Fast, robust algorithm for computing stellarator coil shapes yields designs that are easier to build and maintain

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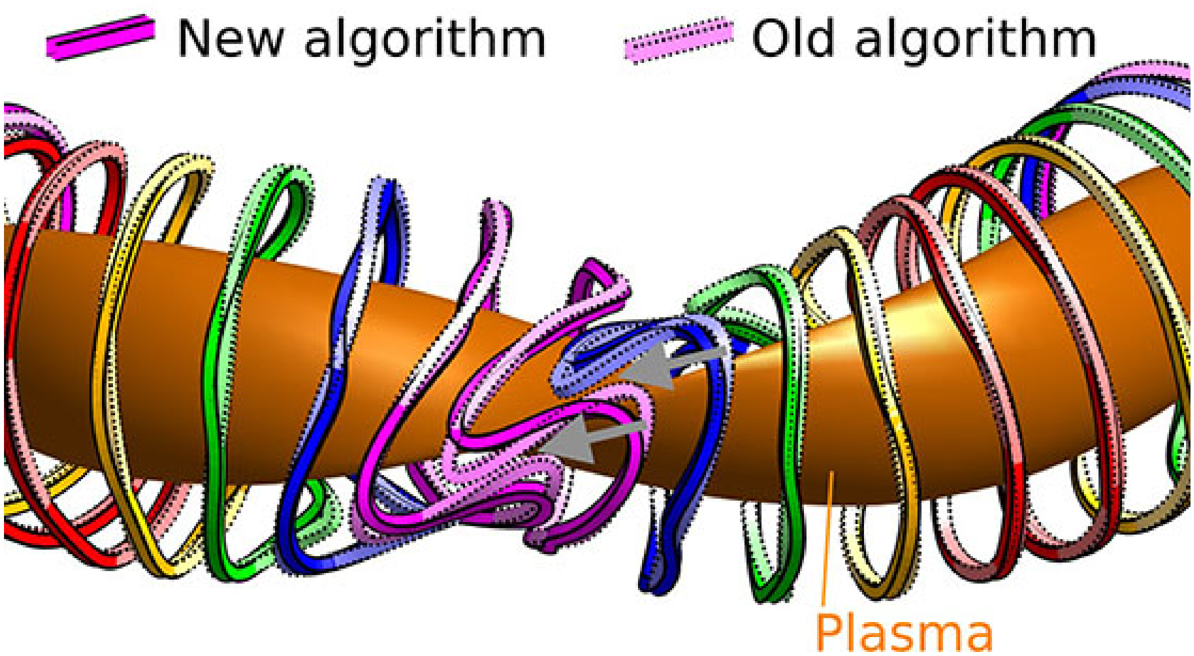

The new algorithm for computing stellarator electromagnetic coil shapes (solid black edges) results in more space between coils than the previous algorithm (dotted edges), as is apparent near the gray arrows. At the same time, the coils from the new algorithm more accurately produce the desired plasma shape. The illustration shows a calculation for the geometry of the W7-X stellarator. Credit: US Department of Energy

A stellarator is a device in which plasma can be confined at temperatures hotter than the core of the sun, using magnetic fields from carefully shaped electromagnetic coils. Scientists modified the mathematical optimization problem used to compute the coil shapes. They increased the space between coils. Increasing the space smooths the coils' sharp bends, while preserving the speed and reliability of the previous method.

The electromagnetic coils of a stellarator are challenging to design. Why? The precise 3-D shaping needed for good plasma confinement must be balanced against several constraints: the coils cannot overlap, there must be adequate space between the coils for diagnostic and maintenance access, and the coil conductor cannot be bent into too sharp of a turn. By smoothing the coil shapes and increasing the inter-coil distances, this new algorithm will enable stellarator designs that are more feasible to build and maintain.

The improvement in coil shapes was achieved by asking a somewhat different mathematical question compared to the question asked previously. In the previous approach, used to design experiments such as the W7-X stellarator in Germany and the HSX stellarator at the University of Wisconsin, the coil shapes were optimized to yield the best approximation of the desired plasma shape, using a small number of sine and cosine functions to describe the coil shapes. In the new approach, the coil shapes are optimized to yield the best approximation of the desired plasma shape at the same time as the distances between the coils are maximized.

This kind of problem, in which you maximize two criteria that sometimes conflict, has many familiar analogies in daily life, such as when you are shopping for a pair of shoes and want both the lowest price and the highest quality. In the new algorithm, the coil designer has more precise control over balancing the competing objectives of "producing the desired plasma shape" and "leaving ample space between the coils."

The new research shows that no matter how you choose to strike this balance, the new algorithm does a better job of maximizing both objectives compared to the previous algorithm. At the same time, the new algorithm is comparable in speed to the previous algorithm. It is also robust; it is guaranteed to always find the globally optimum solution and not merely a local optimum.

More information: Matt Landreman. An improved current potential method for fast computation of stellarator coil shapes, *Nuclear Fusion* (2017). DOI: 10.1088/1741-4326/aa57d4

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