Who Uses *Mathematica*?

Stephen Wolfram

Sometime late in 1987, I was sitting in a glass office somewhere in California, talking to a computer industry marketing expert. "You know," he said, "there aren't very many math professors in the world."

"I know," I said. "But a lot of people learn math. And there's a good reason. Math is useful for all sorts of things." The marketing expert was not convinced. "I still think the main market for *Mathematica* will be math professors," he said.

Nearly three years have passed since then, and needless to say, the marketing expert was not quite correct. But seeing who actually does use *Mathematica* gives an interesting perspective on how mathematics and mathematical methods are used in the world today.

A good way to learn what kinds of people use *Mathematica* is to look through the *Mathematica* registration cards that we receive.

(If you haven't sent in your card yet, please do!)

I picked up a stack of new registration cards today. The first few on the stack were from:

- a management science professor in Hamilton, Ontario
- an electrical engineer in Madrid, Spain
- a mechanical engineer in Los Alamitos, California
- a financial analyst in Stamford, Connecticut
- a physicist in Tsukuba, Japan
- a mathematics professor at Stanford
- an astrophysicist in Mountain View, California
- a chemical engineer in Wilmington, Delaware
- a forest biometrician in Hot Springs, Arkansas
- a computer science graduate student at Berkeley
- an electrical engineer in McLean, Virginia.

The diversity of *Mathematica* users is always impressive. But by analyzing the large number of registration cards we have received, some statistical regularities emerge. The pie chart below shows how the *Mathematica* user population is distributed among different fields.

Engineering emerges as the single most common use of *Mathematica*. Within engineering, electrical engineering is the most common subfield, followed by mechanical engineering.

Second in the ranking comes computer science. The size of this segment is slightly inflated by registration cards received from people who are responsible for computers on which *Mathematica* is used but who do not themselves use *Mathematica*.

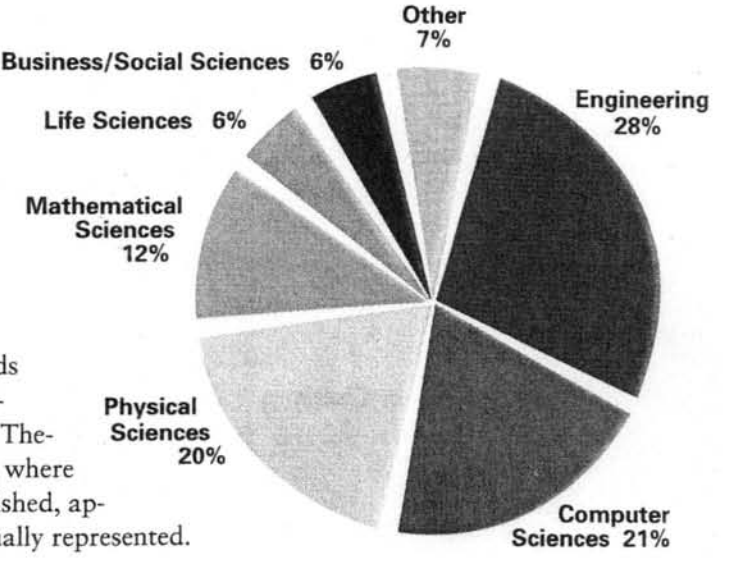
Close behind computer science come the physical sciences. Physics leads by a fair margin, followed by chemistry. Theory and experiment, where they can be distinguished, appear to be about equally represented.

In fourth place come the mathematical sciences. While it is true, as the marketing expert expected, that *Mathematica* is very popular among mathematicians, the number of mathematicians in the world is small relative to the total number of scientists and engineers.

In fifth place come the life sciences, dominated by medical research. And in sixth place comes business, with financial analysis being the most important subfield.

Methods One striking observation about the distribution of *Mathematica* usage is that the "soft" sciences are not too far behind the "hard" sciences. Until fairly recently, quantitative and mathematical methods were largely restricted to the hard sciences, particularly physics. But over the past couple of decades, these methods have spread at an impressive rate to other areas. There are not yet theories in economics, biology or computer science that have the same

Mathematica users by field



generality and depth as those in physics. But for specific problems, successful mathematical models have been developed, and there are hints that some general theories may be forthcoming in this decade.

In general, the use of mathematics and mathematical modeling is on the increase. In many areas, results and decisions based on subjective judgments are being replaced by ones based on objective and, hopefully, correct mathematical models. One reason this is happening is that through electronics, both in computers and communications, the volume of data that can be collected, and the number of elements that can be controlled in a process, has increased dramatically. While one can use human judgment to buy and sell five stocks, or to control five manufacturing parameters, one needs automation to control five hundred of each. And to develop automation, one needs definite, typically mathematical, models.

A column such as this would not be complete without the occasional anecdote. My clearest exposure to the mathematical sophistication of modern financial analysis came when I gave a talk recently about trends in the software industry to a group of bankers. After my talk, there were several questions about Bessel functions. I was quite surprised. "Why do bankers care about Bessel functions?" I asked. I was told that standard models for options pricing use Bessel functions. And hypergeometric functions are also often useful. I already knew that most of the major brokerage firms, banks and so on used *Mathematica*. But then I understood more clearly why.

