Computing 'fusion trees' to explode barriers

Most computers spend only a small fraction of their time as calculators. Instead, they serve as gigantic filing systems, searching for records or sorting data into manageable forms. Now, two computer scientists have discovered a method for hurdling a theoretical barrier that appeared to limit how fast a computer can sort or search.

Developed by Michael L. Fredman of the University of California, San Diego, and Dan E. Willard of the State University of New York at Albany, this mathematical recipe, or algorithm, theoretically could speed the process of shuffling data by circumventing a key step in traditional sorting and searching methods. Whereas standard methods compare two numerically encoded items at a time, the new approach provides a way to compare many numbers at once.

Although not yet applicable to any practical situation, this theoretical result overturns long-held notions, described in nearly every computer-science textbook, concerning the speed of certain algorithms. "When Fredman and I originally made this discovery, people continually asked us where we were cheating," Willard says.

Computer scientists have generally assumed that sorting involves successively comparing two items or numbers at a time to see which one should precede the other. In the worst possible case for a given selection of items, such a process requires making a specific number of comparisons that can be calculated for any number of items. That number represents a kind of minimum speed limit for sorting.

In effect, Fredman and Willard found a way to raise that minimum speed limit. Instead of relying solely on comparisons of number pairs, they manipulate the data and organize the numbers into a new form, dubbed a "fusion tree," which enables them to compare one number against many others during a single computational step. A saving results because the number of instructions needed to manipulate the data is less than the number of comparisons normally required in sorting.

The algorithm developed by Fredman and Willard performs this feat by considering only a small portion of the string of ones and zeros, or bits, used to express each number. "We noticed that when you want to compare one number with several, you don't need all the bits of each of the numbers you are comparing," Willard says.

Their sorting method provides a way to select the relevant bits from a given set of numbers, group these subsets into a single expression and perform certain arithmetical operations to make multiple comparisons in a single step. A similar approach raises the minimum speed limit for searching.

At present, the new algorithms significantly outpace standard methods only when the number of items in the database is sufficiently large. "The complicated nature of these algorithms, as they are currently constituted, does not allow for improved efficiency unless they are being applied to vastly large amounts of data," Fredman says. "Nevertheless, these results suggest that future avenues of research may eventually benefit from the discovery."

That research could lead to practical, efficient methods for sorting items in databases much larger than any in existence today. Fredman and Willard are also exploring the possibility that their approach can speed other algorithms developed in the past to solve various problems, such as finding the shortest or least costly telephone or transportation network to link a number of cities.

"Their work ... will have profound influence on theoretical computer science for years to come," comments B. Gopinath of Rutgers University in Piscataway, N.J.

A paper describing the new algorithms has been accepted for publication in the JOURNAL OF COMPUTER AND SYSTEM SCIENCES. *— I. Peterson*

Record-breaking brightness poses enigma

Two months ago, British astronomers reported finding the brightest object so far observed in the universe — a quasar called BR 1202-07. Now, a British-U.S. team has announced the serendipitous discovery of an object that surpasses the quasar's brightness by 40 percent, glowing with 30,000 times the luminosity of the entire Milky Way.

Unlike the previous record-breaker, which radiates strongly in visible light (SN: 5/4/91, p.276), the new title holder emits 99 percent of its energy in the infrared. While the researchers believe the emission comes from a hot, massive dust cloud, the source heating the cloud remains unclear. In the June 27 NATURE, co-discoverer Michael Rowan-Robinson of Queen Mary and Westfield College in London and his colleagues suggest two possibilities for the enigmatic heat source: a quasar buried at the cloud's core, or a primal burst of star formation in the cloud.

Either way, they may have witnessed the birth of a key celestial structure. On the one hand, Rowan-Robinson reasons, a quasar locked within a dust cloud could not remain there for more than a million years — a short interval, astronomically speaking — because its radiation pressure would blow away the cloud. Thus, if a dust-shrouded quasar induced the radiation, the quasar must have just switched on. On the other hand, if the radiation stems from star formation, then the cloud likely represents a galaxy undergoing its first stellar ignition, he says. "Whether quasar or galaxy, it's a key moment we're catching," Rowan-Robinson says.

The researchers made their fortuitous finding while identifying visible-light counterparts to faint infrared sources detected in 1983 by the Infrared Astronomical Satellite (IRAS). Two years ago, on the last night of a survey with the William Herschel 4.2-meter telescope in La Palma, Spain, they had their sights trained on an object thought to be associated with one of the IRAS sources. By chance, the image of another celestial body fell on the slit of their spectrograph.

In analyzing its spectra, the team deduced that the unexpected find has a redshift of 2.286 — meaning it lies billions of light-years from Earth and must have an inherently high luminosity to be detected at all. Subsequent observations revealed that the visible-light image coincides with that of a faint radio source in the constellation Ursa Major. Both lie at the center of the infrared-emitting region found by IRAS, Rowan-Robinson says.

He calls a hidden quasar "the safer bet" to explain the infrared emission, since quasars have high luminosities. However, the team did not find a broadening of certain spectral lines emitted by the cloud, which they would expect to see if the cloud harbored a quasar. Moreover, the mass of the dust cloud may support the galaxy hypothesis, Rowan-Robinson says. The cloud is composed mostly of metals — which are usually spewed out by stars — and its mass may be as great as a billion solar masses, exceeding the metal mass of a typical galaxy. This would fit with a budding galaxy rapidly undergoing its first, most brilliant phase of star formation — a phenomenon astronomers have long sought to witness.

A finding that starbirth can proceed so rapidly, notes Rowan-Robinson, could overturn standard models, which hold that galaxies assemble gradually. But first, he says, researchers need stronger evidence that the cloud represents a new galaxy, and "we need other examples to convince ourselves that this is not some absolute freak."

— R. Cowen