Fields Centre FOR Quantitative Analysis AND Modelling

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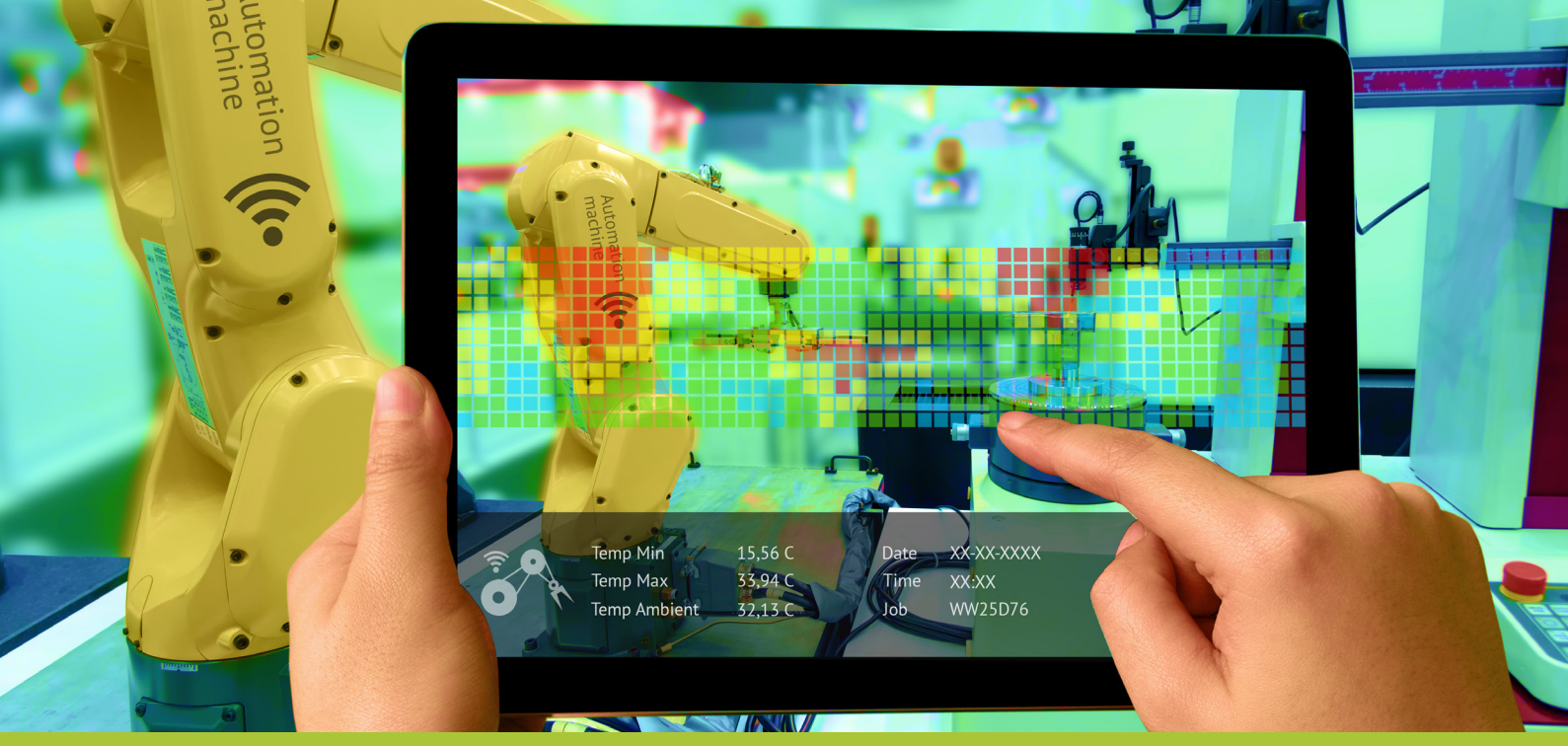

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From the Director

Fundamental research in the mathematical sciences is inextricably linked to the development of the new technologies and products that have made Ontario a nascent technological superpower. Collaborations between industry and academic researchers have assisted in accelerating the discovery process, moving innovation from research to commercialization at a speed that allows companies to remain competitive in an increasingly cluttered global marketplace. However as Ontario's industrial sector continues to grow, there is also a corresponding need for a large pool of talent capable of deploying the cutting-edge techniques and methodologies required to create the technologies of tomorrow.

