gripper to the position you want, and leave it to work out the movement for itself. For a robot, working out how to move an arm to a particular place in space is actually very tough.

Mostly armless

Let's do a thought experiment. You're inside a nuclear reactor and your arm is in a full plaster cast (what a nasty accident that was, get better soon). Your arm can't bend, so now imagine having to get a firm hold of one of those uranium-filled tubes. It's going to be tough. Your arm can only move in very limited ways, and what if there are things in the way? Yipes, problems! After a visit to our thought experiment hospital, the cast is off and you can bend and shake your arm like normal. Now getting to a point in space is oh so much easier. You have more degrees of freedom to play with, the elbow bends again, your wrist rotates, and anything in the way is much less of a problem. More degrees of freedom means greater flexibility for your arm and it's the same for a robot.

On the spot

The sorts of robots used in confined spaces like reactors need to have flexible arms, so they have motors that allow the arm to bend and turn like a human's elbows, shoulder and wrist. Many robots try and produce movements similar to humans. After all, evolution has shown us it's a fairly useful design. Some robots even have more joints; there may be a better solution than the human arm. (In fact other animals do have limbs with more degrees of freedom than us.) But there is a problem. Back to a bit of arm experiment. Touch this full stop (.) with your index finger. Good, now keeping your finger on the full stop and your body stationary, move your arm, flex an elbow, twist a shoulder – there are loads of different ways that you can position your arm to touch the same point in space. Even though your arm has large parts that can't change shape because of their rigid bones, our joints (moved and held in place by our muscles and tendons), give us all that wonderful flexibility.

Are we there yet?

Let's run this back. Suppose you want to reach out and touch that full stop. Your brain uses the wonderful processing power in its visual cortex to work out where you want to move to, but another large brain area called the motor cortex works out exactly how the muscles and joints need to position themselves to make it happen. Engineers would say your brain solves a complex 'inverse kinematics' problem, namely, moving your finger to a particular position given the degrees of freedom and the muscles you have available. The same goes for autonomous robots. You tell the robot to move its gripper somewhere, and the computer takes the strain to work out how. These robots have to solve an inverse kinematics problem, this time with rigid steel 'bones' and electric motor 'muscles', but the computation is the same. In fact some robotics researchers have used information from the way humans solve this problem to help build robot arm computer control systems. These smart robots, which can do some of the thinking themselves, can help in nuclear reactors, outer space, deep under the sea, in fact in most environments where it would be dangerous for humans to go. Like WALL-E, they are built to help.

Just smashing!

Of course all robots in the Dounreay gang aren't so smart. The Brokk 180 robot just smashes through walls, but it takes all kinds of robots to make the world a better place.

Silent running!

Eco-robots have a long history in science fiction films. In a classic SF masterpiece, *Silent Running*, the last of the Earth's plants are preserved on giant space-freighters tended by robots…then the order comes to destroy them.

Hunt for treasure in a SimSubmarine

Now you can become a submarine captain without the hassles of having a crew, joining the navy or even learning to swim. Researchers in the computer science department at the University of Hull have made a 3D submarine simulator that lets you hunt for treasure in southern Europe without leaving the UK.

There are loads of shipwrecks off the coast of Italy, France and Portugal, and they offer some fascinating dives. Unfortunately the shipwreck sites are threatened – the ships themselves are eroding and some divers like to nick their lost cargo. The team from Hull are aiming to preserve the shipwreck sites as they are now, so that people can continue to explore them in years to come.

If you want to try out the simulator it's going to be set up at the Deep Aquarium in Hull, but you can even captain the sub without leaving your computer. From spring 2009 there will be an online version. See the magazine+ section of our website, **www.cs4n.org**, for a link.

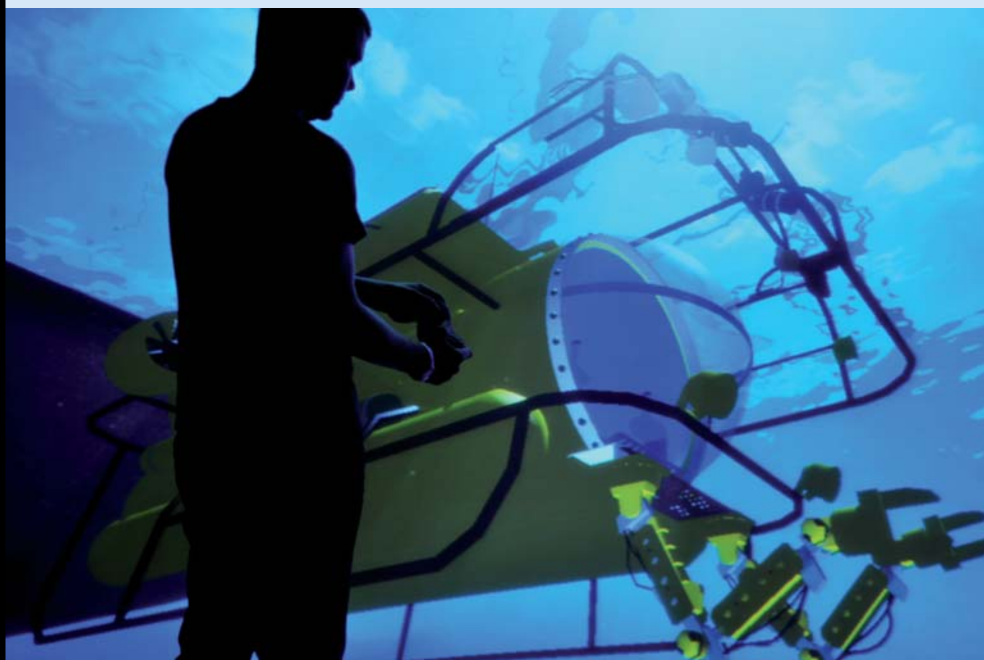


Image credit: the University of Hull

A wild way to escape diseases

Protecting wildlife might save humans as well as animals. In 2008 zoologists found that conserving animal habitats rather than building on them could prevent people from catching diseases. Lots of the most dangerous human diseases began by infecting animals, so figuring out what factors help viruses jump species could help prevent epidemics in the future.

