The Multiple Divisions and Main Challenges in Computational Physics

Azeem Woolery*

Department of Applied Sciences, University of the Punjab, Lahore, Pakistan

Opinion Article

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***For Correspondence:**

Azeem Woolery, Department of Applied Sciences, University of the Punjab, Lahore, Pakistan

E-mail: wool.A@co.pk

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ABOUT THE STUDY

Computational physics is the study and application of numerical analysis to physics issues. Computational physics was historically the first application of modern computers in research, and it is now a part of computational science. It is often considered a subfield of theoretical physics, while others describe it as an intermediary branch between theoretical and experimental physics-a field of study that supplements both theory and experiment.

Challenges in computational physics

Computational physics issues are notoriously difficult to solve precisely. This is attributable to a number of factors, including a lack of algebraic or analytic solvability, complexity, and chaos. On the advanced side, mathematical perturbation theory is occasionally applied. Also, the computational cost and computational complexity of many-body problems tend to increase rapidly. That is something of an issue because a macroscopic system generally contains 1023 component particles. In general, solving quantum mechanical problems is of exponential order in terms of system size, and for classical N-body problems, it is of N-squared order. Finally, many physical systems are inherently nonlinear at best, and chaotic at worst; this makes it difficult to ensure that any numerical errors do not accumulate to the point where the 'solution' becomes useless.

Methods and algorithms: Because computational physics employs a diverse set of issues, it is often classified according to the mathematical problems it numerically solves or the methodologies it implements. Root finding, system of linear equations, ordinary differential equations, integration, partial differential equations, and matrix eigenvalue issue are some of them. All of these approaches are used to calculate the physical parameters of the models. Computational physics also draws concepts from computational chemistry; for example, the density functional theory used by computational solid state physicists to compute solid characteristics is essentially the same as the density functional theory used by chemists to calculate molecular properties.

Computational physics also includes the tailoring of the software/hardware framework to address challenges.

Divisions

For each main subject of physics, there is a corresponding computational branch:

1. Computational mechanics consists of Computational Fluid Dynamics (CFD), computational solid mechanics and computational contact mechanics.
2. Computational electrodynamics is the process of modeling the interaction of electromagnetic fields with physical objects and the environment. One subfield at the confluence between CFD and electromagnetic modeling is computational magneto hydrodynamics.
3. Computational chemistry is a rapidly growing field that was developed due to the quantum many-body problem.
4. Computational solid state physics is a major branch of computational physics that deals directly with material science.
5. Computational statistical mechanics is a branch of computational condensed matter that deals with the simulation of models and theories that would otherwise be difficult to solve.
6. Monte Carlo-like approaches are extensively used in computational statistical physics. More broadly, it is interested in the social sciences, network theory, and mathematical models for disease dissemination and forest fire spread.
7. Numerical relativity is a new subject that seeks numerical solutions to the field equations of special and general relativity.
8. Computational particle physics is concerned with challenges inspired by particle physics.
9. The application of these concepts and methodologies to astrophysical issues and phenomena is known as computational astrophysics.
10. Computational biophysics is a subfield of biophysics and computational biology that applies computer science and physics methodologies to address complicated biological issues.