PROCESS MODELING AND CONTROL

T.F. Edgar
The Department of Chemical Engineering

The University of Texas at Austin

- What is process modeling and control
- Why improve the technology
- Process control research in our department
• Ensure safe plant operation
• Meet product specifications
• Optimize economic performance
• MIMO (vs. SISO) models
• Nonlinear (vs. linear) models
• Stochastic variables
• Large number of variables
- Control System Monitoring and Diagnosis
- Dynamic Modeling of Chemical Processes
- Materials Processing
- Dynamic System Identification
- NMPC and Moving Horizon Predictions
- Optimization Theory and Algorithms
- Statistical Process Monitoring/Fault Diagnosis

www.che.utexas.edu/twmcc
# TWCCC - Multiple Projects

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<tr>
<th>Company</th>
<th>JBR</th>
<th>TFE</th>
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Courting Dow, Boise, Air Liquide, Bayer, Freescale, Intel, Honeywell, TOTAL, Capstone Technology, TresArk
### M.S., Ph.D. Graduates (2004 - 2006)

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<thead>
<tr>
<th>Student/Supervisor</th>
<th>Destination</th>
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<tbody>
<tr>
<td>J. Wang (JQ)</td>
<td>Ph.D. (5/04) Auburn University</td>
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<tr>
<td>E. Haseltine (JBR)</td>
<td>Ph.D. (12/04) Vertex Pharmaceuticals</td>
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<td>R. Good (JQ)</td>
<td>Ph.D. (8/04) AMD</td>
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<tr>
<td>W. Lin (JQ)</td>
<td>Ph.D. (5/05) Postdoc (U. Minn)</td>
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<tr>
<td>P. He (JQ)</td>
<td>Ph.D. (5/05) Tuskegee University</td>
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<td>J. Hedengren (TFE)</td>
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<td>W. Cho (TFE)</td>
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<td>E. Hale (JQ)</td>
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<td>R. Chong (TFE)</td>
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<td>L. Rueda (TFE)</td>
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<td>S. Harrison (TFE)</td>
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<td>C. Harrison (JQ)</td>
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<td>A. Venkat (JBR)</td>
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<td>K. Chamness (TFE)</td>
<td>Ph.D. (12/06) Spansion (AMD)</td>
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<td>G. Cherry (JQ)</td>
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## M.S., Ph.D. Graduates
### (2007 – 2008)

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<tr>
<td>T. Farmer (TFE)</td>
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<td>J. Yu (JQ)</td>
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<td>P. Larsen (JBR)</td>
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<td>E. Mastny (JBR)</td>
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<td>M. Rajamani (JBR)</td>
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<td>C. Schoene (JQ)</td>
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<td>Y. Cai (JQ)</td>
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<td>A. Prabhu (TFE)</td>
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<td>H. Lee (TFE)</td>
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<td>Y. Zhang (TFE)</td>
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<td>B. Bregenzer (JQ)</td>
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<td>D. Weber (TFE)</td>
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<td>S. Abrol (TFE)</td>
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<td>B. Parkinson (TFE)</td>
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Edgar Group Highlights

- 3 PhD’s graduated in 2007-08
- 30+ papers in journals/proceedings published or in press since 1/2004
- 3 new students and 1 postdoc added to group in 2007-08
  B. Gill – IIT; D. French – Ohio State; B. Parkinson – Idaho State; K. Han – Seoul N.U.
- 2007 AEC/APC Student Paper Award (B. Parkinson)
- T. Edgar selected as IFAC Fellow
Ph.D Candidates Graduated in 2008


3. Hyung Lee (8/08): Advanced Process Control and Optimal Sampling in Semiconductor Manufacturing
Yang Zhang

• **First Principles Modeling**
  - Proposed new algorithm for dynamic DOE (P-optimal)
  - Successfully tested on simulated industrial processes
  - Getting data from industrial bioprocess @ Broadley-James

• **Statistical Modeling**
  - Proposed new PCA-based algorithm for data synchronization and on-line monitoring
  - Algorithm package is being commercialized by Emerson
  - On-site software testing @ Lubrizol, Broadley-James
Amogh Prabhu

- Developed performance monitoring methodology for run-to-run EWMA controllers, validated on industrial data
- Missing data estimation performed using data reconstruction for processing monitoring
- New method for state estimation for high mix semiconductor manufacturing facilities
- PID controller optimization for nonlinear processes
Dynamic sampling methodology depends on the characteristics of the process and disturbances
- When the process has little variation, dynamic sampling has little effect but does not degrade the control performance

The online dynamic sampling algorithm was extended for high-mix manufacturing

Using integrated scatterometry with W2W FB control can correct for variations of an etch chamber over time within a lot

Constrained multivariable control in etch is required to achieve better manufacturing performance with more CVs (CD, sidewall angle, uniformity)
Edgar Group Project Areas

• Multivariable Control/Estimation
• Semiconductor Manufacturing Monitoring and Control
• Optimization of Petroleum Reservoir Production
• Flue Gas CO₂ Removal Strategies (Modeling, Control, Optimization)
• Model-based Fault Detection
• Diabetes Closed-loop Control
Multivariable Control and Estimation

- D. French – Wireless feedback control (Emerson Process Management)
- D. Thiele – Model predictive control performance enhancements from dynamic state feedback update (Emerson Process Management)
- J. Lee (postdoc) – Various topics in multivariable control (e.g., multiloop PI controller design, interaction analysis)
- S. Abrol – Use of ISAT in operating training simulators (Chemstations)
- I. Castillo – Fundamental model-based fault detection (Roberto Rocca Fellowship)
- B. Spivey – On-line estimation using fundamental models (NSF – IGERT, joint with John Ekerdt)
Semiconductor Manufacturing Modeling/Control

- New student – Trade-offs between performance and measurement (AMD)
- New student – Control loop performance monitoring (Texas Instruments)
- B. Parkinson – Optimization of plasma etch processing (Tokyo Electron)
- K. Baek – Sensor selection and evaluation for plasma etching (Samsung)
- K. Han – Run to run control (Korean Government postdoctoral fellowship)
- B. Gill – soft sensors in etch processes (Texas Instruments)
Other Projects

• D. Weber– Petroleum reservoir production optimization (Joint with Larry Lake – Oil Company Consortium)

• S. Ziaii – CO₂ absorption process modeling and control/power plant energy integration (Joint with Gary Rochelle – U.S. DOE and UT Carbon Management Consortium)

• New student – Dynamic modeling of blood glucose in Type 2 diabetes
Recent Publications/Presentations

• “Multivariate Statistical Process Control” by Yang Zhang and T.F. Edgar; Chapter 8 in *New Directions in Bioprocess Modeling and Control* by G. McMillan and M. Boudreau (ISA)


• Keynote Presentation at *AdConip Conference* (Jasper, Alberta): “Process Control – Batch to the Future”