Kate Jones from the Institute of Zoology in London and a team of researchers used computer modelling to help do just that. They found that places where people have muscled in on a diverse animal habitat are also the most likely for diseases to make the big leap into humans. That means that programs designed to conserve wild habitats might have a great side benefit for humans too – by staying away it means that we'll catch fewer exotic animal lurgies.

Go fly a kite

What greener hobby than flying a kite? It doesn't use up batteries: all the fun comes from natural energy sources. Better still, it's really exhilarating and, with a big kite, your arms might even feel like they've had a good workout afterwards. If a team from the University of Sussex get their way, future kites might soon be giving robot brains a workout too.

Pain with gain

There is lots of energy in the wind. A large kite can easily drag a person along the ground – which is why there are now sports like kiteboarding and kitesurfing. You could just use that energy for enjoyment, but why not harvest it instead? The idea of wind energy isn't new of course. Centuries ago windmills drove the original energy revolution and their modern counterpart the wind turbine is now touted as one way to wean us off oil.

Wind turbines aren't the only way to generate energy from wind though and actually they are at a bit of a disadvantage. Never mind that local people always want them put somewhere else, no matter where they go they are stuck down at ground level. Down there the wind speeds are low. Also, close to the ground you can't guarantee the supply: when the wind drops it's bye-bye energy. Go higher though and there is far stronger and far more stable wind energy to tap. All you need is a kite with a very long string!

Let it all out

The basic idea of using a kite to generate energy is to let the wind unwind the string. That drives a generator as it goes higher. Then when you run out of string you pull the kite back in and start again. If you can pull the kite back to where it started using less energy than you generated, then your green energy system is off the ground (so to speak). Google think the idea has enough potential to have poured 10 million dollars into one company developing the idea.

Evolve a new brain

Even though the science has been known for a long time, turning that into an industrial strength prototype isn't easy. The big problem is not how to build the kites but how to control them to catch as much energy as possible. You can't just get a kid to hold the kite after all. Enter some robot brains.

Allister Furey and Inman Harvey from the University of Sussex have been exploring how techniques used to develop brains for robots can be used to control energy harvesting kites efficiently. Not only are they giving the kites artificial brains, they're giving them brains that evolve!

Mutate to survive

The pressures on animals that make their species become faster, stronger, or quieter over many generations of children is called an evolutionary pressure (see 'Faster, faster!', right). If you can create an artificial evolutionary pressure – building it into what

computer scientists call a 'genetic algorithm' – you can use it to drive changes in man-made systems too. That's what the Sussex team created. Instead of trying to design the best brain to control their kite themselves, they were going to let evolution design it for them.

To 'survive' the artificial brains need to get more energy from the wind than their rivals

They started by designing a very simple kite controller, which they then released into the 'wild' of their genetic algorithm to see how it got on. To 'survive', these artificial brains needed to get more energy from the tugs and lulls of the wind over a period of time than the rival brains. Those that did best were allowed to have 'children' – new controllers that were random mutations of the original (that is all you are – a mutated version of your parents!) All the children were then tested anew spawning their own children. This went on and on, generation after generation. Over time the evolving brains got better and better at controlling the kites, even starting to fly them in figure-of-8 patterns. That's not only fancy kite-flying, it's a pattern that scientists know is a good way to catch the energy of the wind. The kite controllers had evolved, just like many real creatures have, to efficiently harvest the energy sources available to them. That may even give us a clue to the future of artificial life: computerised creatures that can harvest energy from their environment to sustain themselves just like all animals do.

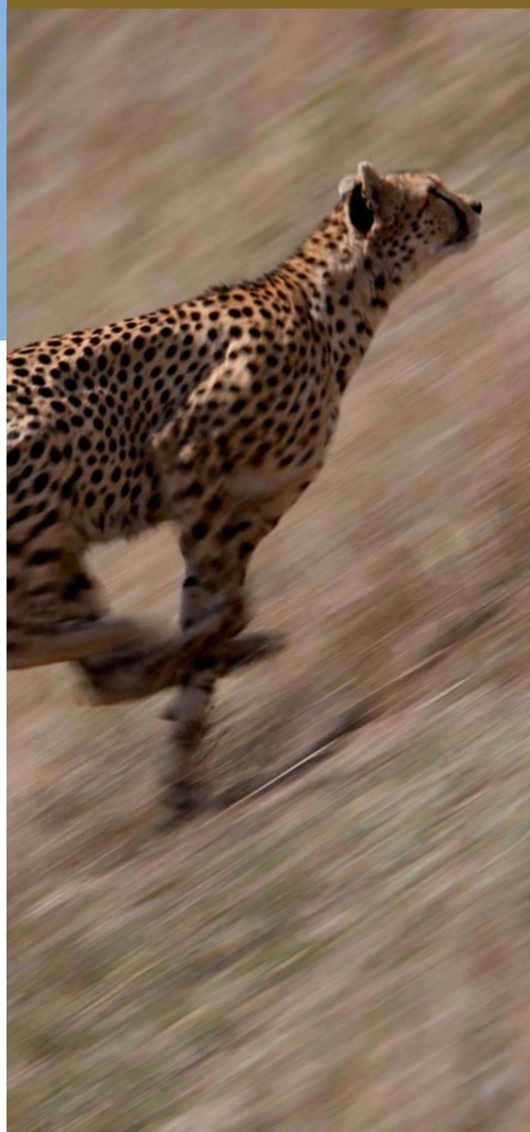
Going out to play

So far the controllers have only been playing with virtual kites in simulations, but one day soon they will be allowed out to play in the real world. When the time comes, the kite-flying computers may have all the fun but we'll have a new source of green energy.

Faster, faster!

In nature, animals within one species are not all the same. There are small differences in how fast one cheetah is over the next, for example. When times are lean and there are few impala or gazelle to catch, that little extra speed can make all the difference. The faster cheetah gets the food needed to feed its cubs. They survive and are likely to have the genes for speed too, some perhaps with genes that make them a little faster still or allow them to run a little longer. The slower cheetah makes do without babies, so the slower genes are lost. Over lots of generations all those little improvements add up and cheetahs get faster.

