biology, almost sci-fi-like. We make prototypes which provoke discussions about whether we want them, whether they are beneficial to the planet. Instead of Design Interactions, it should be called 'Speculative Design.'" Like others in this field, Gross is actively involved in designing all our futures.

Computers can have soul: Scott Draves

"I believe that computation can reproduce the whole creative process, and that ultimately computers can have soul," says Scott Draves. If anyone can communicate that soul, he can. His almost sci-fi presence on my screen (I interview him on Skype)—shaved head with large features and the easygoing yet authoritative way he explains his work as a computer artist—gives the impression that he is definitely at one with the computers running his software.

Draves's spectacular images are everywhere. He is the magus of software art. He is the inventor of Fractal Flames, the first ever open-source graphics software, creating ever-changing images which conjure up brilliantly colored feathers, galaxies, coral reefs, and all sorts of symmetrical and asymmetrical natural forms. Versions of Flame appear all over the world in advertisements and on book covers, including the cover of Stephen Hawking's 2010 book *The Grand Design*. "A graphics package is like a language, and Flame is a visual language, to use the term like Kandinsky did," says Draves, referring to Kandinsky's idea of a "language of form and color." Draves is also the creator of Electric Sheep, run worldwide as a screen saver.

When Draves was ten, in 1978, his parents bought him an Apple II and he "dove right in." He was a natural at programming, quickly moving on from games to constructing graphics. When I ask Draves what he did before computer art, he replies, "There was no before. I've been a math computer programmer guy pretty much my entire life." And an artist too, in the new sense of the term—not wielding a paintbrush or a sculptor's chisel, but a graphics package.

At high school Draves continued doing computer art, "at home

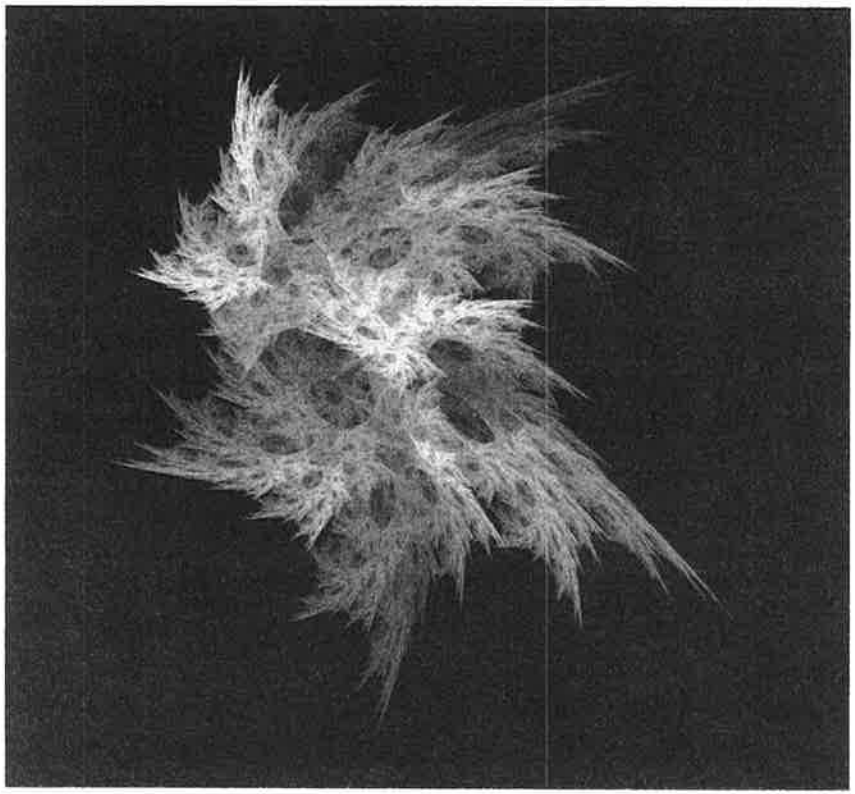
and alone," he recalls. He didn't think it was anything that anyone would be interested in. Studying computer science at Brown University, he found himself spending more and more time with the large computer graphics group there and realized he was not alone. When he showed them his art, they said it was not only cool but "pretty exotic." Nevertheless Draves "still didn't think of himself as an artist."

That happened in graduate school, at Carnegie Mellon University, in Pittsburgh, where he was working on a PhD. Ever since his early days working on an Apple II, Draves had been interested not in using the computer to calculate but as a way to produce the unexpected, to make complex images using algorithms. At Brown he became interested in fractals and wrote a program that produced images which could be used as input for further computations. He called this the Flame algorithm, "creating art out of math."

