AGH UNIVERSITY OF SCIENCE AND TECHNOLOGY

Module name: Art of Modeling in Mixed-Integer Programming

Academic year: 2019/2020 Code: ZSDA-3-0301-s ECTS credits: 3

Faculty of: Szkoła Doktorska AGH

Field of study: Szkoła Doktorska AGH Specialty: —

Study level: Third-cycle studies Form and type of study: Full-time studies

Lecture language: English Profile of education: Academic (A) Semester: 0

Course homepage: —

Responsible teacher: dr hab. inż. Kaczmarczyk Waldemar (wkaczmar@zarz.agh.edu.pl)

Module summary

This course provides an introduction to modeling in Mixed-Integer Programming (MIP). This is the basic tool used in planning in all areas of human activity, among others in engineering, science, medicine, management, agriculture, and industry. The special focus of this course is on practical modeling skills, the typical components of MIP models, and implementation with the help of the Python scripting language and Gurobi commercial solver. Graduates of this course should be able to use MIP models and methods in their research.

Description of learning outcomes for module

MLO code	Student after module completion has the knowledge/ knows how to/is able to	Connections with FLO	Method of learning outcomes verification (form of completion)
Social competence: is able to			
M_K001	work in team	SDA3A_K03	Presentation, Execution of a project
Skills: he can			
M_U001	build a MIP model	SDA3A_U05, SDA3A_U01, SDA3A_U06	Test, Execution of a project
M_U002	use software tools to implement and solve MIP models	SDA3A_U05, SDA3A_U01, SDA3A_U06	Presentation, Execution of laboratory classes, Execution of a project
Knowledge: he knows and understands			
M_W001	standard MIP models and methods	SDA3A_W01	Test

Number of hours for each form of classes

	Form of classes										
Suma	Lectures	Auditorium classes	Laboratory classes	Project classes	Conversation seminar	Seminar classes	Practical classes	Fieldwork classes	Workshops	Prace kontrolne i przejściowe	Lektorat
30	15	0	15	0	0	0	0	0	0	0	0

FLO matrix in relation to forms of classes

MLO code	Student after module completion has the knowledge/ knows how to/is able to	Form of classes										
		Lectures	Auditorium classes	Laboratory classes	Project classes	Conversation seminar	Seminar classes	Practical classes	Fieldwork classes	Workshops	Prace kontrolne i przejściowe	Lektorat
Social competence: is able to												
M_K001	work in team	-	-	+	-	-	-	-	-	-	-	-
Skills: he can												
M_U001	build a MIP model	+	-	+	-	-	-	-	-	-	-	-
M_U002	use software tools to implement and solve MIP models	+	-	+	-	-	-	-	-	-	-	-
Knowledge: he knows and understands												
M_W001	standard MIP models and methods	+	-	+	-	-	-	-	-	-	-	-

Student workload (ECTS credits balance)

Student activity form	Student workload
Udział w zajęciach dydaktycznych/praktyka	30 h
Preparation for classes	30 h
przygotowanie projektu, prezentacji, pracy pisemnej, sprawozdania	30 h
Summary student workload	90 h
Module ECTS credits	3 ECTS

Additional information

Module content

Lectures

1. Linear Programming

1.1 Standard model
1.2 Simplex algorithm

2. Mixed-Integer Programming

2.1 Standard model
2.2 Branch and Bound algorithm
2.3 Branch and Cut algorithm
2.4 Classic models
2.5 Standard model components
2.6 Valid inequalities and model reformulations
2.7 Modelling tips and tricks

3. Software tools

3.1 A Modeling Language for Mathematical Programming (AMPL)
3.2 Gurobi Python interface

Laboratory classes

1. Implementing models in AMPL with the help of GNU Linear Programming Kit.
2. Implementing models in Python with the help of Gurobi.

Teaching methods and techniques:

Lectures: During the lecture, the teacher describes various classic models and modeling techniques with the help of multimedia presentations, spreadsheets, simulations, and other means. To stimulate student activity, the lecturer asks them questions or initiates discussions.
Laboratory classes: By doing laboratory exercises, the students learn about the various tools available to them. While performing projects, the students learn to formulate correct models and implement them. If necessary, the lecturer will provide guidance. While working in groups on certain projects, each student learns to allocate tasks and coordinate activities as part of a team. Writing reports on exercises and projects, the students learn to formulate observations and conclusions.

