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The SIAM Community in Action, From Homeland Security to Education

One has the impression, looking over early plans of the new Department of Homeland Security's Science and Technology Directorate, of being in an atmosphere much like that of Los Alamos in the 1940s. A recent (October 8–9) workshop on homeland security and advanced scientific computing, run for DHS by Steven Ashby of Lawrence Livermore National Laboratory, set a goal of defining ways in which advanced computing technologies could be used to address needs of the department. Speakers at the workshop discussed DHS needs in a wide range of areas: emergency planning and response, borders and transportation security, infrastructure protection, and information analysis, among others.

TALK OF THE SOCIETY

By James Crowley

It was recognition of the important role played by science and technology in World War II that led the U.S. government to make heavy investments through the various funding agencies, starting with the creation of the Office of Naval Research (1946) and the National Science Foundation (1950). In recent years, by contrast, we have witnessed declining levels of science funding within the Depart-ment of Defense—perhaps, paradoxically, because science has been so successful, producing what seems to be a full shelf of technology.

The emergence of new challenges in the mission-driven DHS, however, creates the need for new lines of research, many of them involving applied mathematics and advanced scientific computing. In the words of Maureen McCarthy, director of the DHS Office of R&D, "There is a big need for a scientific computing base to achieve what we need to accomplish."

This was amply illustrated in the October workshop: The operational needs in homeland security are great, so much so that they clearly outstrip our abilities to deliver technology with off-the-shelf solutions. Many promising areas of research can be identified, along with some shorter-term ideas; clearly, though, we also have long-term needs, many of which call to mind those of the 1950s.

Workshop speakers called for research in many areas to address the challenge of rapid identification of individuals with malicious intent. Consider, for example, the problem of border security. Security officers at border crossings have 30 seconds to make a decision—should a vehicle and its driver be permitted to cross the border? What is the state of face-recognition and radiation-detection technologies? Can researchers in those areas provide tools that will help border guards with their task?

How can advanced scientific computing help with the range of problems posed? Clearly, modeling and simulation can play a role in many areas. Looking first at a traditional area, we can envision tools from computational fluid dynamics helping to model and predict the movement of plumes of materials in the atmosphere, although the need to consider particulates and chemical reactions makes this a challenging problem.

Less traditionally, modeling the movement of people—whether in vehicles in traffic, or inside buildings—poses new challenges. A series of sessions on traffic modeling at a recent SIAM meeting presented discrete and continuous approaches. Agent-based models (which track individual components and aggregate the results into larger patterns) are a promising approach to realistic simulations that could be used to develop evacuation plans.

To protect critical infrastructure—like the electric power grid—we need better models that take into account the dynamics of complex systems; built from uncertain components into subsystems and systems, the models will have to incorporate intricate sets of interdependencies and cascading effects. The models should eventually allow planners to accomplish such tasks as identification of critical nodes and assessment of the impact of changes, whether at the level of components or systems. In essence, DHS would like to have simulation tools that provide a decision support system.

It is clear that all the models and resulting simulations have a strong stochastic component, which means that cooperation between statisticians, modelers, and computational scientists is essential. The theme of uncertainty modeling—incorporating estimates of uncertainty in the computed results—was brought out by nearly every speaker at the workshop.

Training is another use of simulation that could have a major impact, as presented at the workshop by Richard Ewing of Texas A&M University. Advanced computing can yield simulation tools for training emergency response personnel (like firefighters). Such tools are also useful in the design of buildings with improved safety features.

Finally, myriad algorithmic and computing issues are associated with data integration and information analysis—two themes that dominated the workshop. Agencies responsible for homeland security have a multitude of databases for a variety of purposes and need the ability to query these databases rapidly, accurately, securely—and within the limits of privacy laws. How can we develop appropriate data models and ontologies that make this possible? And once we have an integrated view of the data, how are relationships to be found within the data? Scalable graph-traversal and pattern-recognition algorithms are called for here.

The applied mathematics community can contribute to homeland security through research in many areas, including pattern recognition, image processing, visualization, modeling of complex and uncertain dynamical systems, and simulation that uses both physics-based and agent-based models.