The calculations, however, turned out to exceed the power of the computers at Brown and also at Carnegie, forcing him to simplify the complex equations he was using. The resulting images, however, were not so good. Then in 1992 he spent the summer at the Nippon Telegraph and Telephone Corporation in Japan, where he had access to a supercomputer. He was finally able to solve his equations in all their glory, "to reveal the beauty contained in them." What emerged were ravishing images, some geometric, some organic, eerily evocative of natural forms.

Back at Carnegie, he showed the images to his PhD supervisor, who advised him not to publish them but to enter them in the competition at Ars Electronica in Linz. It was 1993. He won an honorary mention in the Prix Ars Electronica for the image *Flame #149*. Draves's immediate reaction was, "Holy shit, this is art." He was ecstatic, he had discovered his calling. "This was really what I wanted to do."

Flame was probably the first open-source digital art. Draves took this route, instead of selling it, because he believed that scientific results should be freely shared. This accorded with his support for the GNU Project, begun in 1983 by Richard Stallman at MIT, the



9.6: Scott Draves, *Flame #149*, 1993.

premise of which was that the best way to free computer users was to allow them access to all software, enabling them to share, copy, and modify it.

This seems enough to satisfy the requirements for a PhD, but in fact Draves's PhD topic was "much more complicated," as he puts it. It was related to metaprogramming—the theory of computer languages, of giving meaning to logical statements in a program, and of how people communicate with computers. He finally completed his thesis in 1997.

Two years later he came up with Electric Sheep (see Insert). When a computer is asleep, Electric Sheep comes alive and the computers communicate with each other, producing elaborate abstract forms that continually change when animated. Each user can design their

own screen saver or sheep. The animations appear on everyone's screens and users can vote for their favorites. Following the principle of the survival of the fittest, popular sheep live longer and can reproduce and mutate via a genetic algorithm. Draves sees this as a system combining humans and machines, a cyborg mind made up of hundreds of thousands of computers all working together and all based on mathematics. Computer scientists call it artificial life—mathematics generating biological phenomena that emulate Darwinian evolution.

Draves names as one of his key inspirations Alan Turing, the great British pioneer in computer science and the mastermind behind Bletchley Park, where he designed and built the first digital computer in order to break German codes during World War II, contributing significantly to the Allied victory. Then there was science fiction, which fueled Draves's dreams as a boy, together with concepts like artificial intelligence and artificial life, which led him to wonder, "What is life in the abstract sense? Can it exist in nonbiological and chemical substrates?" Big questions.

Draves's artistic inspiration is Karl Sims, an American computer graphics artist who played an important role in using genetic algorithms which mimic Darwinian evolution. Computer artists may use lines and geometry, as in architecture, while algorithmic artists use graphics packages to create images that constantly change according to the algorithm. What Sims did was to make creatures out of assemblages of blocks, move them around, make them fly, and subject them to the laws of evolution. Certain shapes did better than others. These were saved and constituted starting points for further evolution, passing on the good traits to future generations.

Around 1995, Draves recalls, he was "struggling with the definition of information and meaning." He had come across many definitions by people like Erwin Schrödinger, Claude Shannon, "the father of information theory," and Gregory Chaitin, an important contributor to computer science, especially algorithms. Draves felt uncomfortable with their definitions because "they kept trying to quantify [information]." Then he came across the anthropologist, semiologist, and cyberneticist Gregory Bateson, who famously said

that information is "a difference which makes a difference." Draves recalls, "It was a sign to me that information (and hence beauty) could not be quantified, or reduced to an equation. But I was also reassured that I could trust myself to recognize it. And so I was able to continue to pursue creativity."

"I want to be surprised by the computer. I want to give up control. I want to exceed my imagination," says Draves of the images his algorithms produce. It's the public, not him, who makes aesthetic judgements on creations such as Flame and Electric Sheep, and the evolutionary machinery in his software makes variations on that basis. Some of the choices may not be to his liking, but that makes it democratic.

I ask him whether there are times when he knows what he wants and writes the software for it. "You're right," he says, "it's not black and white." Naturally "for sellable items I select what art collectors pay for." He will then go through the sometimes thousands of images produced and "pick out the best ones, in my opinion, of course."

"I have a love relationship with technology and computers, and my artwork tries to express that," says Draves. This wonderfully expresses the almost symbiotic relationship between Draves and the computer. I ask whether he believes that computers can be creative and even produce art. "Yes," he continues, "although collaborative. Some comes from the computer but most comes from myself and my colleagues. [The computer plays] a minor part, but I feel its presence."

