Alpha geek

Stephen Wolfram, a brilliant but controversial computer scientist, says he has devised a "new kind of science". Has he really?

"THERE is no dramatic distinction between the processes of the weather and the workings of the human brain," says Stephen Wolfram, a physicist and the founder of Wolfram Research, a software company. "There isn't anything incredibly special about intelligence, it's just sophisticated computational work that has grown up throughout human history." Dr Wolfram is hardly the first scientist to compare the human brain to a computer. Alan Turing, who helped develop the precursors of today's programmable computers during the second world war, began considering the possibility of thinking machines in the 1940s. The difference is that Dr Wolfram claims to have succeeded in codifying vast areas of human knowledge and even replicating supposedly uniquely human attributes such as creativity.

"One of my realisations, or maybe it's just a piece of arrogance, is that the amount of knowledge and data in the world is big, but it's not that big," he says. "In astronomy, there's a petabyte—a million gigabytes—of data about what's out there in the universe. There are also swathes of data from digital cameras, Twitter feeds and even road-traffic movements. It's a bit daunting, but I soon realised that the bigger challenge is not the underlying data but the computations that get done on them."

Dr Wolfram has a reputation for making sweeping claims. Once described by *Wired* as "the Bob Dylan of physics", he is a reclusive and controversial figure who has always defiantly done his own thing. Born in London in 1959, he studied at Eton and Oxford, dazzling and infuriating his teachers in equal measure and leaving the university without graduating. He published his first scientific paper at the age of 15, completed a PhD in particle physics at the California Institute of Technology, and had joined the faculty and been awarded a MacArthur "genius" award, worth $128,000, by the age of 21.

The MacArthur money helped Dr Wolfram set up his company, Wolfram Research, in 1987. Its first product was Mathematica, a piece of software that automates mathematical processes. It solves equations, plots graphs, creates models and analyses data. Mathematica is hugely popular among engineers, scientists and financial analysts, and its success gave Dr Wolfram the financial security to continue to do his own thing as an independent scientist and researcher.

His most recent venture is Wolfram Alpha, a website launched in 2009 that he describes as a "knowledge engine that computes answers to questions". Type in "GDP of France versus Britain", for example, and it produces recent figures and a chart comparing the two countries' GDP from 1961-2010. Enter "country with largest population density" and it returns a list, topped by Macau. But type in "best Radiohead album" and it produces gibberish. It is easy to see why comparisons with Google are unfair; rather than trying to organise the world's knowledge, Dr Wolfram wants to make it "computable".

"Search engines are like a blender," he says. "They put all this stuff into one algorithm and deliver a list of links. That's great when it works but it isn't going to work for a lot of the stuff that we care about. Our objective is that pretty much anything you need to go ask a human expert about right now, will be able to be answered automatically." Doing this is, he says, "insanely difficult".

In the beginning

The project's genesis lies in Dr Wolfram's childhood. "Wolfram Alpha today is shockingly similar to ideas I first had when I was 12 years old," he says. Even today, that brilliant child is never far from the surface. Unlike most chief executives, Dr Wolfram would much rather talk about weather prediction or the future of public transport than sales or growth. He considers his 500-strong company his personal intellectual playground, thinking nothing of tasking researchers with assessing his impact in the field of complexity theory or analysing 20 years' worth of computer keystrokes to boost his efficiency. "I found that the best way to do interesting intellectual stuff is to have a company that's successful enough to pay for it," he says.

In fields from archaeology to zoology, his company's researchers are interviewing specialists, scouring the world's libraries and coding the results using Wolfram's own symbolic computing language. With many years of the project yet to run, Wolfram Research already claims to have the largest collection of curated, cross-checked data in the world.

Wolfram Alpha is ambitious, but it pales next to Dr Wolfram's boldest project: ▸▸

"What's the point of universities today? Technology has usurped many of their previous roles."

an attempt to convince the scientific establishment that computer programs, rather than mathematics, are the best way to describe and explain the complex systems that are widespread in nature. Dr Wolfram calls this approach a "new kind of science", or NKS. That is also the title of the 1,200-page book, published in 2002, in which he lays out his theories, the product of a decade's reclusive work.

NKS is chiefly concerned with the behaviour of very simple computer programs, called cellular automata, that exist in a myriad of variations. Although most are uninteresting, a few of them can exhibit great complexity. One of them produces an endless stream of random output, and another has proven to be the simplest ever universal Turing machine – a hypothetical device capable of solving any computational problem that was imagined by Turing in 1936.

