Mathematics Program at ARPA

The Applied and Computational Mathematics Program (ACMP) at the Advanced Research Projects Agency (ARPA, formerly DARPA) offers support for mathematical research in areas of interest to the Department of Defense (DoD). Many of the most difficult scientific and computational problems the DoD faces would benefit from deep mathematical examination and the participation of mathematicians in interdisciplinary teams. To this end, ACMP supports research in areas of the mathematical sciences that have bearing on defense applications.

"ARPA is a mission agency, so we are always looking for mathematics that will revolutionize some area of technical importance to the DoD," says ACMP Program Manager Anna Tsao. All of what ACMP funds is "applied" research, because it must be connected to a specific application of interest to the DoD, although, as Tsao notes, "some of the research is of a very basic nature." However, "good ideas alone are not enough," says Tsao. The success of ARPA projects is measured by the degree to which they follow through with technology transfer.

While ACMP focuses on a few key areas, it is also interested in developing new ideas to support the DoD research mission. "We would like people to come in with revolutionary ideas of interest to the DoD, not just those that are covered specifically by what we are funding at the moment," Tsao says. She points out that ARPA is very much "opportunity-driven", so that the agency can quickly take advantage of new research opportunities.

For fiscal year 1996, the ACMP is focusing on three main areas: signal and image processing; numerical algorithms; and modeling, simulation, and control of materials processes. The first area includes such topics as automatic target recognition, compression, data fusion, and associated problems of electromagnetic scattering. The second area supports the development of algorithms used in the other two areas, as well as in other defense applications.

The third area is receiving particular emphasis for fiscal year 1996. Over the years ARPA has supported a great deal of work in materials research, because the development of new and specialized materials is central to many defense applications. In this realm arise fundamental issues of control of processes to insure manufacturability and uniform quality.

The ACMP initiative in this area focuses on an integrated approach to computer-aided process design that incorporates models of process, sensing, and control into the design methodology. Tsao points out that control theory is studded with "heroic" fixes carried out after a process has been designed and implemented. By contrast, the initiative seeks to develop ways of designing processes that take into account sensing and control from the outset, as is done in designing high-performance aircraft.

This computationally oriented approach leads to mathematical questions in the development of algorithms for modern high-performance computers. For example, certain algorithms can be represented algebraically with tensor prod-

ucts, and it has been demonstrated that such representations provide an effective mechanism for designing algorithms optimized for different computer architectures. This leads to the question of what the algebra can reveal about how to automate the algorithmic design process. "There is a lot of mathematical structure in many algorithms that, if captured in the right way, would expose how to map the algorithms onto a machine," Tsao notes.

ACMP hopes that developing the mathematics underlying well-chosen materials process applications will lead to the development of generic software tools that will be reusable in other applications. As Tsao puts it, "Is there a way to extract out the generic part of the computation and apply good software engineering so that one doesn't have to write new code for every new application?" Ultimately, the goal is to try to develop ways of approaching algorithm development to make high-performance computers easier to use, so that one does not need to become an expert in computing to use them. "For this we will need real involvement by classically trained mathematicians," Tsao says.

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In the materials applications, two main issues arise. The first is the matter of bridging the gap between atomistic models and continuum models. Such a bridge is needed in order to understand microstructure, defects, and stress effects, all of which influence the quality of materials. The other issue is that the sensing and control must be done in real time.

The primary mechanism for identifying proposals for funding at ARPA is a proposal solicitation known as a Broad Agency Announcement (BAA). A BAA provides descriptions of ARPA program topics of interest and broad evaluation criteria. This announcement is published in the *Commerce Business Daily*, which can be found in most university grants offices. Although ACMP does not yet have any specific deadlines for fiscal year 1996, those interested in submitting a proposal are encouraged to contact ARPA early in the fiscal year (which began October 1). For topics not covered under an existing BAA, prospective proposers are encouraged to contact the ARPA program manager to discuss research ideas and their relation to DoD interests. Unsolicited proposals in areas of interest will be considered.

All of the research that the ACMP funds is multidisciplinary. Award instruments may be procurement contracts, grants, or agreements. Grants are generally awarded only to universities and nonprofit research organizations, address more exploratory work than contracts, and typically involve smaller efforts than thosed funded by contract. Procurement contracts can be awarded to any recipient and have specific "deliverables" to be provided by the end of the effort. Agreements provide funds for work by strictly commercial firms or for collaborative work involving industry teams and academia; they are neither contracts nor grants but flexible award instruments that do not include the typical government "boilerplate" terms and conditions. ACMP also supports conferences and workshops on occasion. The DoD sponsors a special program, called the University Research Initiative (URI), which provides grants to university researchers. There is no ACMP-sponsored topic in the URI competition for fiscal year 1996, but there may be in future years.

Tsao, who is on leave from her position at the Center for Computing Sciences, Institute for Defense Analyses, earned a doctorate in complex analysis from the University of Michigan. Having made the leap to applied work several years ago, she understands what classically trained mathematicians can contribute to this kind of work. While the value of areas of the mathematical sciences traditionally regarded as "applied" is already well established, "it's increasingly evident that pure mathematicians can offer a lot in helping to solve these kinds of problems," Tsao says. "If there is a way to get more of them interested, it would be a wonderful thing." Tsao concedes that such problems are not to everyone's taste, but she says, "I think some people who think there are no interesting problems in these areas would be pleasantly surprised."

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