Course 7: Advanced Optimization: Techniques and Industrial Applications

Course Objective: The objective of this course is to provide the students with knowledge on the application of various optimization techniques which can help making decisions for practical problems in industries. Modeling concepts and applications of linear, integer, nonlinear, and dynamic programming as well as network models are addressed. Meta-heuristic techniques are also discussed to obtain good solutions for large scale practical problems in a reasonable computational time. Optimization model and its applications are demonstrated for solving problems in Industry 4 era.

Prerequisite: Operations Research

Learning Outcomes:

The students on the completion of this course would be able to

- Formulate mathematical programs for practical problems in production and supply chain systems (Create).
- Apply appropriate optimization techniques and write codes of optimization models using professional optimization software (i.e., MATLAB, LINGO, or MPL software) to solve single-objective practical problems in production systems, supply chain systems and specific operational problems (Create).
- Find appropriate trade-off solutions for multiobjective decision making problems in production systems, supply chain systems and specific operational problems (Create).
- Use meta-heuristic techniques to solve large scale NP-hard combinatorial problems for both single and multiple objective decision making problems where analytical methods cannot be used (Create)
- Conduct sensitivity analysis to examine the robustness of the solutions resulting from optimization models in order to ensure that appropriate solutions will be deployed in real world situations where input parameters are uncertain and cannot be estimated precisely (Evaluate).
- Understand how to apply digital technology for automated data-driven and in real-world optimization model. (Apply).

Course Outline:

Modules

Module 1: Theory of mathematical programming for convex optimization

Module 2 : Heuristics and Metaheuristics

Module 3: Optimization and Its Applications in Industry 4 Era

Contents (45 hrs. in total)

Module 1: Theory of mathematical programming for convex optimization (19 hrs.)

1.1 Basic Modeling Concepts (1 hr.): Lecture: AC

1.2 Linear Programming (6 hrs.): Lecture: AC + RO (Discussion, Home Assignment, Group project)

1.3 Integer Programming, Mixed Integer Programming, and Combinatorial Optimization (5 hrs.): Lecture: AC + RO (Discussion, Home Assignment, Group project)

1.4 Non-linear Optimization (3 hrs.) Lecture: AC + RO (Discussion, Home Assignment)

1.5 Dynamic Programming (4 hrs.) Lecture: AC + RO (Discussion, Home Assignment)

Module 2: Heuristics and Metaheuristics (16 hrs.)

2.1 Concept of Heuristics and Metaheuristics (1 hr.) Lecture: AC + RO (Discussion)

2.2 Population-based algorithms: GA, PSO, DE) (9 hrs.) Lecture: AC + RO (Discussion, Group project)

2.3 Local Search Methods: ALNS and Tabu Search (3 hrs.) Lecture: AC + RO (Discussion, Group project)

2.4 Multiobjective optimization (3 hrs.) Lecture: AC (Discussion)

Module 3: Optimization and Its Applications in Industry 4 Era (10 hrs.)

3.1 An Overview of Digital Technologies (1 hr.)

This topic aims to give overview information of the tools (digital technology) used in optimization problems in Industry 4.0 era. Lecture: AC + RO (Discussion, Home Assignment)

3.1.1 Digital technology concept

3.1.2 Digital technology hardware & software

3.1.3 Digital technology applications

3.2 Optimization (Opt) concept and Its Applications in Industry 4.0 Era (2 hr.)

This topic aims to give a basic idea of how to apply optimization to the real-world problem in Industry 4.0. Lecture: AC + RO (Discussion, Home Assignment, Group project)

3.2.1 Optimization concept in Industry 4.0 era

3.2.2 Optimization applications in Industry 4.0 and mobile support

- Opt in Warehouse and Inventory Management
- Opt in Transportation problems
    1) Smart Pickup and Delivery system (i.e., customized and real time pick up scheduling)
    2) Real time fleet management, tracking service and transportation condition
- Opt in Scheduling problems

3.3 Optimization (Opt) Design in Industry 4.0 (2 hr.)

This topic aim to enhance student capability to analyze the problem, design, implement and measuring to use the optimization problems in Industry 4.0. Lecture: AC + RO (Discussion, Home Assignment, Group project)

3.3.1 System analysis concept
3.3.2 System architecture, module and component design
3.3.3 Data input/output user interface design
3.3.4 Optimization programming, modeling, and simulation
3.3.5 Evaluating the designed system

3.4 Real-Time Optimization (2 hr.)

This topic aims to deal with practical optimization problems for automated input data. Lecture: AC + RO (Discussion, Home Assignment, Group project)

3.4.1 Checking optimality conditions when input data change
3.4.2 Setting initial solution when input data change

3.5 Case Study (3 hr.)

This topic aims to enable students to apply optimization concept in an Industry 4.0 real-world problem. Lecture: AC + RO (Discussion, Group project)

Learning Resources:

Textbook: No designated textbook, but class notes and handouts will be provided

Reference books and articles:

- Operations Research: An Introduction, 9th Edition, Hamdy A. Taha, Pearson Education, 2013.
- Linear Programming and Extensions, George Dantzig, Princeton University Press, 2016.
- Model Building in Mathematical Programming, 4th Edition, H. Paul Williams, Wiley, 1999.
- Operations Research: A Practical Introduction (Operations Research Series) 1st Edition, Michael W. Carter, Camille C. Price, CRC press, 2000.

Teaching and Learning Method

This is a project-based learning (PBL). During lecture sessions, class discussions and group projects will be conducted. Group projects are included in all modules in order to make students are able to solve the real-world optimization models. Students will practice various skills included developing mathematical programming, heuristics, and metaheuristics. Most importantly, students will be able to apply digital technology for automated data-driven used in the real-world optimization models.

Time Distribution and Study Load

Lectures: 45 hours
Self-Study: 30 hours
Group Project: 15 hours
Discussion: 10 hours

Evaluation Scheme

	CLO 1	CLO 2	CLO 3	CLO 4	CLO 5	CLO 6
Formative assessment method						
Individual reports on home assignments (5%)	X	X			X	
Quizzes (5%)	X	X				
Midway reports and presentations in group projects (10%)		X	X	X	X	
Involvement in class discussions (5%)	X	X				
Demonstration of understanding of knowledge provided during the course (5%)	X	X			X	X
Case studies (20%)	X	X	X	X	X	X
Summative assessment method						

Final reports in group projects (10%)	X	X	X	X		X
Final group project presentation (5%)	X	X	X	X		X
Peer assessment in group projects (5%)			X	X		
Mid-Semester Examination (15%)	X	X				
Final Examination (15%)	X		X	X		

An “A” would be awarded if a student can demonstrate clearly skills in developing mathematical programming, heuristics and metaheuristics to solve real-world optimization models. Additionally, a student can show clearly understanding how to apply digital technology for automated data-driven used in real-world optimization models.

An “B” would be awarded if a student can show good progress in developing mathematical programming, heuristics and metaheuristics to solve real-world optimization models. Additionally, a student can show good understanding how to apply digital technology for automated data-driven used in real-world optimization models.

An “C” would be awarded if a student can show reasonable progress in developing mathematical programming, heuristics and metaheuristics to solve real-world optimization models. Additionally, a student can show reasonable understanding how to apply digital technology for automated data-driven used in real-world optimization models.

An “D” would be awarded if a student shows lack of improvement in developing mathematical programming, heuristics and metaheuristics to solve real-world optimization models. Additionally, a student shows lack of improvement how to apply digital technology for automated data-driven used in real-world optimization models.