Mathematician discovers a quicker way to calculate prime numbers

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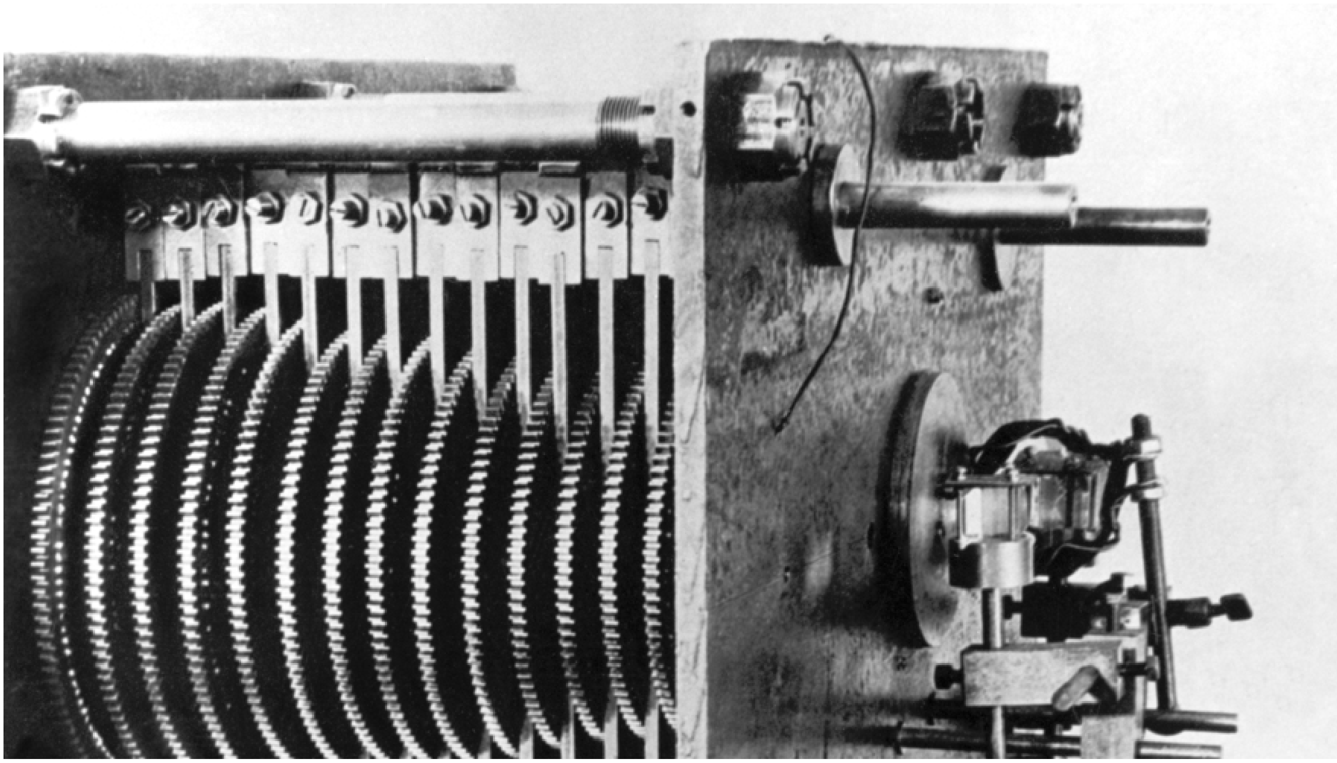

A mechanical gear number sieve built by University of California Mathematics Professor Derrick N Lehmer, Berkeley, California, 1932. It was used to solve number theory problems and could check 5,000 combinations per second, a record that was only beaten much later by computers in the 1960s. Photo by Underwood Archives/Getty Images

Mathematician Harald Helfgott became famous in 2013. He had just solved a 271-year-old problem known as Goldbach's weak conjecture. According to this theory, every odd number bigger than 5 can also be written as the sum of 3 prime numbers. For example, 3 + 3 + 5 = 11 and 19 + 13 + 3 = 35.

Helfgott, 38, went even farther back in time to solve the problem. He came up with an improved version of the sieve of Eratosthenes, a popular method for finding prime numbers invented around 240 B.C. Helfgott's new version would reduce how much physical space is needed in computer memory. This would reduce the amount of time programs need to make that calculation.

