Automatic and statistically robust spatio-temporal detection and tracking of fusion plasma turbulent fronts with parallel R

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Few would argue that fusion energy has been the Holy Grail of renewable energy efforts. The success of this endeavor will have vast environmental, geopolitical, and economic impacts. The grand Challenge is to produce more energy through a fusion reaction than that required to initiate the process in a reactor. A key bottleneck is the turbulence, or unstable motion, of the fusion plasma. Turbulence influences the degree of energy lost by plasma during the fusion process; therefore, controlling the turbulence is critical to viable energy production. Discovery of dynamic turbulent patterns and trends from the data produced by a computer-simulated fusion reaction offers a potential to reveal ways to control the turbulence. Yet, it presents a challenge: how to effectively and efficiently analyze the massive amounts of data, which is inherently complex, noisy, and high-dimensional. To address this challenge, we create a supercomputing analytical methodology to discover, track, and statistically quantify - both in space and time - the intricate patterns of dynamic plasma turbulence from extreme-scale fusion simulation data. This process can potentially predict the structure, dynamics, and function of fusion plasma turbulence. It could also enable similar analyzes required in other disciplines, such as astrophysics and oceanography.