Recently the celebrated futurist Ray Kurzweil, who is also a computer scientist, inventor, and Google executive, predicted that by 2045 there will be robots whose intelligence will surpass that of humans. This is part of what he calls the singularity, when progress will outstrip human ability to comprehend it. Working together with humans whose intelligence and constitution have been enhanced by nanotechnology, machines will dominate life on earth.

Like many computer scientists, Draves thinks Kurzweil overoptimistic, especially as regards the date. But he does think that "there's something going on. Computers and mathematics can capture the essence of life." This view may seem materialistic but, after all, he

says, the brain is ultimately made up of atoms which obey the laws of quantum physics which, in turn, can be programmed into a computer. So, "in principle computers can think." He agrees with Kurzweil on "the arc of history." Computers are becoming faster and faster, he points out, taking over more and more tasks, like translating and finding information, using powerful search engines like Google. He sees nothing to stop this trend. "This is really getting spooky. I see more of a merging of man and machine. If you approach AI with fear," he adds, "this will slow down advance and could precipitate just those conflicts we are afraid of."

Draves "hates science fiction in which there are wars between man and machine. Somebody has to take the first step forward to promote friendship. Giving up some kind of control is okay." Losing control completely would certainly be a disaster, and probably generate a *Terminator* scenario.

When I ask Draves whether he considers himself an artist or a scientist, he replies, "Both." His business card says "Software Artist." I mention that people at MIT and NYU describe themselves as researchers. "Everybody wants to be cool," he replies.

He likes the term "scientist," he says, but insists he isn't one because he doesn't do experiments, and a lot of computer science is really engineering. Yet it is here that you find a blurring between art and engineering.

Draves has won many awards. His work has been shown at Moma .org, the Museum of Modern Art's website, and has appeared in *Wired* and *Discover* magazines. It is also an official skin for Google Chrome—a personalized visual appearance for a Google Chrome page generated by purpose-built software that changes the image at intervals. *Dreams in High Fidelity*, which he considers his masterpiece, produces an infinite variety of patterns in the lobby of Google's headquarters and has been bought for corporate and residential collections nationwide. He also recently produced a work he calls *243*, commissioned by the Gates Center for Computer Science at Carnegie Mellon University. But he has yet to crack the establishment art world.

"The art world doesn't care about technology and vice versa," says Draves. The problem with gallery curators, he goes on, is that they "don't understand the material and can be fooled," which might result in them trying to sell inferior works. There is also the layperson's fear of anything to do with science or technology.

Furthermore, there is the problem of reproducibility. "Anything that's digital is copyable and so in conflict with the concept of sole copy or unique artifact." Materials also wear down, requiring repair and in some cases modernization, which again runs up against the concept of original artifact. "Barriers to acceptance are still numerous."

"The electronic world has created its own world, a ghetto, really," he says. He is optimistic that barriers will come down, though within his world opinion varies from "It's over, we've won," to "Never, they suck," to "I like being separate." One way out may be via today's twentysomethings, who are entering the art world equipped with technological savvy—though "we'll have to wait another twenty years for them to become forty and take over."

Draves discusses all this with his wife and business manager, Isabel Walcott Draves, who is also an Internet strategy consultant. In 2009, in an attempt to break down barriers, she founded Leaders in Software and Art, to put people working in the field into contact with each other. These include software and new media artists, curators, collectors, coders, and collaborators. She organizes monthly salons and occasionally daylong conferences featuring the best artists and speakers from the salon.

Says Draves, referring to Charles Saatchi, the powerful and influential London art dealer and gallery owner, "We have to get past irony and get Saatchi on board!"

Breathing life into data: Aaron Koblin

"I create art with data," says Aaron Koblin. "We live in an exciting time and we must take a step back, look at that data, and try to understand it."

One of Koblin's first projects was *Flight Patterns* (see Insert). He describes it as being "visually exciting while also related to our lives, giving us new perspectives on how we are living." To put it together, he used a huge amount of data assembled by the Federal Aviation Administration, gathered by monitoring aircraft across the US for twenty-four hours on August 12, 2008, including altitudes, makes, and models of more than 205,000 different aircraft. The result is a fascinating, ever-moving animation showing the flight paths of all these aircraft over the United States. As we watch, first the East Coast lights up as the red-eye flights come in from Europe and the early morning flights leave, then the West Coast comes alive, in a complex, elegant, and beautiful spiderweb of activity, like the flights of a myriad of fireflies.

