Center for Computational Engineering

The critical role that computation plays across all engineering disciplines, as well as the industry-based demand for engineers who are literate in computational sciences, has created a clear need for research and educational programs to produce tomorrow's computational engineering leaders. In response to this need, in December 2004 the MIT faculty approved the creation of the integrated multidisciplinary Computation for Design and Optimization (CDO) SM program. In fall 2008, the Center for Computational Engineering (CCE) was formed in the School of Engineering to support computational engineering research and education at MIT. Sixty faculty and researchers from across the School of Engineering are currently affiliated with CCE.

Research

Computational engineering plays an increasingly important role in economic competitiveness, national security, environmental stewardship, and public safety. The emphasis of CCE research activities is on the development of new computational methods and on the innovative application of computational techniques to important problems in engineering and science. Our computational engineering focus is on building computational tools for engineering problems and on the development of new computational tools that are more efficient, more robust, or more capable, as well as the informed application of existing computational tools—in concert with modeling, experimental, and analytical approaches—to address particular engineering problems and questions.

Our research projects are focused on several major methodology themes and several major applications themes. The methodology themes are high-performance computation and computational foundations; multiscale, multiphysics, multifidelity simulations; computational design, optimization, and control; integration of data and simulation; and computational geometry and scientific visualization. The applications themes are materials and manufacturing, nano/micro systems, biological and biomedical processes/systems, infrastructure systems and services, energy, environment, and transportation.

Education

CCE's main educational presence is the CDO master's degree program. CDO became affiliated with CCE during AY2010, with Anthony Patera and Karen Willcox serving as codirectors. At the beginning of AY2011, with the dean of engineering's approval, the codirectors appointed Nicolas Hadjiconstantinou as CDO director.

During AY2011, total enrollment in CDO was 16 students, six of whom were first-year students. Seventeen CDO students were on the September degree list, having completed their studies the previous summer. Three CDO students graduated in February and three graduated in June. Two additional students are expected to receive their degrees in September 2011. To date, we have 104 alumni of the CDO program.

CDO conducted its seventh admissions cycle this past winter and spring. Serving on the admissions committee this year were Luca Daniel (chair), Nicolas Hadjiconstantinou, Ruben Juanes, and Youssef Marzouk. Applications increased by 40% over the previous year, with 71 students applying. Sixteen applicants were offered admission, and nine students accepted and will join CDO in fall 2011. The program will also have nine second-year students, including three dual-degree students enrolled in MIT departmental PhD programs, for a total of 18 CDO students.

Due to the decrease in student enrollment following the end of Singapore-MIT Alliance (SMA) fellowship funding, the CDO academic administrator position supporting the program will be decreased to a half-time position effective July 1, 2011. After six years with the program, Laura Koller is departing as the CDO administrator at the end of June.

Accomplishments

The Kambourides Fellowship in Computational Engineering was established in fall 2008 through a generous donation by Miltos Kambourides, SB '96, SM '97, and his family. The Kambourides family's continued support in AY2011 gave us the opportunity to award a third fellowship. On the selection committee this year were Nicolas Hadjiconstantinou (serving as chair), Michael Demkowicz, and Anthony Patera. Yi-Chieh (Jessica) Wu, a PhD student in the Department of Electrical Engineering and Computer Science, was chosen as the 2011 Kambourides Fellow in Computational Engineering.

MIT's dean of engineering announced the establishment of the SMA Fellowship in Computational Engineering in the spring of 2010 and allocated three nine-month fellowships to CCE to be used over three years. In spring 2011, Karen Willcox (chair), Laurent Demanet, and Alexander Mitsos served on the selection committee. Masayuki Yano, a PhD student in the Department of Aeronautics and Astronautics, was selected as the second recipient of the SMA Graduate Fellowship in Computational Engineering.

The Politecnico di Milano (Polimi)/MIT Workshop on Reduction Strategies for the Simulation of Complex Problems was held January 19–21, at Polimi in Milano, Italy. The workshop, a collaborative effort between the MOX laboratory at Polimi (professor Alfio Quarteroni, director) and CCE, was sponsored in part by a Progetto Rocca travel grant. CCE faculty and postdoctoral participants were Luca Daniel, Tarek El Moselhy, Phuong Huynh, Ruben Juanes, David Knezevic, Youssef Marzouk, Anthony Patera, Qiqi Wang, and Karen Willcox.

On March 10, the first CCE/CDO Student Symposium in Computational Science and Engineering was held with approximately 40 people in attendance. The symposium featured student research demonstrating the development of computational methods and diverse applications of computational tools in engineering, science, and social sciences, ranging from supply chain management and economics to aeronautical engineering and fluid dynamics. Student talks were given by Rory Clune on exploration and human-guided optimization in structural design, Chad Lieberman on a control-theoretic approach to inference for prediction, and Joel Saa-Seoane on simulation of

linear wave phenomena in metamaterials using a hybridizable discontinuous Galerkin method. Several student posters were also presented. The keynote speaker was Jack Little, president and cofounder of MathWorks.

In 2009, a group of CCE faculty proposed a possible concentration in computational engineering for the new flexible engineering degree. In fall 2010, the Department of Aeronautics and Astronautics approved within the new Course 16-ENG SB degree a computational engineering track based on this proposal. CCE will continue efforts to promote this track as a way to increase participation in computational engineering at the undergraduate level.

Future Plans

CCE will examine computational engineering education more broadly and chart a course for a CCE educational presence, including considering opportunities afforded by the SB in Engineering for computational curriculum coordination and development at the undergraduate level and PhD options at the graduate level.

New initiatives planned for AY2012 are a new student seminar series (with student organizers and student speakers) and computational engineering student prizes and an associated yearly awards ceremony.

Faculty Highlights

Faculty affiliates of CCE have been recognized for the following achievements.

Alan Edelman was named a 2011 SIAM fellow by the Society for Industrial and Applied Mathematics.

David Darmofal was promoted to full professor. He also received the Earll M. Murman Award for Excellence in Undergraduate Advising.

Luca Daniel was promoted to associate professor with tenure.

Olivier De Weck, along with coauthors Eun Suk Suh, Michael Furst, and Kenneth Mihalyov, received the International Council on *Systems Engineering* 2010 Best Paper of the Year Award for "Technology Infusion for Complex Systems: A Framework and Case Study" (Systems Engineering, Vol. 13, No. 2, pages 186–203).

Laurent Demanet received an Alfred P. Sloan Research Fellowship.

Ruben Juanes was promoted to associate professor without tenure.

Jaime Peraire was named the new head of the Department of Aeronautics and Astronautics.

Karen Willcox was named the associate head of the Department of Aeronautics and Astronautics.

Bilge Yildiz received a National Science Foundation Faculty Early Career Development (CAREER) award.

Anthony T. Patera, Codirector
Ford Professor of Engineering
Professor of Mechanical Engineering

Karen Willcox, Codirector
Associate Department Head, Aeronautics and Astronautics
Associate Professor of Aeronautics and Astronautics