To see more about how little mutations add up to big changes, go to **www.sodarace.net**



Driven to perfection?

The motor car is part and parcel of modern life, but cars can have a massive impact on the environment, from exhaust fumes to guzzling petrol. Car manufacturers are increasingly looking at ways to make cars greener. As the rules on allowable levels of exhaust emissions get tighter, the need to make the most of the world's dwindling supply of fossil fuels becomes more pressing. Materials engineers develop lighter alloys to build cars with, chemists develop catalytic converters to remove some of the toxic nastiness in exhausts, electronic engineers work to develop efficient new electric engines, and computer scientists chip in by trying to make our vehicles smarter.

The bang, bang, bang of a banger

Today's motor vehicles, on the whole, use the same basic internal combustion engine that's been around for more than a century, and produced many happy hours of engine tinkering in the past. It gets its drive from a series of cylinders with plunger-like pistons inside, held within the engine block. The fuel injection squirts petrol into a cylinder, which mixes with air. The spark plug ignites this mixture and bang – the mixture explodes, pushing the piston. The pistons attached to the different cylinders are all connected to the crank shaft. This cleverly designed bit of zigzagged metal ensures that as one cylinder ignites, pushing its piston downwards and causing the crank shaft to rotate, another of the pistons attached to the crank shaft is forced up in turn. The petrol-air mixture in this cylinder is then ignited and so on in a repeating cycle, each explosion triggering the next phase as the crank shaft continues to turn.

Have a break, have a smart engine

Until recently all a car's cylinders were used all the time, but that can waste fuel. The crank shaft is turning at top speed but the road speed, fixed by the gear you're in, may be much less. You may even be stopped at traffic lights or stuck in a traffic jam, but the crank shaft still spins on regardless. The smart engine management system fixes that. Onboard computers monitor the speed you want to go and reduce the amount of fuel in the cylinders when you don't need that extra power. The smart cylinders take a break. In some smart engines it's even more extreme. When you're stationary the computer system turns the engine off altogether, but allows it to spring back into life the instant you need it. The same smart computer control has even been applied to the engines in motorbikes where computers control the electronic valves on the cylinders, ensuring that performance is there when you need it, but precious fuel isn't wasted.

Reinventing the wheel

It's not just the car engine that can get smarter to go greener – the wheels can too. Scientists at the University of Portsmouth's Institute of Industrial Research have given car wheels the ability to learn the best driving style for a given speed and road condition. The wheels contain a microcomputer and sensors that allow them to detect the road conditions under them; they can also communicate with the other wheels on the car to see how things are on the other corners of the vehicle. All this information is processed by onboard software, and this artificial intelligence changes the car suspension, steering and braking systems accordingly. These smart wheels can learn how to change the car's driving performance depending on the road you're driving. After all, you're going to drive differently over a bumpy, winding country road and a rain-covered motorway. As the car learns it also remembers, and if in future the wheels sense that they are in the same situation, the car's memory changes the way it handles to ensure a safe and fuel efficient drive.

Get switched on

What's a smart plug and how can it help you save energy? Go to the magazine+ section of **www.cs4fn.org** to find out.

Getting out of a jam

Being stuck in a traffic jam is sadly a part of modern city life, and it's not a green scene. Exhaust fumes from idling engines, and all that wasted petrol combusting internally mean it would be far better to avoid these snarl-ups altogether. Just as they reinvented the wheel on page 8 the University of Portsmouth has come to the rescue again, with their smart system called CADRE: 'Congestion Avoidance Dynamic Routing Engine'. This system uses vehicles that are carrying a super-smart type of GPS, or global positioning system. This is a 'smarter than the average car' satnav, because it's able to share information between all the other vehicles carrying similar smart electronics in a 10-mile radius. When the system starts to detect fellow vehicles moving slowly or stopping, it smells a jam, and starts to work out the best route for the driver to take to avoid the road congestion. The driver can then decide if they want to change their route and go the way the artificial intelligence suggests.

It's all going fuzzy

The traffic jam buster's artificial intelligence makes use of a clever concept called fuzzy logic. Normal, (that's un-fuzzy) logic is either true or false, but when it comes to making decisions we humans tend to prefer terms like 'maybe', or 'possibly', or 'highly unlikely but you never know'. How is a poor computer with its binary 1 and 0, true and false way of seeing things going to cope with that kind of information? Well, turns out that the ideas behind fuzzy logic allow exactly that. Fuzzy logic is called a multi-valued logic – it's not just true or false, there are other possibilities in between. For example you detect that cars are moving at 5mph, but is this indicative of a traffic jam? We can have two concepts, jam or no-jam, and rate the two on a sliding scale between 1 and 0. If there definitely is a traffic jam then we would have 1.0jam (or 0.0no-jam which is the same thing), if there is definitely no traffic jam then our fuzzy logic says 0.0jam or 1.0no-jam – you get the idea. This mathematical approach lets us build in a bit of good old human experience. One driver might say that the information that cars were moving at 5mph was 0.7jam and 0.3no-jam, and they clearly think a jam is more probable. Another driver might feel that 5mph wasn't so bad, and so for them its 0.5jam 0.5no-jam. The mathematics of fuzzy logic lets the system build in these uncertainties.

Turn left?

Combining lots of similar human-defined rules for all the other traffic variables, the artificial intelligence system can make a guess based on the available information much like a person would. But, like advice from any 'back seat driver', even if it's got some smart eco-friendly electronics and software in the front seat, its up to you to decide where you're going.

Top flight magic trick

When we move from A to B in a bus, a car or a plane, the fuel we burn releases carbon dioxide into the air and we leave what's called a carbon footprint. Your magical demonstration will show that simple playing cards can move without such eco-damage. In your demonstration you count out exactly 10 cards. You place five of them on one side of the room and the remaining 5 on the other. Then invisibly, and without any trace of CO_2 one card travels from the first pile to the second. Have you really mastered powers of invisible, zero energy transportation, or is it all in the mind of your spectators? Have a look at the magazine+ section of our website, **www.cs4fn.org**, to see how this cunning bit of mind manipulation is possible.

