

Center for Computational Engineering

The critical role that computation plays across all engineering disciplines, along with the industry-based demand for engineers who are literate in computational sciences, has created a clear need for research and educational programs that will produce tomorrow's computational engineering leaders. In response to this need, in December 2004, the MIT Faculty approved the creation of an integrated multidisciplinary master of science program in Computation for Design and Optimization. In fall 2008, the Center for Computational Engineering (CCE) was formed in the School of Engineering to support computational engineering research and education. 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 and application themes. The methodology themes are high performance computation and computational foundations; multiscale, multiphysics, and 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

The main educational presence of CCE is the CDO master's degree program. CDO became affiliated with CCE during academic year 2010, with Anthony Patera and Karen Willcox serving as codirectors.

In AY2010, total enrollment in CDO was 31 students, 23 of whom were first-year students. Of these, 15 were dual-degree fellowship recipients in the Singapore-MIT Alliance (SMA), expecting to earn one degree in CDO from MIT and one in computational engineering from the National University of Singapore. Eight students were second- or third-year students. Sixteen CDO students graduated in September 2009, three in February 2010, and three in June 2010, resulting in a total of 82 students who have completed the CDO program since its inception. Seventeen students are due to receive their degrees in September 2010.

CDO conducted its sixth admissions cycle this past winter and spring. Serving on the admissions committee were Luca Daniel (chair), David Simchi-Levi, Qiqi Wang, and Jacob White. Of the 51 applications received, 12 applicants were offered admission. Seven students accepted the offer and will join CDO in fall 2010. The program will also have eight second-year students and two dual-degree students enrolled in MIT departmental PhD programs, for a total of 17 CDO students in fall 2010. Academic year 2010 was the fifth and final year in which fellowships were offered to CDO students through the Singapore-MIT Alliance. Predictably, this change resulted in a smaller number of applications for fall 2010 admission than in previous years.

Accomplishments

The Kambourides Fellowship in Computational Engineering was established in fall 2008 through a generous donation from Miltos Kambourides, SB '96, SM '97, and his family. Due to the Kambourides family's continued support, we had the opportunity to award a second fellowship in AY2010. The selection committee included Anthony Patera (chair), Sidney Yip, and Krystyn Van Vliet. Chad Lieberman, a PhD student in the Department of Aeronautics and Astronautics, was chosen as this year's recipient.

Through the generous support of MIT's dean of engineering, the Singapore-MIT Alliance Fellowship in Computational Engineering was announced this year. The School of Engineering allocated two nine-month fellowships to CCE to be used over the next two years. The selection committee was composed of Karen Willcox (chair), Dennis McLaughlin, and Alexander Mitsos. The first SMA Graduate Fellowship in Computational Engineering was awarded to Rory Clune, a PhD student in the Department of Civil and Environmental Engineering.

In November 2009, CCE received \$30,000 from the Progetto Roberto Rocca to support travel to the workshop, "Reduction Strategies for the Simulation of Complex Problems," to be held in January 2011 at the Politecnico di Milano in Italy. The workshop is a collaborative effort between the Laboratory for Modeling and Scientific Computing MOX at the Politecnico (professor Alfio Quarteroni, director) and CCE at MIT. CCE faculty participants will include Luca Daniel, Ruben Juanes, Youssef Marzouk, Anthony Patera, Qiqi Wang, and Karen Willcox.

The Center for Computational Engineering initiated activities in undergraduate education through a new flexible bachelor of science in engineering degree with theme-based concentrations. An ad hoc committee composed of David Darmofal, Alan Edelman, Steven Johnson, Youssef Marzouk, Alexander Mitsos, Krystyn Van Vliet, Qiqi Wang, Jacob White, and Karen Willcox (chair) prepared a draft curriculum for a computational engineering concentration and submitted their report to the School of Engineering. The Department of Aeronautics and Astronautics received approval to begin offering this flexible new degree (Course 16-ENG) in fall 2010. Students in Course 16-ENG may choose to concentrate in computational engineering. Our efforts to define a computational engineering concentration have provided the inspiration for further curriculum development and coordination in this area at the undergraduate level.

Future Plans

The center will examine computational engineering education more broadly and chart a course for a CCE educational presence at both the undergraduate and graduate levels, including PhD options. As a result of the report on a computational engineering concentration, CCE received funds from the School of Engineering Education Committee for preliminary development of an undergraduate computational engineering curriculum. David Darmofal is leading a group of faculty members from departments across the School in this effort.

CCE plans to launch a computational engineering fellowship campaign this fall. Our goal is to augment our two PhD fellowships in computational engineering.

Faculty Highlights

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

Markus Buehler received a Presidential Early Career Award for Scientists and Engineers for his Office of Naval Research proposal “Merger of structure and material: Comparative bottom-up analysis of hierarchical protein materials.” He also received the Harold E. Edgerton Faculty Achievement Award.

Jeffrey Grossman received a 2010 Alfred P. Sloan Foundation Research Fellowship.

Jongyoon Han received the 2009 Analytical Chemistry Young Innovator Award.

Ruben Juanes received a Department of Energy Early Career Award for his proposal “Nonequilibrium Physics and Phase-Field Modeling of Multiphase Flow in Porous Media.”

Youssef Marzouk received a Department of Energy Early Career Award for his proposal “Predictive Modeling of Complex Physical Systems: New Tools for Uncertainty Quantification, Statistical Inference, and Experimental Design.”

Anthony Patera was selected as the 2010 Hans Kupczyk Guest Professorship at the Universität Ulm in Germany.

Bruce Tidor was named an American Association for the Advancement of Science Fellow for “Use of Computational Modeling to Make Seminal Contributions to Understanding the Structure and Function of Proteins and in Designing Molecules.”

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

Karen Willcox, Codirector
Associate Professor of Aeronautics and Astronautics

More information about the Center for Computational Engineering can be found at <http://computationalengineering.mit.edu/>.