Fields-CQAM was created in response to this need. The existing gap in skills acquired by graduates in STEM fields, and the industrial skill requirements for highly technical job postings, has an estimated cost of $24.3 billion Canadian per year to the Ontario economy in foregone GDP. We aim to narrow this gap by empowering students and industry practicitioners with advanced quantitative skills through participation in research, experiential learning internships, graduate courses, and workshops. Ensuring that undergraduates, graduates and current industry practitioners meet the skills needs of firms in areas of strategic importance to the province will facilitate their success in positions across the public, private and educational sectors, boosting the technological and economic development of Ontario.

However we seek to not only to meet the current needs of the province, but also look to the future. Today's research informs tomorrow's innovation, and Fields-CQAM is laying the groundwork for future applications of our research, by not only developing the techniques and methodologies to drive forward technological innovation, but also by training the quantitative scientists to apply them.

By meeting Ontario's immediate and long-term skills gap, Fields-CQAM will assist the province in becoming an internationally leading knowledge economy.

Huaxiong Huang
Director, Fields-CQAM

What We Do

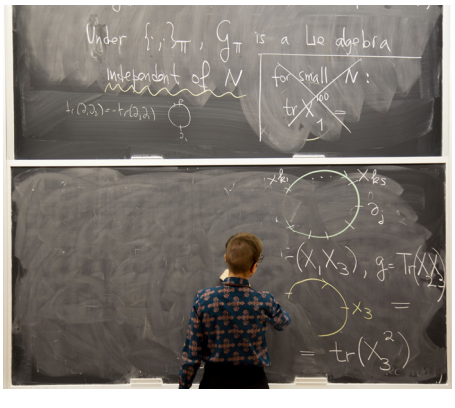
The Fields Centre for Quantitative Analysis and Modelling (Fields-CQAM) was created in response to the need for a critical mass of highly-skilled quantitative scientists capable of deploying the cutting-edge techniques and methodologies required to advance discovery in Ontario's booming technological sector. A network of eleven research and training laboratories based across the province, Fields-CQAM bridges the gap between academia and industry.

Leveraging research collaborations with industry partners, Fields-CQAM researchers solve real-world problems in science and technology while training the next generation of innovators. Our strategy encompasses three central tenets: a network of research and training labs, a startup incubator, and program of scientific activities. Each of these cornerstones is designed to maximize the transfer of highly-skilled personnel and intellectual property from our network into the industrial sector, boosting the provinces' economy. From strengthening Ontario's capacity for rapid response to emerging public health issues using mathematical modelling, to placing Fields-CQAM trainees into industrial internships, to providing training courses to practicioners already in the workforce, Fields-CQAM is working to position Ontario as an international leader in the knowledge economy.

11 Research and Training Labs

2 Incubated Startups

18+ Scientific Activities



Healthcare

Computational Metastasis

UNIVERSITY OF WATERLOO

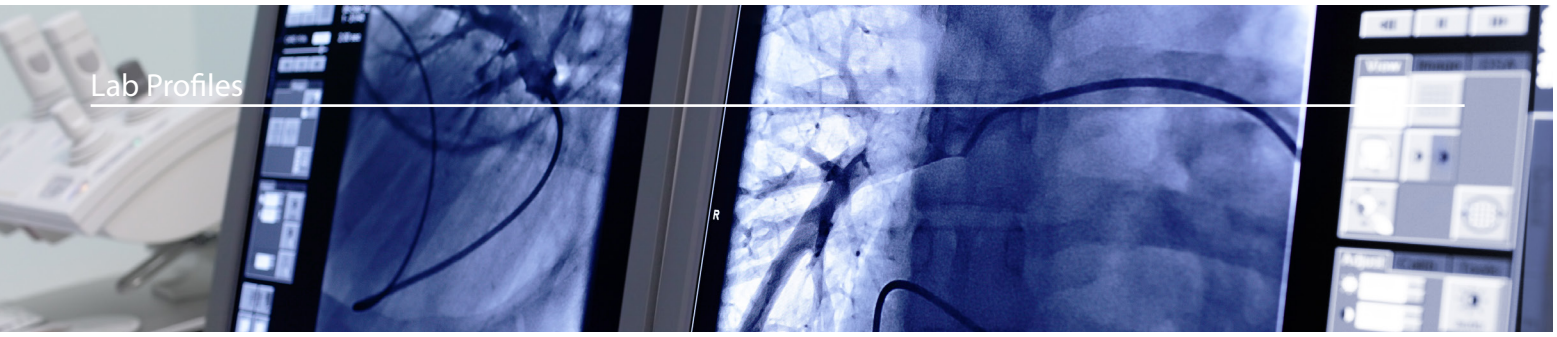
NORTHERNCHEM INC.
www.northerncheminc.com