Warunki i sposób zaliczenia poszczególnych form zajęć, w tym zasady zaliczeń poprawkowych, a także warunki dopuszczenia do egzaminu:

1. All grades are calculated according to a scale compliant with the regulations of AGH studies. A score of 50% is required to obtain the lowest passing grade (satisfactory – 3.0).
2. To pass the laboratory class, the student must complete all laboratory and project assignments, prepare reports, and pass each assignment. The final grade is determined as a weighted average of the grades for all assignments.
3. To pass the course, the student needs a positive total score from all tests. On each test, questions may concern all issues considered in the class from throughout the course. The overall rating is determined as a simple average of all grades. Oral answers allow the student to gain extra credit points for the overall assessment.
4. If the student does not pass any form of a test or assignment by the required date, he/she is entitled to retake it in a form agreed to by the lecturer.

Zasady udziału w poszczególnych zajęciach, ze wskazaniem, czy obecność studenta na zajęciach jest obowiązkowa:

Lectures:
– Attendance is mandatory: Yes

– Participation rules in classes: The students listen to the lecture; if they do not understand something, they should ask questions. If the lecturer asks questions or initiates discussions, the students should present their opinions. Lecture slides are available before each lecture (in the form of a PDF file). Despite this fact, the students should take their own notes during the lectures, especially when solving tasks on the whiteboard (but also to note their own observations and comments). After the lecture (and sometimes before), the students should read the recommended reading materials. Recording or filming a lecture is not allowed without the consent of the teacher.
Laboratory classes:
– Attendance is mandatory: Yes
– Participation rules in classes: The students perform laboratory exercises under the guidance of the teacher or independently in small groups as they carry out different projects. After completing an exercise or project, the students will present their programs and obtained results as well as reports containing a description of their tasks, methods, observations, and conclusions.

Method of calculating the final grade

The student’s final grade is calculated as the average of their grades using the following weights:

Grade	Weight
Tests	60%
Projects	40%

Sposób i tryb wyrównywania zaległości powstałych wskutek nieobecności studenta na zajęciach:

Absence from lectures or missed exercises will be made up by studying the issues discussed in the classroom with the help of the lecture notes available on the e-learning platform. If the student misses a test, then he/she must retake it on a date agreed to by the lecturer.

Prerequisites and additional requirements

Basics of mathematics (including algebra and probability theory) are required to participate.

Recommended literature and teaching resources

1. H. Paul Williams, Model Building in Mathematical Programming, Wiley, 2013.
2. A. Eiselt, Carl-Louis Sandblom, Operations Research, A Model-Based Approach, Springer, 2012, available for download in AGH library: https://link-1springer-1com-1000048xh0028.wbg2.bg.agh.edu.pl/book/10.1007/978-3-642-31054-6.
3. Walukiewicz, S. Integer Programming, Springer Netherlands, 1991, available for download in AGH library: https://link-1springer-1com-1000048xh0028.wbg2.bg.agh.edu.pl/book/10.1007/978-94-015-7945-2

Course software available for download (to be installed on the student’s computer):

4. GPLK (with SciTE) available at http://home.agh.edu.pl/~waldek/glpk/
5. Gurobi (Academic License) available at https://www.gurobi.com/academia/
6. Python 3.6, e.g., WinPython available at https://sourceforge.net/projects/winpython/files/WinPython_3.6/

Scientific publications of module course instructors related to the topic of the module

1. Kaczmarczyk, W., Sawik, T., Schaller, A. and Tirpak, T. (2004). Optimal versus heuristic scheduling of surface mount technology lines, *International Journal of Production Research*, 42(10): 2083-2110.
2. Kaczmarczyk, W., Sawik, T., Schaller, A. and Tirpak, T. (2006). *Production planning and coordination in customer driven supply chains*, Wybrane Zagadnienia Logistyki Stosowanej, Tom 3, Komitet Transportu Polskiej Akademii Nauk, s. 81-89.
3. Kaczmarczyk, W. (2008). Partial coordination may increase overall costs in supply chains, *Decision Making in Manufacturing and Services*, 2(1-2): 47-62.
4. Kaczmarczyk, W. (2009b). Practical tips for modelling lot-sizing and scheduling problems, *Decision Making in Manufacturing and Services*, 3(1-2): 37-48.
5. Kaczmarczyk, W. (2009c). Modelling multi-period set-up times in the proportional lot-sizing problem,

Decision Making in Manufacturing and Services, 3(1-2): 15-35.
6. Kaczmarczyk, W. (2009d). Inventory cost settings in small bucket lot-sizing and scheduling models, *Total Logistic Management*, 2: 27-36.
7. Kaczmarczyk, W. (2011). Proportional lot-sizing and scheduling problem with identical parallel machines, *International Journal of Production Research*, 49(9): 2605-2623.
8. Kaczmarczyk, W. (2020) Valid inequalities for proportional lot-sizing and scheduling problem with fictitious microperiods, *International Journal of Production Economics*, 219, 236-247.

Additional information

Students should bring their own laptop computers to install the Gurobi solver.