Cold hard complexity: learning to talk in nature's language

A gentoo penguin slumps belly-first on a nest at Damoy, on the Antarctic Peninsula. Nearby some lichen grows across a rock, and schools of tiny, shrimp-like krill float through the Southern Ocean. Every one of these organisms is a part of life in the Antarctic, and scientists study each of them. But what happens to one species affects all the others too. To help make sure that they all survive, scientists have to understand how penguins, plants, krill and everything else in the Antarctic interact with one another. They need to figure out the rules of the ecosystem.

Working together

When you're trying to understand a system that includes everything from plants to penguins, things get a bit complicated. Fortunately, ecology has a new tool to help, called complexity theory. Anje-Margriet Neutel is a Biosphere Complexity Analyst for the British Antarctic Survey. It's her job to take a big puzzle like the Antarctic ecosystem, and work out where each plant and animal fits in. She explains that 'complexity is sort of a new brand of science'. Lots of science is about isolating something – say, a particular chemical – from its surroundings so you can learn about it, but when you isolate all the parts of a system you miss how they work together. What complexity tries to do is build a model that can show all the important interactions in an ecosystem at the same time.

Energy hunt

So for a system as big as a continent full of species, where do you start? Anje's got a sensible answer: you start with what you can measure. Energy's a good candidate. After all, every organism needs energy to stay alive, and staying alive is pretty much the first thing any plant or animal needs to do. So if you can track energy and watch it move through the ecosystem, you'll learn a lot about how things work. You'll find out what comes into the system, what goes out and what gets recycled.

Playing with models

Once you've got an idea of how everything fits together you've got what scientists call a model. Not a model you put together with glue, though – a mathematical simulation. The really clever thing you can do with models is start to mess around with them. As an example Anje says 'What would happen if you took one group of organisms and put in twice as much of them?' If you had a system with, say, twice as many penguins, the krill would have to be worried because more penguins are going to want to eat them. If they all run out what happens to the penguins? Or the seals that like eating krill too? It gets complicated pretty quickly, and those complicated reactions are just what scientists want to predict.

The language of nature

Figuring out how an ecosystem works is all about rules and structure. Ecosystems are huge complicated things, but they're not random – whether they work or not depends on having the right organisms doing jobs in the right places, and on having the right connections between all the different parts. It's like a computer program that way. Weirdly, it's also a bit like language. In fact, Anje's background is in studying linguistics, not ecology. Think of an ecosystem like a sentence – there are thousands of words in the English language but in order to make a sentence you have to put them together in the right way. If you don't have the right grammar your sentence just won't make sense, and if an ecosystem doesn't have the right structure it'll collapse. Anje says that's what she wants to discover in the ecosystems she studies: 'I'm interested in the grammar of it, in the grammar of nature.'

Surviving Antarctica

Since models can help you predict how an ecosystem reacts to strange conditions, Anje's work could help Antarctica survive climate change. 'The first thing is to understand how the models work, how the models behave, and then translate that back to the biology that it's based on,' she explains. 'Then say OK, this means we expect there may be vulnerable areas or vulnerable climate regions where you can expect something to happen if you take the model seriously.' If scientists like Anje can figure out how Antarctica's ecosystems are set up to work, they'll get clues about which areas of the continent are most at risk and what they can do to protect them.

Surviving on a continent where the temperature hardly ever gets above freezing is tough, and climate change is probably going to make it even tougher. If we can figure out how Antarctic ecosystems work, though, we'll know what the essential elements for survival are, and we'll have clues about how to make things better. Extracting the secret grammar of survival isn't going to be a simple job, but that's no surprise to the people working on it. After all, they're not called complexity scientists for nothing.

Spot the penguin

Penguin spotting is a lonely job. In the name of science, you sit on a beach for hours at a time, watching as one penguin after another comes waddling past on their way somewhere more fun. You note down how many you saw and when, and then keep on waiting. Time passes. You chew on a piece of grass and push sand around with your toe. Finally, eventually, the penguins all walk back the other way and you note that down too. With the noting-down all taken care of you can head home, knowing not only is your job slow, it's expensive and prone to mistakes too. Hmpgh.

Happily, it could be that biologists may not have to spend much longer getting sand in their trousers. A team from the University of Bristol have built a system that uses CCTV and computer intelligence to recognise one African penguin from another. That way they can leave the spotting to a cheaper, more accurate system, and get on with more important work themselves. The way it works is by recognising patterns. Go to the magazine+ section of **www.cs4fn.org** to find out more.

Cognitive crash dummies

The world is heading for catastrophe. We're hooked on power hungry devices: our mobile phones and iPods, our Playstations and laptops. Wherever you turn people are using gadgets, and those gadgets are guzzling energy – energy that we desperately need to save. We are all doomed, doomed…unless of course a hero rides in on a white charger to save us from ourselves.

Don't worry, the cognitive crash dummies are coming!

Actually the saviours may be a professor of human-computer interaction, Bonnie John, and a grad student, Annie Lu Luo. They're both from Carnegie Mellon University in the US and it's their job to figure out how well gadgets are designed.

If you're designing a bridge you don't want to have to build it before finding out if it stays up in an earthquake. If you're designing a car, you don't want to find out it isn't safe by having people die in crashes. Engineers use models – sometimes physical ones, sometimes mathematical ones – that show in advance what will happen. How big an earthquake can the bridge cope with? The mathematical model tells you. How slow must the car go to avoid killing the baby in the back? A crash test dummy will show you.

Even when safety isn't the issue, engineers want models that can predict how well their designs perform. So what about designers of computer gadgets? Do they have any models to do predictions with? As it happens, they do. Their models are called 'human behavioural models', but think of them as cognitive crash dummies. They are mathematical models of the way people behave, and the idea is you can use them to predict how easy computer interfaces are to use.