Is the universe a computer?

Dr Wolfram believes that all the vastly different complex processes seen in nature, from the markings on a seashell to weather systems to intelligence itself, are the products of such simple computations. The idea that mathematics underpins the laws of nature, which now seems obvious, was once radical. Dr Wolfram proposes an even deeper law, that the universe is underpinned by a set of simple computational rules capable of producing vast complexity, and that nature is just "sampling what's out there in the computational universe". He claims that applying NKS widely could lead to advances not only in mathematics and computing but also physics, biology and even the social sciences.

"I have come to view NKS as one of the more important single discoveries in the whole history of theoretical science," Dr Wolfram declares in his book with characteristic immodesty. Needless to say, not all his peers agree. Some have pointed out that much of his "new kind" of science closely resembles the well-established fields of cellular automata and complexity theory. Others point to a lack of real-world verification for many of his more grandiose claims, or a failure to give sufficient credit to other researchers for some of the ideas presented in the book.

"I collect insults and compliments," Dr Wolfram admits. But his company is already proving the value of his unusual new approach by using it in its products, he claims. "In Mathematica and Wolfram Alpha, there are all kinds of things that we can already compute faster, better and stronger than anybody else, using NKS, a methodology that other people think is completely insane. NKS absolutely gives us a competitive advantage."

Instead of laboriously constructing an algorithm to solve a particular problem, Wolfram Research hunts for candidate programs using NKS—mining the computational universe in just the way that Dr Wolfram believes nature itself does. "We can go out into this computational universe and find all these different programs, each one with its own unique scheme for doing things," he says. "That's usually a very human activity that you might think would involve creativity."

Such computational creativity can be seen (or, more precisely, heard) in action at the Wolfram Tones website, which can produce a two-minute tune in any of 15 genres using NKS. "What I've heard from a surprising number of very upscale, reputable composer types is that this is actually pretty useful," says Dr Wolfram. They go to the website, press the button a few times and get some ideas. Creativity is now free." Zing! Another Wolframism.

Dr Wolfram has no shortage of ideas for how to apply NKS. He predicts algorithmic drugs that tour the bloodstream and activate when needed; universal assemblers to build almost anything from its raw ingredients; DNA-based processors. The future, he says, will not look anything like the present. "We live in a period when technology looks very organised. But that's a fluke, a feature of the history of engineering that reflects what we've learned to build. When we start just going out into the computational universe and finding stuff that works, it's all going to look a lot more bizarrely random."

To say that NKS is far from widely accepted would be an understatement of Wolframic grandiosity. Nearly ten years after the book's publication, there are still just a handful of academic conferences devoted to NKS each year, most of which are sponsored by Wolfram Research. Academic interest in Dr Wolfram's ideas has probably not been encouraged by his deep and abiding personal distaste for mainstream education.

"You have to ask, what's the point of universities today?" he wonders. "Technology has usurped many of their previous roles, such as access to knowledge, and the social aspects." One of the challenges for the 21st century, he suggests, is working out what is even worth teaching. He claims that he recently realised that he had never learned to do long division. "I just missed having to know it and have never needed it. My kids actually showed me how to do it," he says.

He is no longer an academic, but Dr Wolfram does not see himself as a businessman either. "I am not looking to make the biggest possible company. When a company gets really big there are a lot of things that get kind of dull," he says. Nonetheless, he sees great potential in applying his firm's analytical tools to new sources of data in future.

"Lots of new kinds of large scale data sources are starting to show up," he says. "Personal-analytics data is going to be big, with people measuring many things about themselves because it's easy to do so. For instance, I had my entire genome sequenced last year. This illusion that it's all too big, that you can't possibly curate the world's knowledge, is just not true."

It is difficult to assess the validity of Dr Wolfram's theories, or how he will be judged by history. Einstein's bizarre-sounding theories, he notes, took years to become accepted. Is he really a figure of similar importance, as he seems to think? Dr Wolfram presented his ideas at the TED conference in California in 2010, and the audience tittered as he casually likened his creation of Mathematica with Galileo's construction of a telescope, and claimed that NKS was superior to the mathematics-based science of the past 300 years, thus comparing himself implicitly with Newton. Even so, his speech received a standing ovation. But winning over a conference audience is one thing; convincing the scientific community to accept his ideas will be much harder. ■