national science foundation

ANNUAL REPORT 1991

LETTER OF TRANSMITTAL

Washington, D.C.

DEAR MR. PRESIDENT:

I have the honor to transmit herewith the Annual Report for Fiscal Year 1991 of the National Science Foundation, for submission to the Congress as required by the National Science Foundation Act of 1950.

Respectfully,

Walter E. Massey

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Director, National Science Foundation

The Honorable
The President of the United States

Mathematics and Computer Science

A New Sorting Algorithm

For more than 30 years, instructors and textbooks have taught that there is a limit to how fast a computer can sort—a barrier called the "information-theoretic lower bound." In 1991, two NSF-funded computer scientists developed a new algorithm that debunked this conventional wisdom and ultimately will have an impact on information technology, sorting, searching and retrieval.

An algorithm is a precisely specified mathematical procedure for processing data on computers. *Michael Fredman* at the University of California at San Diego and *Dan Willard* at the State University of New York at Albany devised one that could allow surprisingly fast sorting of huge databases. Its speed relative to standard sorting algorithms improves as the database grows.

Fredman and Willard used a new method of organizing data, called a fusion tree, which allows a computer to compare one number against many others during a single computational step. The method may be useful in very large data processing tasks, such as transportation problems involving the least costly way to ship supplies and materials, or determining the cheapest way to connect nodes in a telecommunication network. The researchers stumbled across the method while trying to solve another data-retrieval problem.

Early results suggest that future avenues of research eventually may benefit from this discovery. And the new method of sorting variables will work on common-variety computers because it allows computers to "fuse" numbers so they can sort hundreds of them simultaneously.

The Drum and the Spectrum

Picture a figure from plane geometry stretched over a frame to form a drum. (While most drums are round, there is no requirement that they be so.) To each plane figure, mathematicians assign a set of numbers they call the spectrum of the Laplacian, which roughly describes the sound a drum makes when struck. A question that puzzled experts for years [illegible] phrased as, "Can you hear the shape of a drum?" That is, [illegible] the Laplacian co[illegible] the size and sha[illegible]

Mathematicians [illegible] and *David Webb* of [illegible] University and Scott [illegible] University of Maryland have [illegible] that the answer to this question is [illegible] By using knowledge of how the spectrum of the Laplacian behaves for three-dimensional surfaces (such as that of a sphere) and by taking advantage of three-dimensional symmetries, they were able to squash surfaces together to produce two plane figures with identical spectra that are visibly different.

For mathematicians this work is important because analytical tools such as the spectrum of the Laplacian provide a means to compute the characteristics of geometric objects. The tools being developed in this research may also have important consequences in materials research, where one method of determining flaws involves measuring the spectral response of the material.

Applications of Advanced Technologies

This NSF program supports research and development on applying advanced technologies—particularly computer and computer-controlled technologies—to science and mathematics education. It supports innovative projects to lay the conceptual foundations for technology that will be available within 10 years. The program also aims to speed the advent of revolutionary computer and telecommunications ideas and developments into classrooms. These applications include the following 1991 awards:

- Intelligent Tutors in Algebra and Geometry, *John R. Anderson* at Carnegie-Mellon University. Goals of this research are to develop and demonstrate greatly improved intelligent (computerized) tutoring techniques, and to produce an integrated algebra and geometry tutor that will cover in one year the material normally covered in two.

- Visual Modeling: A New Experimental Science, *Wallace Feurzeig*, BBN Systems & Technologies Corp., Cambridge, Mass. Computer modeling is becoming a standard tool for both experiment and theory, used to study complex processes ranging from the proton's inner structure to the formation and decay of star