Metastasis is a complex multi-step process that accounts for nearly 90% of cancer-related deaths. In metastatic patients with no prior diagnosis records, a tool that can predict the primary cancer site based on the current metastatic state is of paramount importance for guiding therapies. However currently there exists no predictive method that can guide clinical decisions and therapies.

We aim to develop a patient-specific imaging-based predictive framework to model the fluid dynamics within the patient's circulatory system and to simulate the separation, transportation and arrest of cancer cells. This framework will be developed to have the following capabilities: (1) to predict most probable secondary-cancer sites to make clinical diagnosis and staging more efficient and precise; (2) to predict the primary cancer site in metastatic patients with no prior records of the primary cancer for targeted treatments.

Lab Director: Nima Maftoon

Team: Zahra Motamed (McMaster), Elazer Edelman (Harvard & MIT), Javier Ganame (McMaster), Jose Hernandez (Hospital Universitario Marques de Valdecilla), and Julio Garcia Flores (Calgary)



Mathematics for Public Health

SANOFI PASTEUR

YORK UNIVERSITY

This lab will develop new, tailored modelling frameworks and standardized procedures to inform public health and vaccine production decisions and to strengthen Ontario's capacity for rapid response to emerging public health issues and vaccine industrial production needs.

Our lab creates an interdisciplinary interface in four targeted areas: acute respiratory infections, vector-borne diseases, food-borne pathogens, and anti-microbial drug resistance. We provide training for health professionals, students, and post-docs in statistical analysis, optimization, coding, and algorithms that are relevant to predicting and preventing disease spread and providing advice to public health agencies and industry collaborators.

Lab Director: Jianhong Wu

Team: David Fisman (U of T), Amy Greer (Guelph), Andrew Morris (Mount Sinai Hospital), Dongmei Chen (Queen's), and Dion Neame (Sanofi-Pasteur)

