Innovate. Collaborate.

McMaster Advanced Control Consortium

2017 Industrial Brochure

MACC
McMaster Advanced Control Consortium

McMaster University ENGINEERING

More about the MACC

Excellence in research. Industrial applications.

The McMaster Advanced Control Consortium (**MACC**) was established in 1988 to promote and advance **process automation** and related **process systems engineering** technologies through academe-industry interactions. Company membership grew and also diversified, with current member companies spanning the petroleum, chemical, steel, advanced materials, food and control technology vendor industries.

The research is directed by six faculty members in the McMaster Department of Chemical Engineering who have a combined total of **48 years of industrial and 86 years of academic experience**. The remaining research complement comprises of over 30 graduate students, research engineers, and postdoctoral fellows. The high technical skills that MACC graduate students develop through their course work at McMaster and their industrially relevant research make them sought-after and valuable assets to the process industries and their technology suppliers.

MACC holds an annual research review meeting and technical workshop, which provides and opportunity for company representatives to learn about our research directions and provide input, to learn about technical details of the work at a graduate poster session, and to participate in a technical workshop that provides depth in a focussed technical area.

Through collaborative research projects, specific problems and/or areas of interest to an industrial partner may be addressed. Benefits to industry include access to in-depth analysis of the problem under consideration with associated insights and understanding, low-cost evaluation of potential benefits of new methodologies and applications, and early adoption of successful technologies. **Member companies have reported savings of millions of dollars per year**, attributed to interactions with the MACC.

Our Industrial Partners

ArcelorMittal DOFASCO | HAMILTON
CORNING
PEPSICO
Johnson Controls
PRAXAIR
TOTAL

Want More Information?

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PROF. CHRIS SWARTZ

Optimal Operation & Design

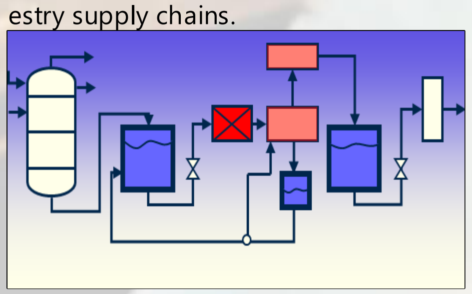
Professor, Director of MACC

The Biggest Bang for your Buck

Optimization for maximum performance

Optimization plays a significant role in MACC research projects. This includes formulation of a wide variety of optimization problem types such as linear programming, nonlinear programming, mixed-integer programming, dynamic optimization and global optimization, and solution through the application of **state-of-the-art algorithms and software**. Many of the problems exhibit features that make them challenging to solve, such as strong nonlinearity, high dimension, discrete decisions, dynamic models, model discontinuity and uncertainty.

Problems are formulated in different modeling environments depending on the application, and include GAMS, AMPL, gPROMS, and Matlab. We also develop **novel formulations and solution approaches**. Applications include economic predictive control, real-time dynamic optimization, supply chain optimization, planning and scheduling, integrated plant and control system design, abnormal situation response, and batch process operation and control. We are currently **working with our industrial partners to apply these techniques** to steel refinery operations, petroleum refining, air separation systems, and forestry supply chains.



What's Happening

Dynamic Operation
Approaches for large-scale problems, parallel computing, uncertainty

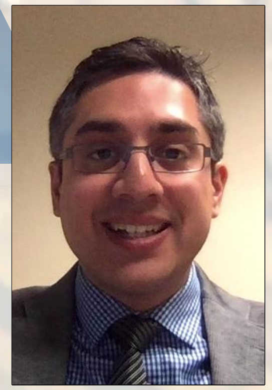
Design for Dynamic Performance
Applications in cryogenic air separation, Kraft pulp mills, electric arc furnaces, supply chain systems

Real Time Dynamic Optimization
Integration with model predictive control. Transient applications

Optimal Planning & Scheduling
More economical plant operations

Prof. Kamil Khan

Global and Dynamic Optimization



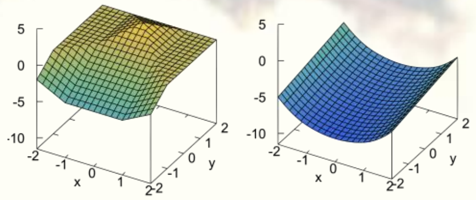
Assistant Professor

Advancing the Frontiers of Optimization

Building the right tool for the job.

Chemical process models often exhibit features such as **nonconvexity** and **discrete switching** that hinder methods for simulation, sensitivity analysis, and optimization. Batch processes, semi-batch processes, and control systems also exhibit **dynamic behavior**, which makes these obstacles even more challenging. At the MACC, we are developing **innovative theoretical and numerical tools** to overcome these obstacles and to implement **efficient**, **reliable**, and **automatic** solution strategies. These tools draw on several recent advances in process systems engineering, algorithm development, and applied mathematics.

Global optimization of dynamic systems is particularly difficult, since dynamics hamper our intuition about the effects of system parameters on system behavior. Nevertheless, our recent **pioneering work** on constructing **smooth convex underestimators** for nonconvex problems suggests a **promising new class of methods** for global dynamic optimization, to broaden the class of global dynamic optimization problems that can be solved in practice. Other tools include **automatic differentiation**, **adjoint sensitivity techniques**, and **nonsmooth analysis**.



What's Happening

Global Optimization
Safety verification by worst-case uncertainty analysis, parameter estimation

Dynamic Optimization
New solution strategies, adjoint gradients.

