# Record Speedups for Parallel Processing

In computer circles, the full potential of parallel processing has always seemed out of reach. In theory, 1,000 processors working simultaneously – with each taking on a small portion of the total computation – could tackle a problem 1,000 times faster than one processor plodding through the problem step by step as most computers do now. In computer lingo, the 1,000-processor machine would then have a "speedup" of 1,000. This would be akin to constructing a building with 1,000 workers rather than just one.

But most computer scientists have been slow to harvest the fruits of this division of labor, because they've believed that such ideal speedups – equal to the number of processors used – were unattainable. This week researchers at Sandia National Laboratories in Albuquerque, N.M., shattered the skepticism by announcing that they have achieved record speedups of more than 1,000 on a 1,024-processor computer. By showing that it is possible to run a parallel machine at near-100 percent efficiency, they have ensured a prominent place for parallel processing in the future of computing.

This future had been in doubt because of the realization that what is gained by dividing up the computation is partly offset by the time it takes for processors to talk to one another and to perform "serial" tasks that simply can't be divvied up. The long-held belief has been that these chores will bog down a parallel machine so much that even with a billion processors, speedups of only 100 are the best anyone could hope for.

As a result, "there's been a psychological barrier to working with thousands of processors on a single problem," says Sandia computer scientist Robert E. Benner.

Now Benner and Sandia colleagues John L. Gustafson and Gary R. Montry have broken through this barrier by carefully crafting computer algorithms designed to get the most out of a parallel processing machine. They ran these programs on a recently acquired, state-of-the-art "hypercube" computer made by NCUBE Corp. of Beaverton, Ore. With the hypercube architecture, processors are connected as if they were sitting at the corners of cubes that fit inside of one another.

The researchers first considered problems involving a few thousand equations – the largest size that could be handled by a single processor – and then divided the problem among increasing numbers of processing units. By judiciously arranging their programs to maximize parallel tasks and minimize serial ones, they achieved speedups of 502 to 637 on the 1,024-processor hypercube. This means that a problem that took 30 hours to run on one processor was completed in about 3 1/2 minutes with the hypercube.

But Benner and his colleagues also realized that they could use the machine most efficiently if they expanded the problem size and complexity while they added more processors. In problems involving wave propagation, mechanics and fluid flow, they achieved speedups of 1,020, 1,019 and 1,011 respectively. These problems account for about half the kinds of scientific and engineering problems that normally concern Sandia researchers. One of the scientists' next projects is to see if other types of problems yield to their parallel processing approach as well.

"These guys did an outstanding job," says Alan Karp, a physicist based in Palo Alto, Calif. "They've shown that you can get almost all the speed that's [available to the machine]."

In so doing, Benner's group was the first to meet a challenge issued by Karp in 1985, who says that at the time there had been a lot of talk about building computers with 1,000 or 10,000 processors, but that no one had shown that these machines would be able to do anything useful. To spur the development of multiprocessors and their software, he challenged computer scientists to demonstrate a speedup of at least 200 on a general-purpose computer. "I didn't think anybody would [meet the challenge] so soon," he says.

With their speedups of 502 to 637 from the fixed-sized problems, Benner and his colleagues were also the recipients earlier this month of the first Gordon Bell Award, which was established to acknowledge important contributions to parallel processing applied to real problems. According to Karp, who was a judge in the Bell competition, second place went to a research consortium that achieved speedups of 458 on a 512-processor machine and 39 with 127 processors. The speedups of all remaining entries were 16 or less.

For the near term, the Sandia work shows that multiprocessors can solve problems as fast as current Cray supercomputers and other supercomputers that contain only a few processors at most – but at about one-tenth the cost, making supercomputer power accessible to more people. And for the distant future, it paves the way for succeeding generations of parallel computers that may contain hundreds of thousands of processors. "By developing more of these massively parallel applications in the future," says Benner, "we're preparing for the day when we'll have a truly awesome machine to run them." – *S. Weisburd*

# Fermat's last theorem: A promising approach

The end of a centuries-long search for a proof of Fermat's last theorem, one of the most famous unsolved problems in mathematics, may at last be in sight. A Japanese mathematician, Yoichi Miyaoka of the Tokyo Metropolitan University, has proposed a proof for a key link in a chain of reasoning that establishes the theorem's truth. If Miyaoka's proof survives the mathematical community's intense scrutiny, then Fermat's conjecture (as it ought to be called until a proof is firmly established) can truly be called a theorem.