One very successful model is called 'GOMS'. When designers want to predict which of a few suggested interfaces will be the quickest to use, they can use GOMS to do it.

Send in the GOMS

Suppose you are designing a new mobile phone. There are loads of little decisions you'll have to make that affect how easy the phone is to use. You can fit a certain number of buttons on the phone, but what should you make the buttons do? How big should they be? You can also use menus, but how many levels of menus should a user have to navigate before they actually get to the thing they are trying to do? More to the point, with the different variations you have thought up, how quickly will the person be able to do things like send a text message or reply to a missed call? These are questions GOMS answers.

To do a GOMS prediction you first think up a task you want to know about – sending a text message perhaps. You then write a list of all the steps that are needed to do it with your new design. Not just the button presses, but hand movements from one button to another, thinking time, time for the machine to react, and so on. In GOMS, your imaginary user already knows how to do the task, so you don't have to worry about spending time fiddling around or making mistakes. That means that once you've listed all your separate actions, GOMS can work out how long the task will take just by adding up the times for all the separate actions. Those basic times have been worked out from lots and lots of experiments on a wide range of devices. They have shown, on average, how long it takes to press a button and how long users are likely to think about it first.

GOMS in 60 seconds?

GOMS has been around since the 1980s, but hasn't been used much by industrial designers yet. The problem is that it is very frustrating and time-consuming to work out all those steps for all the different tasks for a new gadget. That is all starting to change, thanks to a team of researchers led by Bonnie John. Her team have developed a tool called CogTool. You make a mock-up of your phone design in it, and tell it which buttons to press to do each task. CogTool then works out where the other actions, like hand movements and thinking time, are needed and makes predictions using GOMS.

Bonnie John came up with an easier way to figure out how much human time and effort a new design uses, but what about the device itself? How about predicting which interface design uses less energy? That is where Annie Lu Luo, comes in. She had the great idea that you could take a GOMS list of actions and instead of linking actions to times you could work out how much energy the device uses for each action instead. By using GOMS together with CogTools, a designer can now find out whether their design is the most energy efficient too.

So it turns out you don't need a knight on a white charger to help your battery usage, just Annie Lu Luo and her version of GOMS. Mobile phone makers saw the benefit of course. That's why Annie walked straight into a great job on finishing university.

Carbon computers

Want a quick way to get an idea how green your computer is? Download SusiClimate for free from **www.susigames.com/populator/**

SusiClimate tells you your computer's CO_2 - emission as you work.

It's currently just for Macs but they promise versions for other computers soon too.

Is the grass always greener?

Sheep in the Lake District might soon be in for a shock. If they don't keep their eyes open when they're eating, they may end up munching up some tiny sensors scattered throughout the hills where they live. A national team of researchers, led by Professor Joe Sventek at Glasgow University, are exploring how to 'seed' whole areas of our natural landscape with hundreds of tiny battery-powered computers that sense aspects of the world around them. Each computer has a radio transmitter, and together they form a network of sensors. The data they collect is then sent back to much larger computers for analysis, all to help with climate research.

Sounds simple? Just throw a few small wireless computers into a field and leave the rest to the computers and the wireless network? Well, no – there's a huge number of science and engineering challenges involved.

Sleepy sensors

One of the project team's main challenges is power consumption: these sensor computers, also known as sensor nodes, are usually placed in hard-to-reach areas, like mountain slopes or hazardous chemical environments. This means that the period of time between replacing the batteries in the sensor nodes must be as long as possible.

The usual approach to maximising battery life in sensor nodes is to turn off the radio for much of the time, but communication between a pair of nodes requires that they both be awake at the same time. That means sleep periods must be carefully timed between nodes that wish to communicate with each other.

There is another problem though. The sensors' radios are only short-range, so for nodes to communicate, messages usually have to be relayed by nodes in between. The timing of sleep periods may be quite complex in order for a message to be successfully transmitted. Messages that must experience multiple hops may end up being delayed while all of the nodes take a siesta.

Hop to it

To support such multihop communication, the sensor nodes have rules to determine the paths that messages must take to reach their destinations. The rules attempt to find the best path to use for each pair of nodes, minimising the number of hops, sharing the load across the network, and of course, finding the most energy efficient path between sensors dotted among the grass and rocks.

The project team hope to reduce the amount of power the radios use by about half, while keeping delays and dropped messages to a minimum. Since the radio accounts for most of a sensor node's energy use, reducing the energy consumption by half means almost doubling the amount of work that can be done using the same size batteries.

If such improvements in energy consumption can be made on the Cumbrian hills, they can also be used in other mobile devices. How would you like your mobile phone standby time to be doubled? Not only would you get more time between charges, using less energy is good for the Earth.

Finally, back to the sheep. A tiny computer lying on the ground needs an aerial sticking up to improve its transmitting and receiving range for the same amount of power used. How do you design the aerial so a careless sheep doesn't mistake it for a grass blade? More problems for computer scientists to chew on.

Plague!

It's a well known story ...death, panic, the collapse of civilisation... but this time it really happened.

The powers that be, complacent as ever, released a highly contagious disease. They thought it was ok – it was in a contained area with strict quarantine rules. But then the plague got out and spread to the cities. No-one was safe. Worldwide panic followed and society crumbled.

It really did happen, but luckily only avatars died. It was in the online game World of Warcraft. Still, it was a mistake, a bad mistake, but a mistake that may help us stop a similar thing happening in the real world. Why? Because interdisciplinary computer scientist Nina Fefferman heard about it...

A computer game, World of Warcraft, may help keep us safe from the plague.

World of Warcraft has millions of users worldwide and the hardcore always need new challenges. So the game's organisers added a new one in a contained area – the plague. Would you be up for it? Could you survive the plague area? Trouble is it got out and spread very much like a real epidemic. It was carried around the virtual world by travellers and their pets. People went and had a look, believing they could avoid the risk themselves. They didn't!

The game was reset and it could have ended there. Except Nina heard about it. She studies the behaviour of people during disease outbreaks, creating computer models that simulate real epidemics. This helps scientists predict what might happen in future outbreaks and so helps policy-makers plan.

