Engineering Faculty Document No. 44-21
December 17, 2020

TO: The Faculty of the College of Engineering

FROM: The Davidson School of Chemical Engineering

RE: New Graduate Course, CHE 55400 Smart Manufacturing in Process Industries

The faculty of the Davidson School of Chemical Engineering have approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

Course: CHE 55400 Smart Manufacturing in Process Industries
Fall/Spring, Lecture, Cr. 3
Restrictions: May not be enrolled as the following Classifications:
Freshman: 0 - 14 hours
Freshman: 15 - 29 hours
Sophomore: 30 - 44 hours
Sophomore: 45 - 59 hours
Junior: 60 - 74 hours
Junior: 75 - 89 hours

Description: This course surveys the tools and techniques, which are relevant to support the multiple levels of technical decisions that arise in modern integrated operation of manufacturing facilities in the chemical and related process industries. The linkage of these decisions levels and sharing of associated data and knowledge via effective IT methodology is currently termed **Smart Manufacturing** in the US and **Industry 4.0** in Europe. The topics covered in the course include the structure of the operations decision hierarchy, role of online process measurements, elements of sensor network design, information systems to support process operations, plant data reconciliation, detection and diagnosis of process faults, plant wide control, real time process optimization, production planning and scheduling, and supply chain management. Each topic will be addressed by first summarizing the basic role and scope of that component, then discussing the structure of the decision problem, and then will outlining some representative tools available to address that decision problem. Each major topic will include a lecture given by an industrial practitioner who will offer a perspective on the state of industrial practice.

Reason: This new course, CHE 55400 Smart Manufacturing in Process Industries provides an accurate title reflective of its current topics for CHE 55500 Computer Integrated Process. The former title no longer reflects the material covered and this new title provides as clearer assessment of the course material which reflects the developments in all Smart Manufacturing, Industry 4.0 and big data in operations.

Enrollment History: Fall 10 (12), Fall 14 (13), Fall 16 (15), Fall 19 (8), Spring 21 (12)

Sangtae Kim
Jay and Cynthia Ihlenfeld Head of Chemical Engineering

ChE 55400
Smart Manufacturing in Process Industries

Course Objective

This course surveys the tools and techniques, which are relevant to support the multiple levels of technical decisions that arise in modern integrated operation of manufacturing facilities in the chemical and related process industries. The linkage of these decisions levels and sharing of associated data and knowledge via effective IT methodology is currently termed Smart Manufacturing. The topics covered in the course include the structure of the operations decision hierarchy, role of online process measurements, elements of sensor network design, information systems to support process operations, plant data reconciliation, detection and diagnosis of process faults, plant wide control, real time process optimization, production planning and scheduling, and supply chain management. Each topic will be addressed by first summarizing the basic role and scope of that component, then discussing the structure of the decision problem, and then will outlining some representative tools available to address that decision problem. Each main topic will include a lecture given by an industrial practitioner who will offer a perspective on the state of industrial practice.

Course Organization

Faculty:
Professor C. Laird
Professor Z. Nagy
Professor J. Pekny
Professor G V Reklaitis

Guest Lecturers
Dr M. Bassett, Dow Ag Sciences
Dr S. Brown, Invensys
Dr S. Garcia-Munoz, Eli Lilly
Dr A. Giridhar, CSOPS
Dr C. Iles, Evonik
Dr A. Ogden-Swift, Honeywell

Course Coordinator: Professor G.V. Reklaitis
Office: FRNY G027B
reklaiti@purdue.edu
765-494-9662

Course Materials: There are no required textbooks.

Lecture notes will be posted on the course Blackboard site. All supplementary reading and reference materials, consisting of articles from the literature and a selection of book chapters will also be made available on the Blackboard site.

Course Requirements:
There will be five assignments on the following topics: data reconciliation, fault detection using MSPC, plant-wide control, process optimization, and planning/scheduling, using software which will be made available. There will be an in-class midterm and a project in lieu of a final exam.

