Successes and Challenges of Industrial Mathematics

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Overview

- What is Industrial Mathematics?
- Mathematics Careers
- Academic Collaboration (examples)
- Challenges
- Promoting Academic Collaboration
What is Industrial Mathematics?

• **Definition One:** Industrial mathematics is any mathematics not done in academia

• **Definition Two:** Industrial mathematics is mathematics a company pays directly for

Notes:

• “Industry” here includes financial institutions, non-profit organizations, and government departments and labs

• Considering work that has a direct, short term impact on the industry

• Industrial mathematics includes both pure and applied mathematics

• Industrial mathematics research may not be new mathematics
Who does Industrial Mathematics?

- BSc/BA, MSc/MA, and PhD graduates that have careers in Industry that use their mathematical skills. Could come from departments other than Mathematics. (brief description below)
- Academic mathematicians (professors and students) that have projects in collaboration with Industry. (rest of the talk)
Careers in Mathematics

“What can I do with a math degree?”

Qualify for a broad range of careers in business, industry, government, and teaching.

explore the early career profiles of recent bachelor-level graduates with degrees in the mathematical sciences.

www.ams.org/early-careers/

American Mathematical Society
Examples of Careers in Mathematics


- Business Analytics (data mining and operations research)
- Mathematical Finance (algorithmic trading)
- Systems Biology (pharmaceuticals)
- Oil Discovery and Transaction (inverse problems)
- Manufacturing (design optimization)
- Communications and Transportation (cloud computing)
Preparing for an Industrial Career

You have the mathematics background covered, that might be all you need… but the following may also help

- Learn a “real” programming language (C++, java, ...) and software engineering skills
- Develop communication skills
- Learn modelling for a particular application (take courses in another subject of interest). If you are not in a Mathematics department this might be straight-forward, but...
- For some jobs, a graduate education is required
Why Mathematics? (example)

Most of the design work for aircraft now is done with computational tools:

- The physics of airflow are described (approximately) by mathematical equations (modelling)
- The solutions to the equations are approximated using numerical methods (scientific computation)
- Mathematical models must have parameters measured experimentally and must be validated
- The resulting computational tools can be used to quickly and cheaply test many new airplane designs and optimize performance, cost, and safety
- Collaborative work with other scientists and engineers

Insight into problems with Mathematics is quick, safe and cheap (that is, inexpensive)
Representative Quotes from Engineering Literature

The scale up from the laboratory could proceed more efficiently if a predictive mathematical model was available to guide quantitatively the work and aid in the correlation and extrapolation of experimental data.

The mathematical modelling of physical and chemical systems is used extensively throughout science, engineering, and applied mathematics. A wide spectrum of models is expressed as partial differential equations, one of the most widely used forms of mathematics in science and engineering.
Academic Collaboration (Mathematics Department Focus)

Example: My own collaboration with Ballard Power Systems 1998-2010

- MMSC group formed under MITACS
- Financially supported by Ballard and MITACS
- Academic collaboration with professors Keith Promislow, John Stockie, Ned Djilali, Huaxiong Huang, Brian Seymour, Anthony Peirce, Ray Spiteri
- From Ballard: John Kenna, Jean St Pierre, Juergen Stumper, Herwig Haas, Gwang-Soo Kim
- Students and PDFs: Radu Bradean, Arian Novruzzi, Peter Berg, Atife Caglar, Paul Chang, Roger Donaldson, Leslie Fairbairne, Lloyd Bridge, Michael Lindstrom, Jason Boisvert
- Developed and validated computational simulation tools for Hydrogen Fuel Cells
- Multi-scale modelling of stack level fuel cell performance, based on experimentally-fit component models
Some of the MMSC group
Hydrogen Fuel Cells

More information about fuel cell modelling:

Example: André Fortin (Laval) and GIREF

- Worked with several companies (Electricité de France, Michelin, ...)
- Basis for collaboration is a scientific computing framework, MEF++
- Larger academic group, students and PDFs, but also with research personnel
- Ongoing and new projects fund a pool of students
- Existing students work on projects when they finish their coursework
- Personal contacts led to many of the projects
Example: Ian Frigaard

- Industrial PhD with Alcan
- PDF in Austria led to industry job with Schlumberger
- Left Schlumberger on good terms, came to UBC as a faculty member
- Ongoing NSERC CRD (Collaborative Research and Development) projects with Schlumberger
- Complex fluids with petroleum industry applications
- Larger, ongoing group of students and PDFs working on analysis, computation and experiments
Example: Roger Donaldson

- Engineering Physics, Math MSc at UBC, Math PhD at Caltech
- Internships at Google and McMillan-McGee during PhD
- Introduced to Google employees by *personal contact*
- McMillan-McGee contact at an IPSW, directed PhD work
- Started consulting firm: Midvale Applied Mathematics, Inc.
- Several projects, including Deviant Art (data mining)
ET-DSP™ electrodes can be configured around any plume shape. ET-DSP™ can and has been used safely and effectively in populated areas. In fact, Mc2 has installed and operated an ET-DSP™ system beneath an occupied apartment complex in a residential neighborhood and below a major US Highway as can be seen in Figure 7.
Challenges to Academic Collaboration

Academic collaboration with Industry is worthwhile:

- fun, interesting and relevant work (motivational)
- funding opportunities: industrial and government matching
- Good press for the discipline (promotes awareness by the community, students and industry). This is especially important for Mathematics.
- employment opportunities for graduate students
- makes what we teach more relevant

Challenges:

- Finding collaborations and getting funding
- Is the activity valued by your (Mathematics) department? (industrial math research may not be mathematics research)
Finding and keeping collaborations

- Do not underestimate the value of personal contacts
- You need a contact in the company to
  - advocate for the joint project
  - spend time telling you what the interesting questions are
- Contact could come from
  - a personal contact
  - attending an IPSW
  - a MITACS or university development officer
  - cold calling companies
- Know your university’s policies on overhead, intellectual property and contract work
- Be open to work outside your narrow research area
- Give early, useable results if possible, even if not complete solutions
- Have regular meetings with the company
Offering to work for free may not lead to good results

- By getting money from a company, you guarantee some of their attention
- Contract work, NSERC Engage grants, IRAP funding, or MITACS internships may be a good way to start a collaboration
- Taking into account matching money and tax benefits, academic collaboration is very cost effective
- To pursue some collaborations, you may need to build up and maintain a larger group
Supporting Industrial Mathematics

- Track the careers of graduates (they may become more in demand as high tech Industrial problems become more technical)
- Publicize successes
- Encourage and reward (but not demand) industrial collaboration of faculty members in your department
- Where there is a critical mass of faculty interested in the activity, consider
  - inviting industry speakers to your department
  - hiring an industrial outreach coordinator to visit local Industry
1. Showed (reminded) you of the value of an education with mathematics component to Industry
2. Gave some examples of academic collaboration on industrial projects (Mathematics Department Focus)
3. Discussed the benefits and challenges to such collaboration