Health Analytics & Multidisciplinary Modelling

nuralogix

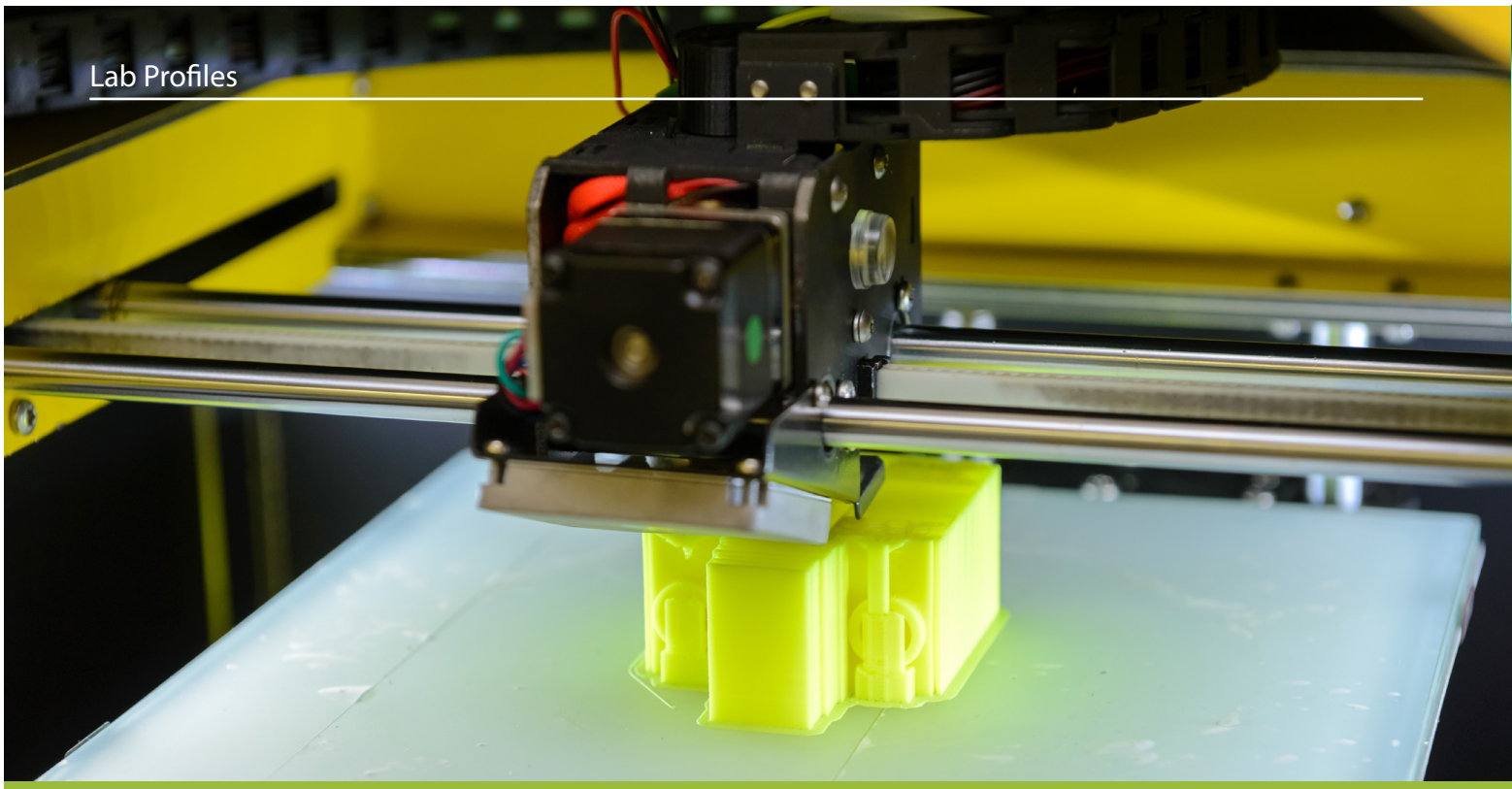
THE FIELDS INSTITUTE

Bioinformatics and big data are revolutionizing healthcare. Mathematical tools are necessary to monitor and predict disease progression using electronic health records (EHRs) or wearable devices (e.g. Fitbit), to improve wait times and scheduling of services (e.g. MRI) and medical procedures, and analyze specific diseases such as diabetes, stroke, and heart failure.

Our lab develops analytical tools and trains highly-skilled personnel in the area of health informatics with a focus on modelling, data analysis, bioinformatics, biostatistics, optimization and experimental design, as well as the medical sciences.

Lab Director: Huaxiong Huang

Team: Arvind Gupta (U of T), Aziz Guegachi (Ryerson), Naveen Vaidya (San Diego State), Michael Chen (York), Xin Gao (York), Kang Lee (U of T), and Marc Thiriet (Paris 6)