Course Grading:

Assignments (5)	50%
Midterm exam:	25%
Final project:	25%

The final project will be executed by student teams and will require a formal report and oral presentation of project results. Student teams may define their own projects on topics relating to their research or technical interest but must employ applications of the methodology covered in the course. Project suggestions will be offered by the faculty and lecturers, if requested by the project team.

Course policies
Attendance is required at all course meetings. A 10% reduction in course grade will be assigned for any student with more than three unexcused absences. Dishonesty in the execution of assignments, project or midterm exam constitutes grounds for failure of the course.

Learning Outcomes

As a result of this course, the student should be able to

- Explain the function, information requirements and main decisions made at each level of the operational hierarchy of an integrated processing system.
- Understand the design requirements of a sensor network, that insures that all variables which must be managed are observable
- Explain what process data storage requirements are and how these requirements are met in integrated process systems
- Know how to use data reconciliation methods to obtain the maximum likelihood estimate of the state of a process
- Explain why exceptional events are important to process operations
- Use multivariate statistic methods to determine whether and when an exceptional event has occurred
- Explain what fault diagnosis is, why it is needed and what general types of methods are available for effective diagnosis
- Understand the role of plant-wide control and how it relates to individual unit operations control
- Be able to test, evaluate and improve a specific plant wide control system design using a process simulation model
- Explain the role of real time process operations and the differences between steady state and dynamic RTO.

- Be able to implement and solve a steady state RTO problem based on material balances
- Explain the differences and relationship between process planning and scheduling
- Represent a process planning problem by formulating a linear programming model and solving it using standard LP tools
- Be able to explain the main decision variables of a process scheduling application and understand the underlying computational complexity of scheduling problems
- Represent a scheduling problem using a state task network and solve it using a commercial solver
- Explain how supply chain management relates to the operational planning of individual processes
- Understand the main components and operational decision variables of a supply chain optimization problem
- Explain the information requirements for effective supply chain management
- Understand where the sources of uncertainty arise in supply chain planning and what strategies can be used to accommodate to these uncertainties.

Tentative Lecture Schedule (to be confirmed)

Date	**Topic**	**Lecturer**	**Notes**
8/26	Overview & syllabus	Reklaitis	
8/28	The operations decision hierarchy	"	Role of each level, differences between batch & continuous
9/2	Information systems & management	Giridhar	ISA architecture, process historians, ERP systems
9/4	Plant data reconciliation	"	Introduction & Linear problem
9/9	Plant data reconciliation	"	Nonlinear form
9/11	Sensor networks & their design	"	Aspects of observability, reliability, accuracy; cost/benefit
9/16	Exceptional events and consequences	Garcia	Overview, Statistical basis & tools
9/18	Fault detection: MSPC	Garcia	
9/23	Fault diagnosis: MSPC	Garcia	
9/25	Model based diagnostic methods	Reklaitis	Overview of qualitative & quantitative approaches
9/30	POTR pilot plant demo	Giridhar	Sensors, EEM, control
10/2	Plant wide control intro	Nagy	
10/7	Plant wide control	Nagy	
10/9	Plant wide control	Nagy	
10/14			October break

10/16	Plant wide control	Ogden-Swift	Industrial experience and applications
10/21	Mid-term exam	Reklaitis	
10/23	Real time process optimization : SS	Laird	Objective & components
10/28	RTO: SS	"	NLP solution methods
10/30	RTO: dynamic	"	Start-up/shut down, grade transition, batch
11/4	RTO: dynamic	"	Solution approaches
11/6	RTO	Brown	Software tools and implementation
11/11	Scheduling & planning overview	Pekny	Objectives & scope, differences, motivating applications
11/13	Planning methods	"	Single/multiperiod LP
11/18	Scheduling methods	"	Problem Representation
11/20	Scheduling methods	"	Solution approaches: MILP
11/25	Scheduling Applications	Iles	Industrial experiences and needs
11/27			Thanksgiving
12/2	Supply chain management	Reklaitis	Components & roles
12/4	Supply chain management	Reklaitis	Integration & uncertainty aspects
12/9	Supply chain challenges	Bassett	Industrial Applications
12/11	Class Project reports	Reklaitis	Team presentations