Miyaoka's method builds on work done by several Russian mathematicians and links important ideas in three mathematical fields: number theory, algebra and geometry. Though highly technical, his argument fills fewer than a dozen manuscript pages – short for such a significant mathematical proof. Miyaoka recently presented a sketch of his ideas at a seminar at the Max Planck Institute for Mathematics in Bonn, West Germany.

"It looks very nice," mathematician Don B. Zagier of the Max Planck Institute told SCIENCE NEWS. "There are many nice ideas, but it's very subtle, and there could easily be a mistake. It'll certainly take days, if not weeks, until the proof's completely checked."

Fermat's conjecture is related to a statement by the ancient Greek mathematician Diophantus, who observed that there are positive integers, $x$, $y$ and $z$, that satisfy the equation $x^2 + y^2 = z^2$. For example, if $x = 3$ and $y = 4$, then $z = 5$. In fact, this equation has an infinite number of such solutions.

In the 17th century, French amateur mathematician Pierre de Fermat, while reading a book by Diophantus, scribbled a note in a margin proposing that there are no positive-integer solutions to the equation $x^n + y^n = z^n$, when $n$ is greater than 2. In other words, when $n = 3$, no set of positive integers satisfies the equation $x^3 + y^3 = z^3$, and so on. Then, in a tantalizing sentence that was to haunt mathematicians for centuries to come, Fermat added that although he had a wonderful proof for the theorem, he didn't have enough room to write it out.

Later mathematicians found proofs for a number of special cases, and a computer search performed a decade ago showed that Fermat's last theorem was true for all exponents less than 125,000. But despite the efforts of innumerable mathematicians, a proof for the general case remained elusive (SN: 6/20/87, p.397).

In 1983, Gerd Faltings, now at Princeton (N.J.) University, opened up a new direction in the search for a proof. As one consequence of his proof of the Mordell conjecture (SN: 7/23/83, p.58), he showed that if there are any solutions to Fermat's equations, then there are only a finite number of them for each value of *n*. However, that was still far from the assertion that there are no such solutions.

Some of the key ideas for Faltings' proof came from the work of Russian mathematician S. Arakelov, who was looking for connections between prime numbers, curves and geometrical surfaces. Both Arakelov and Faltings found that analogs of certain classical theorems already well established for geometrical surfaces could apply to curves and provide information about statements, such as Fermat's last theorem, that involve only integers.

About a year ago, A.N. Parshin of the Steklov Institute in Moscow, following Arakelov's lead, proved that if the arithmetical analog of an inequality, or bound, governing certain geometrical structures were true, then Fermat's last theorem would also be true. That inequality, in its original geometric form, had been discovered by Miyaoka and Shing-Tung Yau, now at Harvard University. By showing that the so-called Miyaoka-Yau inequality, in a modified form, also applies to the appropriate arithmetical structures, Miyaoka has apparently completed the chain of reasoning leading to a proof of Fermat's last theorem.

Miyaoka's results also demonstrate the increasing number of links being forged between diverse mathematical fields. If Miyaoka's proof turns out to be correct, then, according to some experts in arithmetical algebraic geometry (as this new field is called), similar methods may be useful for tackling a variety of tough mathematical problems.

"Fermat's last theorem is not important in mathematics directly," says Zagier. "It has no consequences." But the search for a proof has, over the years, prompted the development of much new mathematics. "It's a pity," he says, "that this goal may disappear."