Sensitivity Analysis
Switching systems, automatic differentiation, reachable set descriptions.

Prof. Prashant Mhaskar

Nonlinear Chemical Process Control

Associate Professor

What's Happening

Safe Parking Nonlinear Systems
Fault-tolerant control, handling of failure conditions, Lyapunov MPC

Integrating Nonlinear Control w/ Optimization-Based Control
Stabilizing nonlinear MPC, handling uncertainty and noise, energy system applications

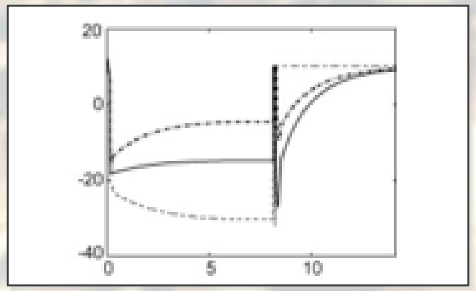
Model Predictive Control for Batch Systems & Bio-Systems
Safe-steering frameworks, reverse time reachability regions

Control Your Most Difficult Processes

Keep it running when it counts!

Quality process control is essential for the successful operation of any chemical process. At the MACC, we are researching and developing **cutting edge control technologies** to meet the challenges of today's industry. We are currently looking at process control for **continuous** and **batch** processes; **advanced model predictive control** techniques; strategies for detecting and responding to process faults using a **safe-parking approach**; **integrated optimization and control** strategies; and strategies for integrated design and control. Advancements in these areas are applied to applications in energy, biofuels, and bulk chemicals.

We are developing control systems which address even the most difficult processes to operate. For example, we have developed the first systems which detect when fault occurs and then uses a **Lyapunov-based model predictive controller** system to guide the plant to a "safe-parking" state where the fault can be remedied without having to shut down the plant. Other examples include integrated control and optimization systems which **better handle high uncertainty and process noise.**



Solving the Energy Crisis

one system at a time

At the MACC, we are working to develop new and innovative chemical processes which improve the "**triple-bottom-line of sustainability**", meaning that the processes are not only more environmentally friendly, but also socially acceptable and yet still economical. This can take several forms, such as reducing or **eliminating CO_2 emissions** at low cost, reducing the amount of fossil fuels that must be consumed, **increasing the use of renewable resources**, reducing the "cradle-to-the-grave" **life-cycle impact** of a process, or **improving the thermal efficiency**.

We are developing processes which produce chemicals and energy in a more sustainable way. This might include processes which use existing technology in better ways (such as **polygeneration** and **gasification**), or processes which exploit up-and-coming technologies (such as **solid oxide fuel cells**, **semicontinuous systems**, and **nuclear-to-liquids**). We use state-of-the-art process **simulations**, **process synthesis** techniques, strategies for integrated **design**, **control**, and **optimization**, **life cycle impact analyses**, and techno-economic analyses to create, investigate, and analyze sustainable processes.

What's Happening

Power Generation with No CO_2
Solid oxide fuel cell systems, energy storage, smart buildings, bulk power

Integrated Gasification, Reforming
Advanced flexible polygeneration using natural gas, coal, and petcoke.

Sustainable Synthetic Fuels
Nuclear-to-liquids, bio-to-liquids. Refinery gas reuse and CO_2 capture.

Process Intensification
Chemical plants on a truck. Semicontinuous distillation.

Associate Professor

Prof. Thomas A. Adams II

Sustainable Energy System Design

What's Happening

Production Scheduling
Inventory pinch point methods, uncertainty in production times, derivative-free optimization

Liquid Products Pipelines
Algorithms for large scale scheduling and planning

Integrated Planning, Scheduling
Inventory pinch point methods for long range production planning

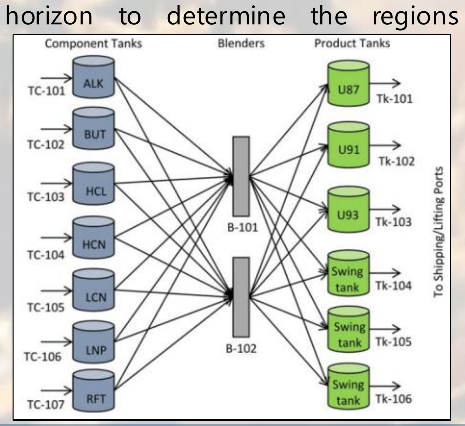
Process and Power Distribution
Integrating chemical processes with power production

Professor

Efficient and On Time

Produce and deliver faster, better!

Process plant scheduling is a computationally difficult problem , even if the plant behavior is described by approximate nonlinear models. We have developed a novel scheduling algorithm which enables **rapid solutions of large scale scheduling problems** for both linear and nonlinear processes. The algorithm relies on **inventory pinch points** along the scheduling horizon to determine the regions where optimal operating conditions are constant. A **discrete time period planning model** is used to optimize allocation of swing storage and association of specific product shipments with the product inventories. A detailed schedule of operations is then computed via continues time scheduling model. The algorithm computes solutions within times that are 2 to 3 orders of magnitude shorter than previously published research.



We have also developed an algorithm that **estimates of Bayesian networks** representing the production process, which enables us to estimate the most likely production time for each step. Scheduling of production is then computed by an algorithm which combines linear programming with parallel simulated annealing and frog leaping evolutionary algorithms.

Prof. Vladimir Mahalec

Optimization, Planning & Scheduling