Advanced Manufacturing & Robotics

Geometry Processing & Fabrication

UNIVERSITY OF TORONTO

AUTODESK

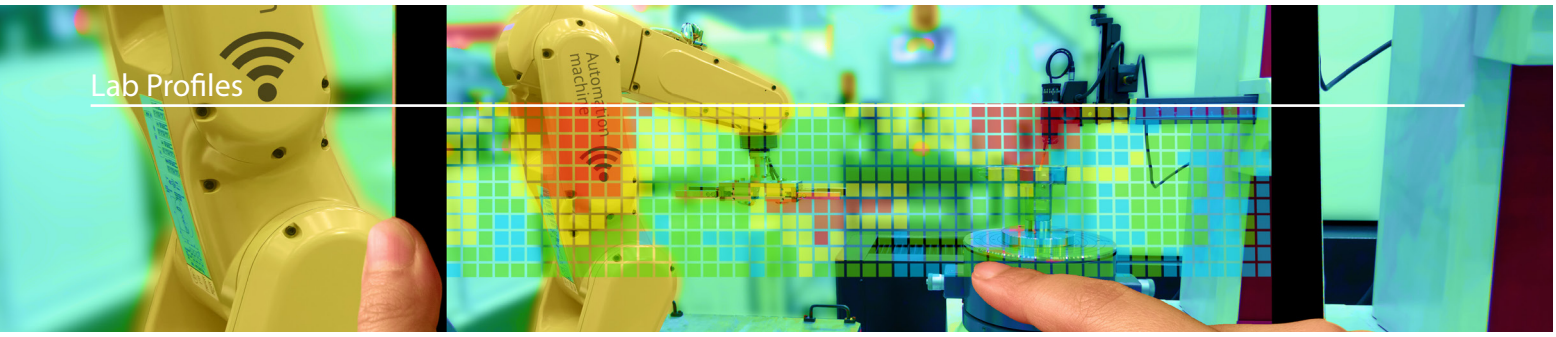
Current geometric design tools are indirect and require esoteric training. Ad hoc pipelines for preparing geometry for fabrication involve many phases and typically many different people or groups. Meanwhile, core geometry processing algorithms are not robust to data imperfections, which are now commonplace.

Our approach is different. We adapt fundamental mathematics to work with messy geometric data. An archetypical example is our past work on generalizing the classic formula for determining the inside from the outside of a curve to messy representations of 3D surface geometry commonly found throughout computer graphics and computer aided design. This work enables downstream processing.

We are pioneering large-scale testing of geometric algorithms. This empirical evidence of robust implementation complements correctness proofs. Robust core subroutines allows us to create complete geometric design systems connecting creation to fabrication in a single pipeline, similar to "what you see is what you get" word processing.

Lab Director: Alec Jacobson

Team: David I.W. Levin (U of T), Eitan Grinspun (Columbia), Leonardo Sacht (Universidade Federal de Santa Catarina, and Maks Ovsjanikov (Ecole Polytechnique)



Human-Machine Symbiosis

UNIVERSITY OF TORONTO

Human-machine symbiosis seeks to achieve a deep integration of human and machine, enabling the design of information technologies that conform perfectly with the human: physically, socially, and psychologically. Our lab develops models of human perception, capabilities, and anomalous-events needs to enable deeper integration, and achieve greater utility in applying information technologies.

Models developed by the lab include the psychophysics of human perception and of social processes to better integrate new technologies for multi-user scenarios. These models are then validated and used to create fundamentally new technologies that enhance human capabilities. Such technologies include gesture sensors, touch sensors, user interface software, and technologies to assist those with accessibility issues in living better lives.

Lab Director: Daniel Wigdor

Team: Tovi Grossman (U of T), Fanny Chevalier (U of T), Mark Chignell (U of T), Karan Singh (U of T), and Ravin Balakrishnan (U of T)

Chemical Process Mathematics

QUEEN'S UNIVERSITY

Chemical process industries use data and mathematical models for key business purposes including: design of manufacturing processes and products, scale-up of inventions, selecting production strategies, and process automation. Models and data are used to bring new products to market and to improve safety, quality, environmental compliance, and profits.

Our lab works with the private sector to develop models for their specific processes and business needs, including optimizing operating conditions, developing control schemes that make effective use of data, and developing methodologies for planning experiments to assess uncertainties associated with model predictions and business decisions. Students trained in the lab develop skills in modelling, optimization, statistics, and control that are needed in industry, and will have an understanding of challenges faced by companies as they implement more sustainable green-chemistry and bio-based technologies.