Prime numbers are something like "atoms of mathematics." They are numbers which can only be divided by themselves and the number 1. Eratosthenes of Cyrene — a Greek mathematician, astronomer and geographer — invented a practical method to identify them: the “sieve,” or filter. “Like many other children, I was taught this in primary school when I was 10, with a table,” says Helfgott, who is currently a researcher at the National Center for Scientific Research and the University of Göttingen.

Crossing Out Numbers

In order to use this sieve to find all prime numbers between 1 and 100, for example, one first has to write down the list of numbers in numerical order. Then one starts crossing them out in a certain order. First, one crosses out all the multiples of 2 (except the 2). Multiples are all numbers that can be evenly divided by a certain number. Multiples of 2 are 4, 6, 8, 10, etc. After this is done, one crosses out all the multiples of 3 (except the 3), the multiples of 4 (except the 4), and so on, starting with the next number that had not been crossed out. The numbers that are left at the end will be the primes. This method can be written as an algorithm, or step-by-step process. Computers can run it very quickly.

While working on a book about Goldbach's weak conjecture, Helfgott began thinking about the problem of the sieve of Eratosthenes. In particular, he thought about how much space or memory it needs. "Computers today are very fast," Helfgott says. "But the memory is still limited."

Judging Algorithms

Mathematician Jean Carlos Cortissoz Iriarte says there are two things to look at to see how good an algorithm is. First, one has to look at the number of steps per bit given an input. Then one has to look at how many bits need to be stored in memory while the steps of the algorithm are executed. In terms of the number of steps per bit, the sieve of Eratosthenes is "relatively efficient," Cortissoz Iriarte says. But when the algorithm is used to find primes for very large numbers, it requires lots of memory. At that point, the sieve "stops being efficient."

Helfgott found a way to adjust the sieve of Eratosthenes to use less memory space. To find all prime numbers up to a trillion, Helfgott's new version is much more efficient. It only "requires a few million bits instead of a billion bits," Helfgott says. His ideas were presented in July at conferences in Buenos Aires, Argentina and Paris, France.

Sieve Of Eratosthenes Is Special

To understand the advantage of the new sieve, Cortissoz Iriarte offers a comparison. “Let's pretend that you are a computer," he says. To store information in your memory "you use sheets of paper. If to calculate the primes between 1 and 1,000,000, you need 200 reams of paper (10,000 sheets) ... with the algorithm proposed by Helfgott you will only need one fifth of a ream (about 100 sheets),” he says.

There are other sieves or algorithms to identify prime numbers. But Helfgott notes that the sieve of Eratosthenes is special. It can also work with other mathematical operations such as factorization. This method breaks down any number into the product of prime numbers and is used to encode information in a safe way, such as for conducting electronic bank transfers or online purchases. "Factoring has become a key element" of modern civilization, Helfgott says. Eratosthenes would never have imagined it.

Quiz

1 Read the introduction [paragraphs 1-3].

Based on the article, why is reducing physical space important to computer memory?

(A) Reducing the physical space a program takes up in the computer's memory increases the amount of memory needed for programs to make calculations.

(B) Reducing the physical space of program in a computer's memory improves the accuracy of the program's calculations.

(C) Reducing the amount of physical space needed for a computer program increases the security of the entire computer.

(D) Reducing the physical space of a program in the computer's memory lessens the amount of time programs need to make calculation.

2 Read the section "Judging Algorithms."

What is MOST likely the reason why the author included Jean Carlos Cortissoz Iriarte's analysis of the sieve of Eratosthenes?

(A) to comment on how important prime numbers are to computers

(B) to characterize how most people attempt to come up with new algorithms

(C) to provide a simple explanation of how computers use algorithms

(D) to highlight the importance of Helfgott's improved algorithm

3 Read the sentences from the introduction [paragraphs 1-3].

> *Mathematician Harald Helfgott became famous in 2013. He had just solved a 271-year-old problem known as Goldbach's weak conjecture. According to this theory, every odd number bigger than 5 can also be written as the sum of 3 prime numbers.*

Which word from the text helps you understand the meaning of "Goldbach's weak conjecture"?

(A) solved

(B) problem

(C) theory

(D) numbers

4 Read this sentence from the section "Crossing Out Numbers."

In particular, he thought about how much space or memory it needs.

Read the sentences below. Which sentence uses "space" in the SAME way as the sentence above?

(A) The mathematician took a trip through time and space.

(B) The rocket's orbit took it to the deepest parts of space.

(C) Jean felt like a space cadet after she forgot her multiplication tables.

(D) The expensive dining table took up most of the space in the room.

Answer Key

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