Advanced Process Control in ExxonMobil Chemical Company: Successes and Challenges

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Session 10B01: In Honor of Tom Edgar’s 65 Birthday II
Outline

- Process Industries Advanced Control Toolbox
- ExxonMobil Chemical’s Advanced Control Experience
- Engineering Specialists: Process Control
- Advanced Control Improvement Needs
- Tom Edgar’s Impact
- Summary & Conclusions
Process Industries Advanced Control Toolbox

Primary Function
Closed Loop Multi-period economic
Closed Loop economic
Multi-variable constraint
Base Regulatory

**Process Characteristic:**
- Continuous
- Cyclic
- Semi-Continuous

**Model Rigor:**
- Technology Maturity

**Closed Loop Multi-period economic**

**Multi-Period Real Time Optimization (MPRO)**
Approximate nonlinear economic optimization over a time horizon

**Real Time Optimization (RTO)**
Provides economically optimal targets to LMPC

**Linear Model Predictive Control (LMPC)**
- Stabilizes plant, push linearity to constraints

**Real Time Optimization (RTO)**
Provides economically optimal targets to LMPC

**Nonlinear Model Predictive Control (NMPC)**
Provides combined nonlinear economic optimization and control

**Dynamic Optimization (DynOpt)**
Provides nonlinear economic optimization over a time horizon

**PID**
- Single input-single output control, multilevel cascade, surge margin

**Sequential**
- Logic-based, discrete

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Linear Model Predictive Control (LMPC)

- **LMPC is the most widely used advanced control technology**
  - Medium Size application routinely delivers significant energy savings as well as additional production
  - Example: Butadiene Recovery Unit, Baton Rouge Chemical Plant
    - 40 Manipulated Inputs, 50 Controlled Variables
    - Reduced steam consumption 12MBTU/hr ($800k/yr)
  - Example: “Typical” Ethylene Plant
    - 77 Manipulated Inputs, 189 Controlled Variables
    - 109 Additional Feed Forward Inputs
    - Energy Reduction / Feed Increase on similar scale

Stabilize

Optimize
Real Time Optimization (RTO)

- Optimize the plant automatically on hourly basis by setting the underlying MPC setpoint
- Utilize real time price / cost information and plant constraints
- Cover all key unit operations in the plant
- Utilize rigorous thermodynamics and reaction kinetics to represent plant steady-state behavior
- Plant wide scope provides substantial benefits
Nonlinear Model Predictive Control

- Most ExxonMobil Chemical Company applications are first-principles based with some empirical elements
- Largest penetration of technology in polymers area
- Consistent control of properties through grade transitions is significant benefit of applications
- Modeling and parameter estimation require significant effort
- Little (if any) plant testing required

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![Graph showing transition amount and probability]
Engineering Specialists: Process Control

- Relatively small central group
- Maintain expertise in supported technologies
- Support site projects and initiatives
- Provide higher level support for applications worldwide
  - Sites maintain significant expertise in supported technologies
  - Central group facilitates application updates, troubleshoots modeling and technology issues
- Keep up to date with “State of the Art Technology”
  - Collaboration with academic researchers to deliver proof of concept applications
  - Work with vendors to drive technology improvements to address issues discovered at manufacturing sites
Importance of Industrial Participation

- Actively contribute to professional societies
- Actively participate in joint academic / industry consortia
- Maintain a fresh perspective
  - Seminars from visiting professors
  - Support graduate student internships
- Actively participate in vendor user groups
- Collaborate with colleagues internally
Advanced Control Improvement Needs

- **Linear MPC**
  - Better control infrastructure design
  - Model consistency and closer integration to RTO
  - Identification tools that systematically enforce relationships between variables

- **Real Time Optimization**
  - Better NLP & MINLP solvers and parallel computing to handle large scale, mix-integer, and complementarity problem
  - Better understanding of distributed optimization & control

- **Nonlinear MPC**
  - Improved state / disturbance estimation methods
  - Parameter estimation
  - Improved integration of first principals and empirical models
  - Evolution to dynamic optimization
Tom Edgar’s Impact

• Education
  • Undergraduate – embraced new technology for course organization, teaching concepts, and working problems
  • Graduate – direct research of and maintain funding for a substantial research group
  • ExxonMobil has directly benefited from the quality of graduates produced

• Research
  • More than 250 refereed journal articles and significantly more conference publications

• Industrial Collaboration
  • Texas – Wisconsin – California Control Consortium
  • Making students available for internships and to work directly on problems of interest to industry
Summary & Conclusions

• Advanced control has been extremely successful applied to industrial problems.

• Advanced control is not a “solved problem”, many research challenges still exist.

• Ongoing academic and industrial collaboration is needed.

• Maintaining capability to sustain applications is an ever-present challenge.

• Educators such as Tom Edgar are key to supplying the next generation of engineers with understanding of the technology and its capability.
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