Her team studied what had happened in the game and saw that people's behaviour was both very realistic and included things no one had thought of before. As a result of the game outbreak, they are now adding such behaviour to the models so they can study the consequences.

They hope to run experiments in other games in the future. So you never know, your avatar might one day save your life... and millions of others too.

Like father like son: the space family Garriott

One Friday morning in Kazakhstan last October, just as most people were beginning their day, computer game designer Richard Garriott (see last issue) and the crew of a Soyuz TMA-12 spacecraft were landing after Richard's 10-day mission on board the International Space Station.

Richard had spent a busy time up aloft, talking to schools on Earth, running experiments to help develop new medical drugs, and helping us keep an eye on environmental change. Richards's dad, former NASA astronaut Owen Garriott, had taken lots of photographs of the Earth from space when he flew aboard Skylab and Spacelab1 back in the 70's and 80's. Richard's 'next generation' mission included taking a new set of pictures for comparison, to see how well nature conservation projects had been doing, and also to identify new places on Earth where there were ecological problems.

Image credit: Space Adventures Ltd

Making space for space

So what did this next generation space adventurer discover? As this edition went to press the results were still being processed, but in a recent email to the cs4fn team Richard said he had "great success with a 500-target list and a great piece of software created just for earth observations targeting". For a future issue "I would love to talk about the goal, the process, and the results!" he added. We will be making some space available on **cs4fn.org** to tell you about the software the team created, and to show you some of Richard's out-of-this-world photos just as soon as they are ready. The countdown begins.

Scratch, bite, decay and sniff

Could you tell the smell of a mouldy cucumber leaf? What about the delicate aroma of a tomato plant that's been nibbled at by mites? If not, never fear. Environmental scientists at Lancaster University have just the solution: an electronic nose. Plants are always giving off chemicals (that's what gives them their smell), but after they've been attacked by pests they give off a little bit more. The team at Lancaster have tested an electronic nose as a way for farmers to tell when plants are being attacked.

The scientists let loose a storm of abuse on some unsuspecting cucumbers, tomatoes and peppers – the poor things had to deal with mites, mould and even having holes punched in their leaves. The researchers found the e-nose could detect the small change in the plants' chemical signatures after they'd been attacked. They hope their new discovery could be used to sniff out plant attacks early, before too much damage is done to a farmer's crop.

Be an animator and win!

The University of Manchester is running a competition to find the best computer animation from UK schools. For a 1 minute-long animation you could win prizes like laptops and vouchers. The deadline for entries is 1 May 2009, so now's your chance to get started on your way to being a prize-winning animator! For more information visit **www.cs.manchester.ac.uk/animation09**

The Game of Life

Some serious fun!

Life on Earth can be quite serious at times. Species multiply rapidly then die out, rainforests come under threat, and herds of animals migrate over massive distances to find new homes. What's it all about and how can we start to understand what's going on? Part of the answer starts with a game.

John Conway is a British mathematician who was fascinated by a problem first posed in the 1940s by the grandfather of computing, John von Neumann, to find a way for a machine to create copies of itself. Conway set about experimenting with replicating mathematical machines. He called his invention the Game of Life, but little did he know back in 1970 that it would turn out to be about more than hypothetical critters made from maths.

Conway's rules for living on a grid

Conway set his game up on a square grid. In each of the grid positions, called cells, there are two possibilities: the cell is either alive or it's dead (which is quite a harsh distinction, but it's only a game). Each cell is surrounded by eight neighbouring cells including diagonals. Time in the game clicks on by in steps. At each step the rules of the game are as follows:

1 Any live cell with less than two live neighbour cells dies. After all you need friends and support to get along, and loneliness is a terrible thing.

2 Any live cell with more than three live neighbours dies a tragic death caused by overcrowding.

3 Any live cell with two or three live neighbours lives on unchanged – like Baby Bear's porridge this situation is just right.

4 Any empty cell with exactly three live neighbour cells will be filled with a new living cell. It's a babies thing: life breeds new life.

As games go it's not Grand Theft Auto, but when Conway played the game some strange things started to happen, and the results would have some far-reaching consequences.

Look what's happening?

The maths caused patterns – lovely, wonderful patterns – to appear, move, vanish and change. The variety seemed endless. Players started to give the patterns names. Patterns that remained the same in the same place were called still life. The ones that would repeat were called oscillators, and others that moved over the board were called spaceships. Special names for special patterns that appeared included gliders, which were shapes that floated over the screen, and pulsars, where three oscillators joined beautifully together. Pulsars in space, with their regular bursts of energy, had just been discovered so the excitement of this spilled over into the game. Computer science had made the mathematics come to life in front of the world's eyes.

The Game of Life has a lot to do with real life.

Meanwhile, behind the scenes

Conway had chosen his simple rules carefully. He had experimented with various different rules until he found a set that produced something that would catch the public imagination. Just as the designers of TV game shows try and find rules that produce dramatic tension and everything-can-change-in-an-instant-plenty-of-surprises-and-you-can-play-along-at-homeness, Conway designed his constraints to do the same thing.

He decided there shouldn't be a pattern of cells where it's obvious from the start that it will just grow and grow. He wanted a bit of tension – life and death needed to be in balance. But there should be some initial patterns were life would indeed win out and the patterns could grow and grow and…grow. Death was still on the menu, though. Some patterns would look like they were going to make it, reproduce and be successful, then after a time – shock – they faded away completely, from overcrowding or just spreading out too much. Some patterns would just get boring. Their life wouldn't be going anywhere, they would just flip-flop between a few patterns forever and ever.

Hmm, lets call it a cellular automaton

What Conway had invented was a new kind of algorithm, a new kind of recipe for a computer to follow. The idea that really complex things could happen when a cell just received very basic information from its eight nearest neighbours was a surprise. This new technique was called cellular automata: cellular because it was on a grid, where each square could simply be alive or dead, and automaton because it followed well-defined rules automatically.

