ESG UQÀM
École des sciences de la gestion
Département d'Analytique, Operations et Technologies de l'Information (AOTI)
Université du Québec à Montréal

Syllabus

ADM9956

Advanced optimization methods for the management of complex systems

Automn 2023

Lessons hours :	**Mondays, from 14h00 to 17h00**
Dates :	**From September 05 to December 20, 2023**
Teaching Mode :	**In presence**
Lecturer :	**Franklin Djeumou Fomeni**
Office :	**ESG-UQAM, Pavillon J. A. De Seve, DS - 3778**
Availabilities :	**Preferably by appointment**
Email :	**djeumou_fomeni.franklin@uqam.ca**

GENERAL OBJECTIVES

The main objective of this course is to familiarize the student with advanced optimization methods to support decision-making in the context of the management of complex systems. The student will acquire in-depth knowledge of linear, integer and combinatorial optimization methods. Starting from basic properties in linear algebra, we will incrementally explore optimization techniques aimed at solving increasingly complex optimization problems effectively and efficiently.

At the end of this course, the student will have a strong background in the theory of mathematical optimization and will have acquired technical skills allowing him/her to implement solution methods. The student will be able to analyze the complexity of different methods and to critically analyze the different methodological options available for solving optimization problems in the management of complex systems.

Content Summary :

- Linear programming: simplex method, fundamental theorem of linear programming; duality; dual simplex method.
- Binary and integer programming: branch-and-bound method, cutting planes method, polyhedral theory, complexity analysis.
- Decomposition methods: Dantzig-Wolfe decomposition, column generation, Lagrangian relaxation.
- Heuristic and metaheuristic methods

ASSESSMENTS AND WEIGHTING

Students will be assessed on the following works :

- ✓ A mid-term exam (written and in presence) 30%
- ✓ A final exam at the end of the session (written and in presence) 30%
- ✓ Coursework (in team)
  - Written document 30 %
  - Oral presentation 10 %

The evaluation scale to be used will be based on the following grid :

Grade	Min included	Max excluded	Grade	Min included	Max excluded	Grade	Min included	Max excluded
A+	90	100 [1]	B+	77	80	C+	65	70
A	85	90	B	73	77	C	60	65
A-	80	85	B-	70	73	E	0	60

[1] This score is included

Description and guideline of the session coursework :

The session coursework must be carried out in teams of two or three students. Each team will have to choose a topic around a decision-making context, then discuss solution methodologies that could be appropriate for the chosen and then implement one of these methodologies. The topic will be chosen by mutual agreement between the teams and the lecturer. The work will consist of a synthesis of the relevant literature for the chosen topic as well as the choice and implementation of one solution methodology covered in the course. The evaluation will be based on a report of approximately 15 pages. Both the content and the form will be assessed.

The session coursework will be concluded by a class presentation at the end of the session, during which, the members of each team will have the opportunity to present their work to the whole class.

IMPORTANT : All the teams must be formed no later than the end of the third lessons. The topics must then be validated no later than the end of the eighth lesson. In both cases, please send the names and permanent codes of the team members, as well as a draft of the work plan by e-mail to the address : djeumou_fomeni.franklin@uqam.ca.

DOCUMENTATION

Here is the list of the main references that will be used throughout this course

1. **George L. Nemhauser and Laurence A. Wolsey, « Integer and combinatorial optimization ». John Wiley and Sons Inc., 1999.**
2. **Y. Nobert, R. Ouellet et R. Parent, « Méthodes d'optimisation pour la gestion», Gaëtan Morin éditeur, Chenelière Éducation, 2ème édition, 2016, 454 pages.** https://www.coopuqam.com/422040-Livres--produit.html
3. A list of scientific articles will also be indicated directly on the Moodle website associated with the course

TEACHING METHODS

The acquisition of knowledge and the learning of the different decision-making models and techniques will be achieved through lectures, which will be supplemented by periods of discussion and also by the application of the techniques seen in class in individual and group work.

Attendance at class is the responsibility of the student. Thus any absentee should not expect any individual lessons to fill in the missed explanations. In addition, the planned content of the courses could be modified during the semester according to the needs of the students.

DESCRIPTION THE LESSONS : Topics to be covered

Linear programming and its applications :

- Production planning
- Multi-period optimization modeling
- Network flow problems

Theory and solution methods of linear programming :

- Fundamental theorem and duality
- Graphical method, simplexe method and interior points method.

Modeling with binary variables:

Learn to model several classic combinatorial optimization problems with binary variables, including: traveling salesman problem, vehicle routing problem, linear knapsack problem, bin packing problem, set-covering problem, partitioning problem, facility location problem, network design.

Theory of integer programming :

- Continuous relaxation on an integer program
- Polyhedral theory
- Complexity theory (problem and algorithm)

Heuristic algorithms for integer programming problems :

- Greedy algorithms (transportation problems, bin packing, knapsack problem)
- Constructive heuristics
- Local search, variable neighborhood, adaptive neighborhood

Metaheuristic algorithms :

- Genetic algorithms
- Tabu Search
- Simulated annealing

Cutting planes method :

- Valid inequalities and separation problems
- Gomory's fractionnal cuts
- classical valid inequalities for knapsack-like constraints
- Valid inequalities for network flow problems

Decomposition method :

- Column generation
- Dantzig-Wolfe decomposition
- Lagrangian relaxation

Development of exact algorithms :

- Branch-and-Bound
- Cut-and-Branch
- Branch-and-Cut
- Branch-and-Price