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Mathematica's Developer Asks, “Can Algorithms Replace Equations?” FREE

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An Interview with
Stephen Wolfram

Mathematica's Developer Asks, "Can Algorithms Replace Equations?"

Stephen Wolfram, who says he has helped to revolutionize computational physics by creating the software package Mathematica, is working on his next revolution.

Wolfram, a recipient of the MacArthur award who received his Ph.D. in physics from Caltech when barely 20 years old, runs his multimillion dollar software company, Wolfram Research Inc., while continuing an active program of theoretical scientific research. He spoke to *Computers in Physics* from his home in Illinois, where he is working on a book that he hopes will change the way scientists model phenomena.

Wolfram, who has many multidisciplinary interests, no longer considers his occupation to be that of a physicist, but he retains a fondness for physics because, as he puts it, physicists tend to be entrepreneurial, in contrast to researchers in many other fields. "Physicists like to jump into thinking about neural networks or issues in financial analysis and things like that," he said.

No longer an academic, either, he remains a scientific researcher. "I enjoy basic science very much. If you want to do basic science and you don't have a choice, do it at a university; if you have a choice, then you can do without the university," Wolfram said.

Born and raised in England, the son of a mother who taught philosophy at Oxford and a father who divided his time between careers as a businessman and as a novelist, Wolfram developed an early interest in science. By age 15, he had published his first physics paper, and he entered graduate school at Caltech at 18, after attending (but not graduating from) Eton and Oxford.

In this early part of his career, Wolfram focused on theoretical particle physics, the field in which he received his Ph.D. in 1979. "I did not quite get my Ph.D. while I was still a teenager; I missed by about three weeks," he noted.

He stayed on at Caltech and became the youngest person to receive a "genius" grant from the John T. and Catherine D. MacArthur Foundation. During this time he also developed his first software product, SMP (Symbolic Manipulation Program). Following a dispute with Caltech administrators over the intellectual property rights to SMP, Wolfram left for the Institute for Advanced Study in Princeton, NJ. There, he focused on the theory of cellular automata, later moving his research group to the University of Illinois at Champaign-Urbana.

In 1987 he established Wolfram Research to develop and market Mathematica, a software environment for handling a wide variety of technical computations. Mathematica, he acknowledges, was built in part on the lessons he learned while developing SMP.

First released in June 1988, Mathematica was, according to Wolfram, a grander, bolder vision—a "single, coherent system" that dealt with a broad range of technical computations. "The idea with SMP was to build something that concentrated on symbolic and algebraic manipulation," Wolfram said. "My goal [with Mathematica] was to build a very general tool that would be useful in any kind of technical computation."

Even during the development of SMP, Wolfram had tried out a number of fairly radical ideas about computer language design, some of which worked better than others. "I was able to basically take the ideas that had worked out well and build them into Mathematica in a slightly better way," he said.

He is very proud of what has been achieved in Mathematica. "What's great is to be able to take those high-end,

> *"If you want to do basic science and you don't have a choice, do it at a university; if you have a choice, then you can do without the university."*

creative new [designs] and package them in such a way as to make them useful to a wide range of people—people ... [who] don't want to know about computer science, [who] don't want to know about numerical analysis, [who] just want to solve some problem in biotechnology or financial analysis," he said. "To me, that's one of the most satisfying ways one can use one's ideas and intellectual achievements in science."

For many physicists, a computer used to be a tool for large calculations only, Wolfram says. "Nobody would think of using a computer to do the little calculations that would otherwise take you 10 minutes, but would take you 15 seconds on a computer. They would only use a computer to do a calculation that would take you two months to do by hand and a week on a computer," he said.

Wolfram believes his software is helping to modernize computational physics. "I heard in the computer industry many times, people saying, 'My god, why are these computational physicists still using Fortran? Why do we have to cater to these people who want Fortran compilers? This language is grotesque!'," he noted. Wolfram claims for one of his achievements "a shift from people using Fortran to using Mathematica." According to Wolfram, "By now, a million or so people know at least the basics of the Mathematica language."

