Graduate Studies in Computational Science at U-M

Graduate Certificate in Computational Discovery and Engineering and PhD Program in Computational Science

Eric Michielssen and Ken Powell
Computational Science and Engineering: What is it?

The development and innovative use of mathematical/computational algorithms/models for research, science and engineering, data analysis and interpretation, product development, and forecasting.

Computational Science is now widely accepted as the third pillar of science, complementing theory and experimentation.

U-M offers several opportunities for specialization in this booming field, and engaging with other researchers in computational science.
Computational Discovery and Engineering: Why?

**Education**: Training towards developing and deploying advanced mathematical algorithms on High Performance Computing (HPC) resources to accelerate discovery and solve pressing scientific and engineering problems.

**Research and intellectual community**: Introduction to the depth and wealth of CDE research at UM; become part of UM computational community.

**Competitive Advantage**: Prepare yourself for career in computational science (industry, government, education).
Electronic and Communication Engineering

- Modeling: necessary for continuing miniaturization and integration
- Simulation: multiscale, spanning several physical domains, needed for converting designs to manufacturable systems
Aerospace Engineering

- Computation: Gas dynamics, structures, controls
- Computational Fluid Dynamics
- Experiments can be expensive and difficult
Climate and Space Physics

- Interdisciplinary
  - Geophysical fluid dynamics
  - Applied math
  - Scientific computing
  - Large datasets
- Large range of temporal and spatial scales
Material Science/Physics

- Continuum-level simulations
- Atomistic and molecular dynamics
- Quantum-mechanical calculations
- Time scales: femtoseconds to years
- Mechanical, chemical, thermal, and electrical behavior of materials
- Find mechanisms behind observations
- Predictive calculations to help design new materials
Biomedical Engineering

- Image processing
- Visualization
- Fluid mechanics
- Fluid-structure interactions
- Protein engineering and drug design
- Biomaterials modeling
Structural Engineering

- Experimental research is expensive, dangerous, and often not feasible
- Computational structural simulation is indispensable
- Allows new insights into resistance mechanisms
• Multiphysics and multiscale simulations
• Reactor design
• Continuing investment by Dept. of Energy
Astronomy and Astrophysics

- Computational cosmology: models the formation and evolution of large-scale cosmic structure
- Matching the large, complex, and time-varying datasets generated by earth and space-based astronomical observatories, to challenges in computer science and statistics
Information Science and Data Mining

- Explosive growth in storage, sensors, and online activity
- Produces data that can be used in many scientific applications.
Physics

- Computational physics: material self assembly, superconductivity, condensed matter physics, dark matter physics,…
Math

- Numerical PDE solvers, nonlinear dynamics, mathematical optics, computational fluid dynamics
Parallel Computing

- Large, complex computing systems running for long periods
- Real-time solutions
- Distributed computation combined with sensing to reduce datasets to manageable sizes
- On campus resource: Flux infrastructure
Others

• Computational chemistry, biology
• Computational statistics, operations research, complex systems
• Computational business (analytics), finance, econometrics
• Computational social sciences (automated information extraction systems, social network analysis, social geographic information systems (GIS), complexity modeling, and social simulation models)
• …
Industrial and Operations Engineering

- Theoretical and applied
- Complex systems modeling
- Event simulation
- Stochastic and non-linear optimization

Many fields:
- Health care
- Energy
- Telecom
- Transportation
- Manufacturing
Competitive Advantage: High Demand for CDE Experts (1)

BLS: Computer and Mathematical Occupations will add 788,000 jobs by 2020, making it the 6th-fastest growing major occupational group.
McKinsey & Co. Report: “By 2018, the U.S. faces a shortage of 140,000 to 190,000 people with analytical expertise and 1.5 million managers and analysts with the skills to understand and make decisions based on the analysis of big data.”
Computer science will experience a dramatic shortfall of degrees — 40,000 gap between openings and degrees earned (BLS, NCES, NCWIT)
Two Educational Programs (micde.umich.edu)

• **Certificate program:**
  • Open to all M.S. and Ph.D. students
  • Lightweight – recognition of exposure to / knowledge of field of computational science
  • Top-off fellowships available

• **PhD program:**
  • Offers opportunity for much deeper specialization in computational science
  • Ph.D. in X and Scientific Computing
CDE Certificate: Academic Requirements

- Nine graduate credit-hours in approved courses (methodology and application)
  - All courses w/ substantial computational content are allowed
  - One course can be double counted w/ other degree
- CDE-related non-credit experience
  - e.g., internship, research, another course
  - Can be double counted w/ other degree
- Attendance at MICDE Graduate Research Symposium and MICDE Distinguished Lecture Series
- All info on MICDE website
CDE Certificate: Contacts

- **Iain Boyd** | Aerospace Engineering
- **Mike Cafarella, Quentin Stout, Tom Wenisch** | EECS, CSE
- **Andy Caird** | CAEN HPC
- **Amy Cohn** | IOE
- **Tom Downar & Bill Martin** | Nuclear Engineering
- **Sharon Glotzer** | Chemical Engineering
- **Christiane Jablonowski** | AOSS
- **Vikram Gavini & Krishna Garikipati** | Mechanical Engineering
- **Manos Kioupakis** | Materials Science and Engineering
- **Eric Michielssen** | EECS, Electrical and Computer Engineering
- **David Sept** | Biomedical Engineering
- **Tom Finholt** | SI
Ph.D. Program in Scientific Computing: Academic Requirements

- Must be pursuing a PhD in a home department at U-M
- Thesis topic and committee composition must reflect an emphasis on scientific computing
- Must take three courses (9 credits) in numerical methods and three courses (9 credits) in computer science and computing applications outside home department
- One of the prelim questions must be related to scientific computing
- Meeting the requirements appends “and Scientific Computing” to their diploma (e.g. PhD in Aerospace Engineering and Scientific Computing)
Ph.D. Program in Scientific Computing: Contacts

- Talk with your advisor about your interest in the program
- Email Prof. Powell (powell) and Ms. Bonnie Bryant (blbryant) to set up an appointment
- Work with them to set up your plan of study to meet the program requirements
What are my choices as a Master’s student?
Only the Certificate is available

What if the courses I’d like to count towards the certificate or degree are not listed on your website?
Contact us, we likely can accommodate you

As a PhD student, can I do both the Certificate and the Joint degree?
No

How do I choose which to do?
The commitment for the Joint degree is greater: you need to do a prelim question on scientific computing, there are more courses required, and you need to take computer science. Choose which fits for you.
### MICDE, ARC and Flux

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<th>MICDE:</th>
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<tr>
<td>• College of Engineering</td>
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<td>• School of Information</td>
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<td>• Advanced Research Computing at U-M (ARC)</td>
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<td>• U-M Office of Research</td>
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<td>• Provider of the Flux HPC Cluster</td>
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<td>• Shared service</td>
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<td>• Allocation model</td>
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Questions?

Eric Michielssen | emichiel@umich.edu
Professor, EECS
Associate Vice President for Advanced Research Computing
Director, Michigan Institute for Computational Discovery and Engineering

Ken Powell | powell@umich.edu
Arthur F. Thurnau Professor, Aerospace Engineering
Director for Research Computing Infrastructure, Advanced Research Computing

micde.umich.edu