Lab Director: Kim McAuley

Team: Hector Budman (Waterloo), Martin Guay (Queens), Luis Sandoval (Waterloo), Thomas Adams (McMaster), Chris Swartz (McMaster), Serdar Yuksel (Queen's), Nick Hudon (Queen's), Devon Lin (Queen's), Xiang Li (Queen's), Jim McLellan (Queen's), Bahman Gharesifard (Queen's), and Simant Upretti (Ryerson)

Data Prediction & Risk

Computational Methods in Industrial Math

RYERSON UNIVERSITY

Current economic development is based on a continuous increase in the efficiency of business processes and industrial organization. This increase is obtained through better collection of business process data, data analytics tools and advanced simulation and optimization techniques. Including available data within optimization of processes requires constructing complex mathematical models. In particular, many real world scenarios exhibit high combinatorial complexity, need to include several sophisticated constraints imposed by the business environment, and consider uncertainty. Including all key features characterizing industrial processes and their business environment leads to complex mathematical models.

The complexity of the problems leads to a need for large, sophisticated computational systems, consisting of hundreds or thousands of computational units. Our lab tries to narrow the gap between huge demand from industrial side and the lack of tools on the academic side. Our goal is to focus on developing new mathematical methods and tools (new theorems, algorithms, and computer implementations of them, for non-standard industrial applications).

Lab Director: Pawel Pralat

Team: Ayse Benner (Ryerson), Konstantinos Georgiou (Ryerson), Bogumil Kaminski (SGH Warsaw School of Economics), Andrei Raigorodskii (Moscow Institute of Physics and Technology, and Przemyslaw Szufel (SGH Warsaw School of Economics)

Modelling & Prediction of Anomalous Events

CARLETON UNIVERSITY

Prediction of anomalous or rare events, such as the automated identification of fraudulent financial transactions, the prediction of novel microRNA molecules within the human genome, or the correct diagnosis of rare cancerous biopsies, is both important and challenging. This lab focuses on the development and evaluation of statistical models and machine learning systems for mixed mode data, and on making predictions in the presence of class imbalance. Graduate training is critically needed in this area since many events of interest in the real world tend to be rare.

Our lab offers training to address the unique challenges associated with applying statistical machine learning for the prediction of rare events. The inherently low prevalence of rare events must be explicitly addressed during both the training and testing of such systems; otherwise systems either dramatically under- or over-predict rare events. Application areas include biomedical informatics, network security applications, sports analytics, and business informatics.

Lab Director: Shirley Mills & James Green

Team: Steven Wang (York), Sreeraman Rajan (Carleton), Ana-Maria Cretu (Carleton), Claire Austen (Environment & Climate Change Canada), Song Chai (Carleton), and Paul Villeneuve (Carleton)

Inference & Prediction

UNIVERSITY OF WATERLOO

Our laboratory aims to create new model-based and data-driven tools for discovering fundamental structures and detecting anomalies in multivariate time-series. These tools have specific application to two problems: (i) health monitoring, anomaly detection and anomaly characterization in jet engines using quickest change detection (QCD), and (ii) reducing uncertainties in precipitation intensity prediction for winter de-icing programs for commercial airlines.

Lab Director: Sri Namachchivaya

Team: Sue Ann Campbell (Waterloo), Siv Sivaloganathan (Waterloo), Sander Rhebergen (Waterloo), Nicolas Perkowski (Humboldt) , and Peter Imkeller (Humboldt).

Finance

Systemic Risk Analytics

McMASTER UNIVERSITY

Defined as the risk of a threat to the stability or integrity of the financial system, systemic risk affects virtually every business. Banks and large financial institutions have a clear interest in assessing their own systemic risk and those of their counterparts. Equally important, insurance companies and other long-term investors are exposed not only to crashes in asset prices, but also to the more lasting consequences of crises. Other industrial sectors with keen interest in systemic risk are financial technology companies that both drive and are exposed to disruptive innovations.

Our lab builds on the expertise of investigators and their network of collaborators to facilitate the interaction between the industrial sectors described above and researchers in systemic risk. Through industry-led projects, internships, mini-courses, conferences, and industrial problem solving workshops, the lab will equip its industry partners with state of the art theoretical models and analytical techniques, while obtaining practical understanding of the problems of interest.