Although his privately held firm now employs nearly 200 people, Wolfram continues to play a part in Mathematica's further development. "My main role is to figure out the strategy, provide some leadership, and try to get good people to come and work with us." He retains responsibility for the details of the user-level design of the product—for what users actually see—but he feels that he can rely on his staff to come up with good ideas. "My best situation is just to agree with their ideas rather than figuring it out for myself."

Over the next year, he sees two new directions for Mathematica: the expansion of its programming language as a general-purpose, high-level computer language and an increased focus on electronic publishing and interactive documents.

He sees interactive-document technology as radically changing scientific journal publishing. With such technology, according to Wolfram, investigators can not only describe their research and present illustrations of their results but also include as an integral part of the description computer code defining the assumptions used, for anyone to copy and run.

At present, Wolfram's scientific research is taking up much of his time. The starting point for his new book is the observation that, for the past three centuries, there has been little change in how scientific models are made: the scientist tries to write down equations (often partial differential equations) describing the phenomena under investigation and then tries to solve the equations by hand or using a computer.

"This approach is fairly successful in some areas of physics, particularly when the phenomena you are describing are fairly simple, like the trajectory of some projectile or the orbit of a planet," Wolfram said. "But we know perfectly well that when you are trying to deal with more complex phenomena, this traditional approach ... just fails completely."

He cites as examples, not just parts of biology, but also fluid mechanics, and areas of quantum field theory.

"Computational physics has not given us a clear understanding of what goes on in fluid turbulence, for example," Wolfram asserted. "It's not through lack of trying: there are thousands of people out there spending their time doing this, but there haven't been spectacular results."

Models based on partial differential equations are actually very ill-suited to computers, he suggests. "My idea has been to see whether one can start from scratch. Ignore calculus, ignore all of these kinds of traditional mathematics, and just start from things that are easy to describe from a computational point of view, things that could be described by one line of Mathematica code, and say, 'Can you use those kinds of basic algorithmic structures for making models in science?'" he said. "The basic answer, which I hope that my book will elaborate greatly on, is 'yes.'" *[Note from the Editor: For additional discussion of this theme, see Roscoe Giles, "What does computation have to do with 'real' physics?," CIP 7:5, (1993)485.]*

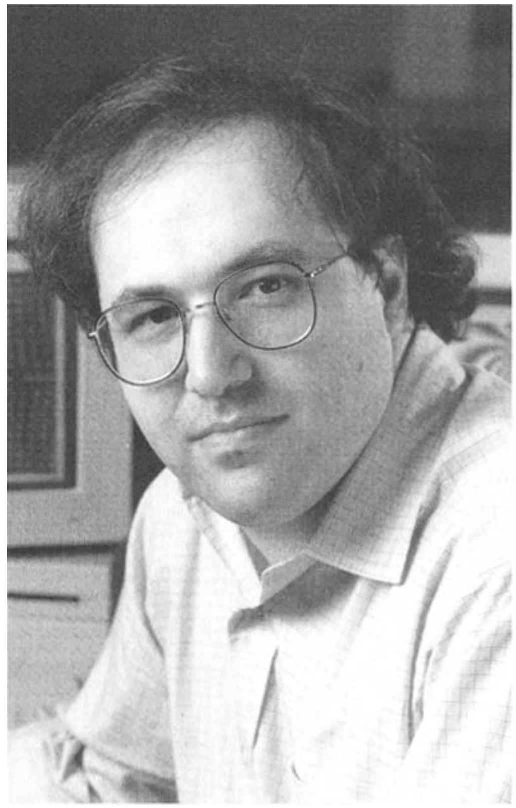

Photo courtesy of Wolfram Research

Wolfram says his discoveries will open up a new direction for science. "The phenomena I've discovered are so obvious that they could have been discovered eons ago, but they weren't," he said. "It's exciting to be able to take these phenomena and develop a kind of an intuition about how simple computer programs work that really gives one a quite different perspective on how one might make models in science."

Wolfram wonders whether his discoveries, at least the ones relevant to physics, will be absorbed into what is currently called computational physics, or whether they will give rise to a new subdiscipline while computational physics "goes on its merry way for the next 50 years," continuing to solve partial differential equations.

"We shall see what happens," he said. "I won't place bets on that issue."

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