It's not just a game though. Cellular automata have since been used to work out how diseases spread in a population, how animals migrate over continents, how coral reefs develop, how plant populations or weed infestations flourish or die, and how plants spread in rain forests or alpine slopes. Because the method is powerful but simple, most areas of biology and ecology have had cellular automata applied somewhere, and some very useful results have been discovered.

Not bad for something that started out as a game.

Find out more about cellular automata in the magazine+ section of our website, www.cs4fn.org

Faster than a speeding bullet

A flat, parched section of desert will, in a few years' time, become a stage. The drama played out on it in October 2011 will star the screaming rockets and air-gulping jet engine of the world's fastest car, Bloodhound SSC. The driver, Andy Green, will be attempting to blaze his way into a new land speed record at 1000 miles per hour. That's about five times faster than the fastest road car in the world. It's also about twice the speed of an airliner, one and a half times the speed of sound and even faster than the bullet from a .357 Magnum. There's no getting over it – when Andy Green is strapped behind the wheel of Bloodhound SSC he will be going very, very fast indeed.

The Bloodhound gang

Bloodhound's designers haven't got to the desert yet. Right now, in fact, they're in Wales. Their team are making sure Bloodhound works the way Andy wants it to. He'll be the only person ever to drive it, so they're building it to steer and respond the way he likes. But even more importantly, the designers are the ones responsible for Bloodhound's sleek body shape – like a fighter plane with wheels. In the old days the airflow over a car's body got lots of testing inside wind tunnels, but wind tunnels can't reproduce the extreme conditions Bloodhound will face. Instead the aerodynamics will all be designed and tested with computer simulations.

Ben Evans, an engineer at the University of Swansea, works on those simulations, and he explains that there were two main things to think about when designing Bloodhound. You want the car to stay on the ground, and you want it to flow smoothly through the air – the lower the drag, the faster the car can accelerate. Any car needs to have good aerodynamics, but it's going to be incredibly important for Bloodhound because of the speed they expect it to reach. The right shape won't just make it faster, it'll mean the difference between piloting a car and an out-of-control fireball.

Use the forces

An ordinary car can depend on the Earth's gravity and the traction of the wheels to help keep it steady, but when you're going so fast you can outrun a bullet those helpful forces are too weak to rely on. "To make it a land speed record car it has to be steered using wheels, not aerodynamic devices," says Ben. "But actually, above about 300, 400 miles an hour, the aerodynamic forces acting on the wheels…those forces are far larger than the actual traction forces between the wheel and the desert surface." So the wheels on Bloodhound will really work more like fins on an airplane.

The aerodynamics at 1000 mph don't just affect the steering. Since the aerodynamic forces are ten times larger than gravity at that speed, the designers need to make sure the shape of the car helps push it into the ground. Except they need to test that shape in their models to make sure they get it right. Ben explains that "if you push down too hard on the car you can easily turn it into a plow, or an aircraft – and we don't want it to be either of those things."

So what will happen when the team from Swansea go to the desert? They'll start sending the car off on trial runs to see if it's behaving the way they expect it to from their simulations. They'll start off slowly, says Ben. "We're obviously not going to tell Andy Green, the driver, to go out to the desert and put his foot down, off you go, a thousand miles an hour." Sensors all over the car will report back to the designers whether their predictions were correct. This testing phase takes a while – about three years – but they need to make sure everything's right before Andy fires up the afterburners for the record attempt.

Green-coloured car

What's the impact on the Earth of this rocket-powered adventure? The team know that it might not seem too green to be shooting across a desert in a jet on wheels, but Bloodhound will have a surprisingly small carbon output – for the few years it's running, this jet-powered speed demon will produce about as much carbon as five normal cars. That's not nothing of course, and so there are other ways that Bloodhound is helping to offset its impact on the Earth. You learn a lot about efficiency from designing the world's fastest car entirely on computers, so the lessons from making Bloodhound leaner and meaner will help others to design airplanes and cars that use less fuel.

The need for speed

You might think that one of the designers of a thousand-mph car has always been a huge petrolhead. "Yeah, it's a funny thing," says Ben. "When this project landed on my desk and I was asked if I was interested, I didn't know the first thing about cars – I mean I drive around in a little Fiat Panda 1.1 litre and I've never been involved in car racing or anything like that." He says it's the scientific challenge of Bloodhound that gets him really excited. When that scientific challenge is exploding through the sound barrier in a thousand-mph missile on wheels, we think it sounds pretty exciting too.

The eye of the storm

What does the UK look like when it snows?

Next time a really big storm passes over that feels awesome from below, why not look at it from above as well? You can the next day.

It will be there in the Dundee Satellite Receiving Station Archive. Whenever a satellite passes over, the Dundee computers automatically suck up the data it's transmitting. That data isn't just numbers – the numbers turn into stunning pictures of the earth taken by the satellite as it passed by. Some of the satellites – geostationary ones – sit over the same point on earth all the time and take an image of that place every 15 minutes. That means if there is a geostationary satellite above you then you can even track the eye of a storm when it passes over.

Perhaps you've heard about forest fires raging across the continent. Are they visible from space? Go and have a look. What about volcanoes erupting, oil refineries exploding or algae blooming? They're all there, with lots more too. The images look amazing but they also have a serious side. Environmental scientists use them in their research, tracking changes to the planet: from changes in land use to investigating algal blooms. Satellite images are a godsend to researchers.

Computer scientists may not always be saving the planet directly, but from creating the code that allows satellites to send data, to helping turn numbers into stunning images that make people take notice of problems, computer scientists are helping.