Viewers can home in on cities, observing the density of flights above New York's three airports, for example, or isolate the different types of airplanes or the different altitudes. Certain areas of the US remain stubbornly black, as if they are no-fly zones—a fruitful area for conspiracy theorists. Apart from the sheer beauty of the animation, it's also a very effective way to communicate a huge amount of information, drawing out the patterns in a vast amount of data.

"I'm 50 percent artist, 50 percent nerd," says Koblin—a self-effacing self-portrait of the creative director of the data arts team at Google.

Born in 1982, Koblin has won many awards for work that uses data visualization to explore how we interact with systems of our own creation. His work is in the permanent collections of the Museum of Modern Art in New York, the Victoria and Albert Museum and Tate Modern in London, and the Pompidou Center in Paris, and was exhibited at the Japan Arts Festival for several years running. Tall, boyish, with floppy dark hair, he radiates confidence and expertise combined with a laid-back Californian manner.

Koblin was interested in computers from an early age. At the University of California, Santa Cruz, he studied computer science and took a minor in film studies. He then did graduate work at the

patterns, as in his meticulous drawings depicting lines of sound and the locations of the speakers which will produce it. The ability to sense what is aesthetic is learned from experience gained through experiment.

Paul Friedlander, physicist and magician of light, also says aesthetics has to do with simplicity of design, as in ancient and primitive art, which he loves. The pseudonymous Jim Miller of the American artists' group EyeCandy ArtWorks wrote of him, "In a time when so many artists resort to bizarre and shocking gimmicks to achieve originality I take solace in the work of Paul Friedlander and others like him. They prove that beauty still has a place in modern art."

Ken Perlin, who won an Oscar for creating Perlin noise, for rendering animations more natural, agrees that "simpler is better" but adds that in order to be aesthetic, a work also needs to be pleasing to the eye. The question is, of course, whose eye? We are back to the riddle of individual taste.

Rolf-Dieter Heuer, director general of CERN, asserts that functionality is the essence of beauty. To him, functionality is aesthetic and "goes along with beauty." He gives as an example the alignment of cables laid out in parallel, like a work of minimalist art. "If it functions well," he says, "it has to be beautiful."

To Julian Voss-Andreae, whose sculptures evoke the ambiguous quantum world, aesthetics is satisfactory design. "To me, form and function are always a unit and both together make a good design, like in math or engineering," he says. "I cannot separate the experience of discovering or understanding such a solution from a beautiful aesthetic experience."

Rick Sayre, a supervising technical director at Pixar, says, "I don't have a precise definition of aesthetics. For us an element of aesthetics is when there is intention behind the work and the intention is to create a certain emotional response in the viewer and that emotional response is going to be motivated by the story and is also going to be influenced by specific desires of the director." Thus, in *The Incredibles* the aim was to create a simple skin texture that, like real human skin, responds to light. The real test, says Sayre, is whether the audience likes what it sees. If not, Pixar changes it until they do. The viewer's response is the filter that tempers the end result.

Jonas Loh, who creates extraordinary sculptures depicting data, such as his eerily organic *The "Gestalt" of Digital Identity*, or *Emoto*, the mountain range depicting emotions communicated in tweets during the 2012 Olympics, sees himself as searching for "new aesthetic forms while also researching how to communicate them." For him, aesthetics involves the communication of facts, which is what data visualization is all about. Aesthetics is a visual thing tied in with information content, he says. The higher the information content, the greater the aesthetic value.

A concrete example is Harry Beck's 1931 map of the London Underground. Its function is to navigate below ground, so Beck didn't worry about topographical features like hills, roads, or tunnels. He used his extensive experience drawing electrical circuits made up of horizontal and vertical lines and lines at forty-five degrees to the horizontal to produce a visual representation containing a great deal of information in a minimal graphical style. The map of the London Underground is a supreme example of the aesthetic of functionality. It has become iconic, serving as a model for tube maps of other cities.

Scott Draves, maestro of the computer-generated image and creator of Flame and Electric Sheep, sees his work as a collaboration between himself and the computer, in which the computer is an equal partner. "I want to give up control [to the computer]," he says. "I want to exceed my imagination." Electric Sheep is driven by the principles of Darwinian evolution. The public makes aesthetic judgments, choosing from among endlessly generated abstract animations which Draves's software changes on the basis of their decisions, even though their choices may not be to his liking. Thus aesthetics functions as a Darwinian device in which only the most interesting or beautiful survives.

Similarly, the computer artist William Latham, who creates spectacular images of virtual organic life forms, uses aesthetics to select