Miyaoka is now busy carefully rechecking his proof and waiting for word from other experts who are studying his manuscript. "Things are looking good at the moment," says mathematician Lawrence C. Washington of the University of Maryland in College Park, who has been monitoring the situation. "But I don't think anyone wants to certify the proof yet." It's a time for both caution and excitement. — *I. Peterson*

# FOI may open secret cache of energy data

As former director of the Justice Department's Office of Privacy and Information Appeals, Quinlan J. Shea Jr. is an expert on the Freedom of Information Act and how it can be used to disclose data the government would rather not share with the public. Now, as special counsel for the National Security Archive in Washington, D.C., a private nonprofit clearinghouse of government documents, Shea is using Freedom of Information (FOI) requests and appeals to dig up "secret caches of government records." His latest conquest is the Department of Energy (DOE). Late last month he unearthed titles to 545 "limited [distribution] reports" that had been collected by the DOE's Office of Scientific and Technical Information (OSTI) in Oak Ridge, Tenn.

Until now, Shea says, even the titles to these unclassified reports "have been off-limits to the entire public." The reason the DOE has been unable to make these documents publicly available is that their subject matter falls under the data-control provisions of one or more laws, according to Charles Spath, OSTI's assistant manager for information acquisition and appraisal. Samples he cites include copyright laws, the Small Business Innovation Act (which protects proprietary data of commercial value to its developers), export-control laws and controls on unclassified nuclear information.

Shea, however, says he doubts that a solid case can be made to protect each document on the list. For example, he says that despite OSTI's assertions to the contrary, copyright is not a defense against a document's disclosure under FOI. And so, to test the DOE on its defense of these restrictions, Shea planned this week to file a new FOI request, asking for copies of about three dozen documents from the list. A number include English translations of research published in Soviet journals. If he succeeds in getting any or all, Shea says, this will be the first time an outsider has penetrated OSTI's library, with holdings estimated to exceed 600,000 documents.

Ironically, Spath says, concern over OSTI's restricted-access reports developed after his office sent out an Aug. 4, 1987, memo offering certain university libraries a chance to collect microfiche copies of the documents. These libraries were already receiving other, unrestricted-access OSTI documents.

"Our intent," Spath says, "has always been to make our information as widely available as possible." In fact, it was to broaden the availability of these controlled-access reports that OSTI offered them to university-based DOE contractors through their libraries, he says.

The memo said that to receive these "limited reports," libraries must promise to prohibit their viewing by anyone other than employees of government agencies — especially the DOE — and their contractors. Paula Kaufman at Columbia University in New York City read this as a new attempt by the government to restrict public access to unclassified research.

Upset at the prospect, she sent the memo to Nancy Kranich, a New York University librarian and chairman of the Coalition on Government Information, 43 organizations — including the American Association for the Advancement of Science and Shea's National Security Archive — that are fighting restrictions on access to information.

Learning of the memo through the Coalition, Shea offered to investigate. The FOI request he filed with the DOE in September asked for a list of these "limited reports," any other memos involving such documents, any additional documents covered by such memos, records explaining why restrictions had been placed on these unclassified documents and a chance to view each document in a DOE reading room. On Oct. 22, OSTI's deputy assistant manager responded, saying there was no list of restricted documents and no additional memos. Moreover, the deputy assistant manager informed Shea that all the documents he referred to were available for review at OSTI's reading room in Oak Ridge, but only "by organizations and individuals authorized to have access to them." That excluded Shea.

Shea appealed OSTI's response to DOE's Office of Hearings and Appeals — and won. OSTI challenged the appeal in mid-January, saying production of a list would be too time consuming. Furthermore, OSTI officials claimed that since their data were in a computer, manipulating them to create the list would amount to creating a new file — something they are not required to do under the Freedom of Information Act. The appeals board disagreed, and on Feb. 24 Shea got his list of 545 titles.

Meanwhile, a number of university librarians say they are still concerned about OSTI's Aug. 4 proposal and a Nov. 9 follow-up memo that attempted to smooth ruffled feathers. Jay Lucker, director of libraries at MIT, says that while his libraries won't accept documents requiring restricted access, "I'm still concerned about what [OSTI] is not sending me. . . . Unless there's a [national] security issue at stake," he believes, "these materials ought to be made available to everyone." — *J. Raloff*