How computational physics is uniting science and revolutionizing society

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I am continually fascinated by the rapid development of our field of computational physics. In just a few years we have grown from a small topical group into a substantial division of the American Physical Society. Our current membership is passing the 2000 mark, out of a total society membership of 43,000.

Computers are now much more than tools for analysis. They provide us with innumerable intellectual challenges, ranging from algorithm development to allowing us to explore novel concepts such as self-organized criticality. Simulational science in particular continues to grow as a major subfield. Three-dimensional studies ranging from fluids to dynamical molecular systems are becoming routine. In my own field of particle physics, four-dimensional lattice gauge calculations are giving useful handles on hadronic properties; indeed, lattice results now appear in the standard tables of particle properties. Observation of a quark gluon plasma is the goal of the relativistic heavy ion collider being built at Brookhaven, and computer simulations have been crucial to estimating the transition temperature and providing confidence that this machine will operate in an interesting energy range.

Beyond our rapid growth, we are an unusual division. Most of our members do not consider computational physics their primary affiliation, but joined because of a secondary interest in computing as a tool. Taking the division officers as an example, I myself am a particle physicist, the upcoming chair Dan Barnes studies plasmas, and his successor Barry Klein specializes in condensed matter. This diversity leads to considerable strength. In these days of overspecialization, it has become increasingly difficult to communicate with our colleagues in different subfields. But via computing we are discovering a common ground, and more and more frequently discover that our colleagues are working on closely related problems. This cross-fertilization provides us with a rich resource for ideas. In my own area of lattice gauge theory, we directly borrow techniques from the statistical mechanics and condensed matter communities.

Our division's annual meeting, Physics Computing '95, will be held 5-7 June in Pittsburgh. Just as our division is a bit unusual, so will this meeting be. Indeed, because of our diversity, it is inappropriate to have the detailed technical seminars of a more specialized meeting. Instead, at this conference the plenary talks will be more at the level of colloquia, with the speakers presenting overviews of their fields in the context of the revolutions stemming from dramatic advances in computing.

About half the scheduled time will be spent in these plenary sessions attempting to reach the entire physics community. The remainder will be devoted to parallel sessions for more specialized purposes. Included are sessions on nonlinear dynamics, materials science, lattice gauge theory, plasmas, and physics education. These sessions will provide participants an opportunity to learn more on areas related to their current interests. More specific information on the meeting can be found at the URL:

`http://penguin.phy.bnl.gov/www/pc95.html`

Computational physics, while uniting many areas of science, is also developing specializations within the field. Many of us are involved in large scale simulations, ranging from fluid flows to quarks and gluons. These diverge over algorithms, ranging from Monte Carlo to molecular dynamics methods. Another group of computational physicists primarily uses computers for information handling; as examples we have the proliferating preprint bulletin boards and the increasing use of physics simulations for educational purposes. Still other physicists use the computer primarily as an analysis tool, particularly for handling the immense quantity of data emerging from modern experiments. Indeed, the data rates expected at new accelerators such as the Large Hadronic Collider, under construction at CERN, go beyond current capabilities and will rely on anticipated improvements in computer hardware.

Often these widely disparate approaches to computational physics interplay in unexpected ways. Considering perhaps the most dramatic example, it was a team of experimental physicists trying to collaborate over long distances that produced the World Wide Web. This tool has now become an essential part of our attempts to keep up with the rapid expansion in physics.

The Web is spectacularly exploding far beyond the physics community. Practically every day one reads in the newspaper how it is is revolutionizing the way society thinks of information. We as physicists can rightfully feel proud about the origins of this revolution. We are accustomed to feeling that much of the basic research in physics, and most particularly in the high energy realm, has no direct practical application. Sometimes we argue for spinoffs such as accelerators for medical research. But we are now observing in a completely unexpected direction how computational physics is affecting society in a way that will dwarf basic research expenditures.

Where will this trend lead? That is what is so exciting; we don't know. Physicists have long been among the largest users of computer cycles, but there is often a tendency to think that this is mostly tedious data analysis. We do, of course, do that, but at the same time we find ourselves unconsciously revolutionizing society.