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Another meeting held in Washington, DC, at about the same time had a decidedly different focus. The Alfred P. Sloan Foundation, which actively supports the creation of professional master's-degree programs in the sciences on campuses across the U.S., held a meeting to assess progress and to give program participants the chance to exchange ideas. With support from Sloan, SIAM has been gathering data on the programs that touch our discipline.

The goal of the Sloan project is to provide students with technical training for nonacademic employment. The focus has been on interdisciplinary programs, like computational biology and the mathematics of finance.

SIAM members were well represented both in the audience and at the speaker's podium. The program in industrial mathematics at Michigan State University, run by Chuck McCluer, is among the earliest of the Sloan-funded programs. It combines training in mathematics with instruction (over a series of weekends) leading to a "mini-MBA"; the idea, McCluer explained, is to give graduates technical expertise, along with sufficient background in business that they are able to communicate with nontechnical people in their companies.

Bogdan Vernescu of Worcester Polytechnic Institute also described a program in industrial mathematics, as well as a second WPI program, in financial mathematics. José Castillo, who initiated a Sloan-funded program in computational science at San Diego State University, also attended the meeting.

Many of the programs are relatively new, and the jury is still out out as to how well they will meet the goals; clearly, though, many are off to an energetic start.

Discussions of professional master's programs were also on the program of the recent conference "Mathematics for Industry: Challenges and Frontiers," organized by the SIAM Great Lakes Section, under the leadership of David Field and a very hard-working committee. Held October 13–15 in Toronto, the conference emphasized industrial problems and methods for solving them. Lee Seitelman organized a panel on professional master's-degree programs; descriptions of sample programs, including those at WPI and Michigan State, elicited enthusiastic comments from industrial participants.

One of the most striking presentations was that of Rebekah Stephenson, soon to graduate from the Michigan State program. The best testimonial to the effectiveness of her talk about her experiences was the business card offered by a participant from industry, accompanied by the message "let's talk."

Clearly, a challenge for the organizers of a meeting that focuses on industry, rather than on a particular subdomain of applied mathematics, is to choose topics that will bring together a diverse set of people. The Toronto conference seemed to succeed in that task, with a carefully selected set of themes.

Like the homeland security workshop, the Toronto conference emphasized uncertainty. Whereas homeland security needs error bounds on simulations and tools for decision-making under uncertainty, however, speakers in Toronto discussed the reduction of error in industrial processes and the optimal design of robust processes. As computational simulation takes on a bigger role in the design of industrial processes, capturing the uncertainty in models becomes important to the eventual aim of optimal design and control under uncertainty. As speakers at both meetings made clear, research is urgently needed in this area, which brings together statisticians, applied mathematicians, and computational scientists.

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Attending meetings in Washington, I am always impressed by the visibility and energy of the SIAM community. An often-heard complaint used to be that our discipline did not participate in activities at the national or international level, that we failed to show leadership in science. That is not the case today.

Members of the SIAM community have taken leadership roles in many settings, ranging from homeland security to new educational programs. One prominent example is long-time SIAM member Charles Holland, formerly of AFOSR and now Deputy Undersecretary of Defense for Science and Technology. Another is Alan Laub, director of the Department of Energy's SciDAC program; Laub recently chaired HECRTF (an interagency task force on high-end computing) whose soon-to-be-released report promises to be very influential.

Other SIAM members can be found in administrative positions in academia, as deans (Richard Ewing at Texas A&M and Tony Chan at UCLA being but two examples) and provost (David McLaughlin at New York University).

Our community is generally well represented at funding agencies, whose leaders nevertheless point out that filling critically important positions is an ongoing challenge. We rely on strong representatives (both scientifically and administratively) from the community to ensure that programs get the attention and direction they need to push the science. Without strong, effective people in leadership positions, programs will fail to grow and in extreme cases wither and disappear.

Readers are encouraged to consider spending time at one of the funding agencies. Each is quite different in the way it operates—DARPA, say, is very different from NSF. Yet we can all agree that each is vitally important to advancing our discipline. Each offers members of the community its own set of interesting opportunities to have a say in the way their scientific areas evolve.

Many of the agencies, including NSF, are now actively and even urgently seeking people. Interested readers are encouraged to discuss possible opportunities with agency officials. Most agencies offer positions for two- or three-year rotators on leave from their home institutions.