Lab Director: Matheus Grasselli

Team: Tom Hurd (McMaster), Sebastian Jaimungal (U of T), Alvaro Cartea (Oxford), Alexander Lipton (SilaMoney & MIT), Ian Buckley (Canadian Securities Transition Office), and Dan Rosen (d1g1t)

Financial Data Analytics

UNIVERSITY OF WESTERN ONTARIO

Financial data analytics is a mission critical tool throughout the finance, banking, and insurance communities. Financial institutions require data analytics skills in each part of their business, ranging from risk management, to fraud detection, and even to the marketing of their services. Datasets being used by the banking industry are no longer limited to core financial information but also include social network and social media data.

Understanding how to convert this data into usable insights requires not only the strong financial institution subject matter expertise embodied in the lab but also expertise in data analytics techniques and cutting-edge techniques such as topological data analysis. Through a wide range of activities and programs, this lab will provide in-depth training in financial data analysis, state-of-art techniques for parameter estimation, and model uncertainties jointly with other labs.

Lab Director: Matt Davison, Mark Reesor, and Adam Metzler

Team: Tom Salisbury (York), Marcos Escobar (Western), Rogemar Mamon (Western), Lars Stentoft (Western), Doug Woolford (Western), and Rick Jardine (Western)

Startups

Fields-CQAM is structured to ensure that our discoveries are rapidly exploited for the benefit of Ontario's economy. This rapid transfer of knowledge requires best practices in intellectual property management and a pro-active incubation strategy for innovative startups.

Fields has a long history of fostering some of the best and brightest Canadian startups of the last fifteen years, from Sigma Analysis to R2 Financial Technologies to JUMP Math. Fields-CQAM continues in this tradition, encouraging the founding of startups based on mathematical techniques developed within the Centre. In addition to providing physical infrastructure, Fields-CQAM provides customized logistical support such as education, mentoring, networking, advice, and connections to risk capital.

THE FIELDS-CQAM ADVANTAGE

- Access to world -class talent in the mathematical sciences
- Discounted registration fees for Fields conferences, workshops or software courses.
- Networking opportunities with other large-scale startup incubators
- Mentorship expertise from former incubated startups
- Use of Institute facilities for networking and meetings
- Branding opportunities and administrative support

"Fields was a great place to incubate a company, the right place to build a mathematical product. Incubating at Fields was more than just the administrative support . It was the whole environment."

- Dan Rosen, founder of R2 and d1g1t

Scientific Activities

Fields-CQAM leverages the expertise of our academic researchers to train students and industrial practitioners to meet the skills needs of firms in areas of strategic importance to the province. Our training strategy is multi-dimensional, spanning practitioners, academic disciplines, and industrial sectors. Fields-CQAM scientific activities span from short courses designed for supplementing the knowledge of those already in the workforce to longer programs focused on more advanced methods.

The result of these programs are a cohort of highly qualified personnel with the necessary skills for positions in the public, private, and educational sectors.

> There are some fascinating mathematical problems that come of industry that we will never know about if we do not work with our colleagues in industry. We have fantastically well-trained students in mathematics that need to understand how to apply their skills to practical problems in industry, and this gives them a training wheels environment to learn that.
>
> - Matt Davison, Fields-CQAM Lab Director

Lab-Based Research Training

Labs are the most significant Fields-CQAM training platform, with students acquiring industrial research skills under the supervision of leading researchers.

Fields Undergraduate Summer Research Program

The undergraduate program trains students in teams of 4 - 6 to address industry-inspired challenges posed by Fields CQAM labs.

Graduate Programs

Graduate courses bring together multi-institutional cohorts of students to learn advanced techniques from international experts.

Thematic Programs

Fields-CQAM pool expertise from across it's labs to organize large-scale, skills-based collaborative programs, comprised of graduate courses and workshops.

Industrial Problem Solving Workshops

IPSWs connect industries with faculty, postdocs, and graduate students who have expertise in industrial-case studies.

Industrial Research Internships

Graduate students are placed into partner firms for academic-industry research projects supervised jointly by an academic and industry supervisor.

Hands-On Industry Focused Training

Short-courses for industry practitioners that highlight and disseminate the latest analytical methods and their application in an industrial setting.

Today's research.
Tomorrow's
INNOVATION