As well as looking at what fields the users of *Mathematica* are in, one can look at their job titles. The most common job title is researcher/scientist. Following that are professor, engineer and computer professional. In general, about one third of the users of *Mathematica* are in academia. The remainder are in industry, government and so on. It is interesting to note that while most of the percentages have been fairly constant over the past year, the percentage of student users has grown from 4 percent to 8 percent. This growth is doubtless a consequence of the increasing availability of lower cost *Mathematica*-capable computers. When *Mathematica* first came out, for example, registration cards from high-school students typically had addresses in Beverly Hills or the Upper East Side of Manhattan. Now there are no such geographical divisions.

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Some of the most unexpected uses and users of *Mathematica* lie in the "other" category on the pie chart above. In this category are humanities professors, artists, doctors, lawyers, business executives and public officials, to name just a few.

Scientific Culture While most of these people use *Mathematica* as part of their job, some of them, I suspect, are simply interested in mathematics. They use *Mathematica* as a way to explore mathematics and to expand their scientific culture. In past centuries, great discoveries have been made by amateur mathematicians. In this century, only astronomy has seen important amateur contributions. But with new fields of mathematics being opened up by computer experimentation, I suspect that once again it may be possible for people without extensive technical knowledge to contribute significantly to progress in mathematics.

Beyond the statistics, it is interesting to look at the actual registration cards our users send us. Sometimes, the cards tell some kind of story. I noticed one where the occupation was listed as "computer professional: software; hobby: financial analysis." The address was in Portola Valley, California. I recognized the name as one of the founders of Sun Microsystems.

Another registration card had the suggestion: "Use the definition of Stirling numbers from my book." The name of the user was Don Knuth. The strange thing was that in building *Mathematica* we had in fact used the definition of Stirling numbers from his book. But he had written another book. It's a pity there are no upgrade contracts for books.

Once a registration card suggested that *Mathematica* include "a scale model of the Great Pyramid." I took this suggestion merely as a compliment on the completeness of *Mathematica*, until I learned that the user who had made the suggestion was an author who had written extensively on pyramid power.

As well as knowing *who* uses *Mathematica*, it is also interesting to see *how* it is used. We received some data on this from a long questionnaire filled out by attendees of the 1990 *Mathematica* Conference.

We asked how much people use the various elements of *Mathematica*. The overwhelming majority of people said that they used all of numerical computation and that they used graphics and algebra extensively. Calculus and matrix operations were next in rank.

The majority of people said they did at least some kind of programming in *Mathematica*. About one third said they had written a program at least several pages long. On average, they said it took them about a day to do this. And they said that the longest run time for any *Mathematica* program they had written was typically between 10 minutes and one hour.

We asked people what experience they had with other programming languages. Over 50% said they had a working knowledge of FORTRAN, while 45% said they knew BASIC. About half this number said they knew C or Pascal, while less than half again said they knew LISP or APL. In fact, more knew Assembler than either LISP or APL.

The programming languages known by *Mathematica* users reflect in some ways the history of scientific computation. It is worth remembering that when computers were first built, it was thought that a total of perhaps 10 computers would be needed throughout the U.S., and that most of them would be used for scientific computation. As it turned out, computers were first used in large numbers for data processing and later for word processing. The languages for scientific computation progressed little, and in fact by the 1980's, the idea of using computers for scientific computation was almost forgotten, leading to the comments of the marketing expert quoted at the beginning of this column. But looking at the diversity of users of *Mathematica*, I think we can conclude that scientific computation is again achieving widespread importance.

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Virtual Memory Adds to Macs Running *Mathematica*

by Richard Gaylord

Running the enhanced version of *Mathematica* on a Macintosh computer reveals two major limitations of the machine: its speed and memory capacity. The latter problem can now be easily and inexpensively overcome using an INIT, appropriately called Virtual, which enables you to give your Mac virtual memory ranging from 2 to 14 megabytes. You set the amount of virtual memory using the Virtual icon in the Control Panel. The amount of virtual memory available is limited by two factors: you must have an amount of contiguous free space on your hard disk equal to the amount of virtual memory and the maximum amount of virtual memory that can be set is 15 MB minus 1 MB for each occupied NuBus slot.

When running *Mathematica* under Finder, you have the entire amount of virtual memory available to you. When running under MultiFinder, the maximum memory size for *Mathematica* can be set to about 7 MB, depending on the size of your system and the number of INITS in it. Using virtual memory is slower than using RAM, but we have found that a Macintosh IIcx with 2 MB of RAM and Virtual runs at about the same speed as a Mac II with Virtual and 5 MB of RAM. We have also been able to open 5 or 6 other applications under MultiFinder and run *Mathematica* concurrently. In both cases the operation is smooth and gltich-free.

If you have a Mac II, you need to buy the version of Virtual that includes a PMMU chip. However, the PMMU chip is necessary in order to use the forthcoming System 7.0 (or to use A/UX), and since Virtual can be purchased from a mail-order company for less than the price of the chip itself from other sources, you can consider Virtual as essentially a free bonus that you get simply by upgrading your Mac II.

Owners of a Mac IIcx, SE/30, IIx or IIci already have a PMMU chip, and you can buy the less expensive software versions of Virtual. The argument for these individuals to buy Virtual may be less compelling since System 7.0 will include virtual memory, but if users' experience of System 6.0 is any indication, it may be some time before a reliable version of System 7.0.x is available.

Using Virtual, Mac owners can now run memory-intensive *Mathematica* computations or graphics and/or use other applications while *Mathematica* runs concurrently in the background. It greatly enhances both the Mac itself and, especially, the Mac running *Mathematica*. Virtual is available from Connectix Corp. in Menlo Park, California, (415) 324-0727.

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