COURSE DESCRIPTION CARD - SYLLABUS

Course name
Operational research [S1SI1E>BOP]

Course

Field of study
Artificial Intelligence

Year/Semester
3/5

Area of study (specialization)
–

Profile of study
general academic

Level of study
first-cycle

Course offered in
English

Form of study
full-time

Requirements
elective

Number of hours

Lecture
30

Laboratory classes
30

Other
0

Tutorials
0

Projects/seminars
0

Number of credit points

5,00

Coordinators

dr inż. Michał Tomczyk
michal.tomczyk@put.poznan.pl

Lecturers

Prerequisites

Mathematical knowledge from the secondary school. Programming skills. Knowledge of the Python language.

Course objective

The course aims to introduce the students to the main topics in Operational Research (OR). These include linear programming, simplex algorithm, dual programming, sensitivity analysis, network optimization models, dynamic programming, integer programming, nonlinear programming, job scheduling, and heuristics. The students should get to know the basic methods, techniques, and algorithms for each of these sub-fields to use them for practical problem-solving.

Course-related learning outcomes

Knowledge:
K1st_W1: has an extended, in-depth knowledge of mathematics, which is useful for formulating and solving complex computer and IT tasks concerning, among others, problem modeling within the scope of artificial intelligence and data analysis
K1st_W3: has a detailed, well-grounded knowledge of fundamental computer science problems within

the scope of artificial intelligence, including machine learning, data analysis and mining, inductive reasoning, information retrieval, optimization techniques, and decision analysis.
K1st_W4: knows and understands the basic techniques, methods, algorithms, and tools used for solving computer problems as well as problems in artificial intelligence, including an automated recognition of patterns in data of different types and their synthesis to knowledge, conclusions, and recommendations
K1st_W5: has a basic knowledge of key directions and the most important successes of artificial intelligence understood as an essential sub-domain of computer science, making use of the achievements of other scientific disciplines and providing solutions with a high practical impact

Skills:
K1st_U3: can formulate and solve complex problems within the scope of computer science and, in particular, artificial intelligence, by applying appropriately selected methods (including analytical, simulation or experimental approaches)
K1st_U4: can efficiently plan and carry out experiments, including computer measurement and simulations, interpret the obtained results and draw conclusions based on the experimental outcomes
K1st_U5: has basic intellectual capabilities in social and economic sciences, needed for carrying out the engineering activities and allowing to detect the economic, ethical, legal, and social aspects when formulating and solving the IT tasks
K1st_U7: can carry out a critical analysis and an assessment of the functioning of both computer systems and AI methods
K1st_U9: can adapt the existing algorithms as well as formulate and implement the novel algorithms, including the algorithms typical for different streams of AI, using at least one well-known tool
K1st_U10: can retrieve, analyze and transform different types of data, protect it against undesired access, and carry out data synthesis to knowledge and conclusions useful for solving a variety of problems that occur in the work of a computer scientist - a specialist in the field of AI, including issues of industrial, business, and administrative nature

Social competences:
K1st_K1: understands that knowledge and skills quickly become outdated in computer science and, in particular, AI, and perceives the need for constant additional training and raising one"s qualifications
K1st_K2: is aware of the importance of scientific knowledge and research related to computer science and AI in solving practical problems which are essential for the functioning of individuals, firms, organizations as well as the entire society
K1st_K5: can think and act in an enterprising way, finding the commercial application for the created AI-based systems, having in mind the economic benefits as well as legal and social issues

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Lecture: Assessment test is conducted at the last lecture. The students need to solve several computational tasks concerning the subjects presented during all lectures. Each task is evaluated individually, being allocated a certain number of points. The points are summed up and a standard scale is used to derive the final marks: <50% - 2.0, [50%, 60%) - 3.0, [60%,70%) - 3.5, [70%,80%) - 4.0, [80%, 90%) - 4.5, and [90%, 100%] - 5.0.
Laboratory classes. After each class, students solve practical, programming assignments and report their solutions to the instructors leading the laboratory classes within two weeks. Each assignment is evaluated on a scale from 2.0 to 5.0. The final grade is computed as an average from the individual marks, with the proviso that the two worst out of ten marks obtained throughout the semester may be neglected.

Programme content

Linear programming, the simplex method, duality theory, sensitivity analysis, network optimization models, dynamic programming, integer programming, nonlinear programming, metaheuristics, job scheduling, queueing theory.

Course topics

Linear programming: basic notation and possible transformations of constraints; modeling an optimization problem using linear functions; solving the problem using a graphical approach;

formulating a matrix representation of the model.
The simplex method: obtaining the augmented representation of the model; introduction to the simplex method; solving the problem algebraically and using the simplex tableau; introduction to the Big M method.
Duality theory: the matrix form of the optimization model; the fundamental insight for solving problems using the simplex algorithm; duality theory and interpretation of the dual problem; specifying primal-dual relationships.
Sensitivity analysis: using the fundamental insight for revising the simplex tableau; the general procedure for the sensitivity analysis, analyzing how changes in the model can potentially affect the solution; introduction to the dual-simplex algorithm.
Network optimization models: the transportation and assignment problems; the transportation simplex method and the Hungarian algorithm; the shortest path problem; the Dijkstra's algorithm; the minimum spanning tree problem; the maximum flow problem; the minimum cost flow problem; introduction to the network simplex method.
Dynamic programming: solving typical for the scope of OR problems using deterministic dynamic programming, concerning discrete and continuous decision variables; probabilistic dynamic programming.
Integer programming: applications; branch and bound algorithm for solving pure binary integer problems and mixed-integer problems; the branch-and-cut algorithm.
Nonlinear programming: graphical illustration, types of nonlinear problems, the Karush-Kuhn-Tucker condition for constrained optimization; quadratic programming.
Metaheuristics: solving typical for the scope of OR problems using tabu search, simulated annealing, ant colony optimization, and evolutionary algorithms.
Job scheduling: single and multi-stage job scheduling problems, open-shop problems, flow-shop problems, job-shop problems.
Queueing theory: basic queueing system, M/M/s processes.

Teaching methods

Lecture: slide show presentations on different sub-fields of Operational Research, illustrated with examples and practical assignments that serve as a summary of the lectures and preparation for the assessment test.
Laboratory classes: solving illustrative examples on board and coding problem solutions in Python, conducting computational experiments, discussion on the chosen methods, teamwork.

Bibliography

Basic:
Introduction to Operations Research, F. S. Hiller, G. J. Lieberman, McGraw-Hill, 2021.
Linear and nonlinear programming, D. G. Luenberger, Y. Ye., Springer, cop. 2008.

Additional:
Introduction to Stochastic Models in Operations Research, F. S. Hiller, G. J. Lieberman, McGraw-Hill, 1990.
Introduction to Operations Research, G. J. Ecker, M. Kupferschmid, John Wiley, 1988.
Linear programming : basic theory and applications, L. W. Swanson, McGraw-Hill Book Company, cop. 1980.

Breakdown of average student's workload

	Hours	ECTS
Total workload	125	5,00
Classes requiring direct contact with the teacher	62	2,50
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	63	2,50