See the images at **www.sat.dundee.ac.uk**

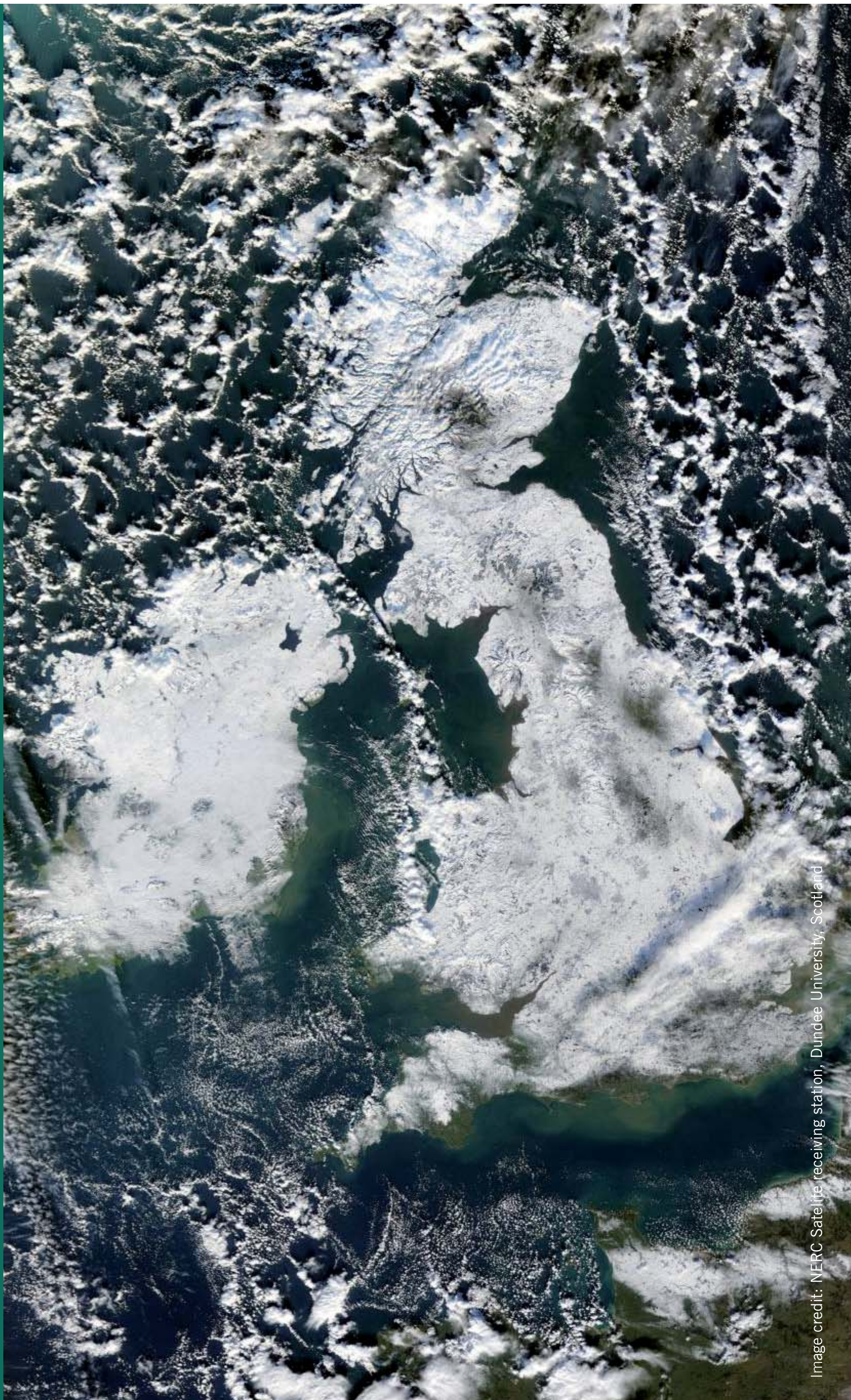


Image credit: NERC Satellite receiving station, Dundee University, Scotland

Back (page) to Nature

When we think of understanding nature, we tend to think of sciences like biology, chemistry, physics or ecology. However there are some surprising ways that computer science can help us understand the natural world around us, from the small to the large scale.

Small

The bluetongue virus is spread by insects, and if a sheep or cow is bitten by an infected insect it can kill. Cases of bluetongue used to be very rare in Britain, but changes in climate make it easier for the virus to survive in the UK, and some experts believe it could become a significant threat to livestock farming in the coming years. To help combat this virus you need to know what it looks like first. Rather than create a normal 3D computer graphic of the virus, researchers at Warwick University used computer technology to create a plastic model of it that researchers can touch. The molecular data about the virus is sent to a 3D printer, which then uses a laser to melt plastic powder into the correct 3D shape. Having the bluetongue virus in scientists' hands will hopefully help in finding the cure.

Motto: A virus in the hand can be handy

Medium

Bees are really, really important! As they travel around to collect nectar they pollinate the flowers they land on. Without bees, life on Earth could become very bleak. Unfortunately bees in Europe are vanishing. It's little to do with Dalek invasion plans; it's probably because the habitats where they nest and forage for nectar are becoming damaged and polluted. In Britain three species of bees are now believed to be extinct and another eight are in serious trouble. Understanding how bees behave in the wild would help conservation efforts, but how do you follow a bee? One answer from scientists at Queen Mary, University of London is to use RFID technology (Radio Frequency IDentification). This is the same technology that is used by shops to tag things like DVDs and clothes, and that sound an alarm if a shoplifter walks out with them. These devices store an ID on a tag. It can be read just by holding the tag near a special reader. Tags can be stuck on a bee without hurting it, but it lets the researcher know when that bee is around. Bee readers can be set at the entrance to the hive, or out in the fields so that each time the bee goes by, click! The computer records it. Using this information may help us make life better for these hard working and useful insects.

Motto: RFID and follow that bee

Large

Nature doesn't get much bigger than the planet Earth, and as challenges go you can't get much bigger that getting to grips with global climate change. Computer science is helping sift through all kinds of data to try and understand what's going on. Looking at how temperatures, ocean gulf streams, ice shelves or sea levels might change requires the ability to predict from the present to the future. Satellites, expeditions, weather stations and so on collect massive amounts of important data about our planet, and feed these into computer simulations. The simulations are complex mathematical descriptions of the world that help predict, given the past and current data, how future events could unfold. (For more on complexity, see page 10.) Computer scientists are applying techniques called data mining and machine intelligence to pull together all these various sources of data, often from very different databases, and automatically extract the important information. They're also helping the simulations run faster by spreading them over networks of machines, allowing results in days rather than months.

Motto: All together now, can we fix it?

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