COURSE DESCRIPTION CARD - SYLLABUS

Course name
Decision analysis [S1SI1E>ADEC]

Course

Field of study
Artificial Intelligence

Year/Semester
3/6

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 (e.g. online)
0

Tutorials
0

Projects/seminars
0

Number of credit points

5,00

Coordinators

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Lecturers

Prerequisites

Basic mathematical knowledge from mathematical analysis and linear algebra. Programming skills in Python. Knowledge acquired during the courses on Introduction to AI, Combinatorial Optimization, Operational Research, Machine learning, Deep learning, and Information Retrieval.

Course objective

The course aims to introduce the students to the main trends of Decision analysis (DA). In this first half of the semester, we will focus on Multiple Criteria Decision Aiding, which deals with evaluating decision alternatives in the presence of multiple criteria. MCDA is one of the branches of Operational Research and Artificial Intelligence that Poznan University of Technology is famous for. In the second half of the semester, we will start with game theory. It has been traditionally considered a study of strategic interactions between rational agents, but nowadays, it is more often considered a science of logical decision-making. Then, we will move to social choice theory focusing on combining individual preferences into a collective decision. Finally, we will come back to Multiple Criteria Decision Making, emphasizing optimization problems, where one should discover solutions that are good in terms of many relevant objectives.

Course-related learning outcomes

Knowledge:
K1st_W3: has a well-grounded knowledge of fundamental computer science problems within the scope of decision analysis, including multple criteria decision aiding, game theory, computational social choice, and multiple objective optimization
K1st_W4: knows and understands the basic techniques, methods, algorithms, and tools used for solving computer problems as well as problems in decision analysis, including method for decision aiding, game theory algorithms, voting methods and electoral systems, classical and evolutionary optimization methods
K1st_W5: has a basic knowledge of key directions and the most important successes of decision analysis understood as an essential sub-domain of artificial intelligence, making use of the achievements of other scientific disciplines (including sociology, political sciences, and economics) and providing solutions with a high practical impact; knows the history and recent trends in decision analysis

Skills:
K1st_U1: 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_U3: can formulate and solve complex decision problems (e.g., choice, ranking, classification, sorting, optimization) within the scope of computer science and, in particular, artificial intelligence, by applying appropriately selected methods
K1st_U4: can efficiently plan and carry out experiments, including computer measurements and simulations, interpret the obtained results and draw conclusions based on the experimental outcomes in the context of decision problems and approaching them with the preference learning methods
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; decision analysis, social choice and game theory are at the core of social and economic aspects of AI
K1st_U7: can carry out a critical analysis and an assessment of the functioning of both computer systems and AI methods, including decision aiding methods, optimization algorithms, and voting rules
K1st_U9: can adapt the existing algorithms as well as formulate and implement the novel algorithms in Python, including the algorithms typical for decision analysis applications
K1st_U10: can retrieve, analyze and transform different types of data (with the emphasis on multi-dimensional data), and carry out data synthesis to knowledge and conclusions useful for solving a variety of decision problems
K1st_U11: can adapt and make use of the models of intelligent behavior (e.g., artificial neural networks or decision support methods) as well as computer tools simulating such a behavior

Social competences:
K1st_K1: understands that knowledge and skills quickly become outdated in 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 AI in solving practical problems which are essential for the functioning of individuals, firms, organizations as well as the entire society
K1st_K3: knows the examples of poorly functioning AI systems, which led to the economic, social, or environmental losses
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:

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Lecture: exam in the form of an assessment test. At the students" request, it may be divided into two parts. 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 or 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.

Programme content

Introduction to Multiple Criteria Decision Analysis and the PROMETHEE methods: operational research vs. decision analysis, multiple criteria decision problems, preference information, preference model, the general scheme of MCDA methods, an overview of PROMETHEE, marginal preference functions, preference degrees, ranking construction in PROMETHEE I and II, selection of the most preferred subset of alternatives in PROMETHEE V, example applications of PROMETHEE.
Multiple criteria sorting with the ELECTRE TRI-B method: main principles of ELECTRE TRI-B, an overview of ELECTRE, concordance and discordance tests, outranking credibility, the SRF procedure for weight elicitation, pessimistic and optimistic assignment procedures, example applications of ELECTRE TRI-B.
Multi-Attribute Value Theory and preference disaggregation in the UTA method: additive value function, bisection method, SWING method, preference disaggregation, ordinal regression, UTA method, Kendall"s tau, dealing with inconsistency, UTADIS method, example applications of UTA-like methods.
Analytical Hierarchy Process and the Choquet integral: hierarchical problem structuring, prioritization of hierarchy elements, pairwise comparisons on a ratio scale, eigenvector method, computing scores in AHP, inconsistency verification, condition of order preservation, rank reversal, example applications of AHP, weighted sum, the meaning of weights in various methods, the Choquet integral.
Rough Set Based Decision Support - Classical Rough Set Approach: vague concepts, granules of knowledge, lower and upper approximations, class boundaries, reducts and core, decision rule, the LEM2 algorithm for rule induction, certain, possible, and approximate rules, classification with bucket brigade algorithm, example applications of rough set theory.
Introduction to Preference learning: Choquistic Regression and ANN-based Algorithms: the role of preferences in the contemporary world, preference learning, object, instance, and label ranking, performance measures, machine learning vs. MCDA, from logistic regression to Choquistic regression, neural networks in preference learning.
Game Theory - Solution Concepts in Strategic Games: strategic games in normal form, split or steal, prisoner"s dilemma, Pareto efficiency, pure Nash equilibria, mixed Nash equilibria, battle of the sexes, the game of chicken, computing Nash equilibria, elimination of dominated strategies, correlated equilibria
Game Theory - Congestion and Extensive Games: congestion games, traffic congestion, El Farol Bar problem, Rosenthal theorem, potential games, the existence of pure Nash equilibria, Moderer and Shapley theorem, better-response dynamics, price of anarchy, Braess" paradox; extensive games, translation from the extensive into the normal form, Zermelo"s theorem, backward induction, subgame perfect equilibria, ultimatum game, centipede game.
Social Choice Theory - Voting Rules: computational social choice, how do we vote, the most famous voting rules (stage procedures, positional scoring rules, Condorcet extensions, non-standard rules) and electoral systems (majoritarian, proportional, semi-proportional, mixed).
Social Choice Theory - Additional Aspects (Properties, Theorem, Manipulation, Power indices): properties (e.g., anonymity, neutrality, monotonicity, independence of irrelevant alternatives, Pareto, non-dictatorship, strategyproofness); voting paradoxes, impossibility theorems (May"s Theorem, Arrow"s Theorem, and Sen"s Theorem), manipulation, Gibbard-Satterthwaite Theorem, control, the Shapley-Shubik and Banzhaf power indices.
Introduction to Multiple Objective Optimization - Classical Optimization Methods: example MOO problems, formulation of MOO problem, types of MOO methods, what means solving MOO problem, weight sum method, epsilon constraint method, achievement scalarizing function, no-preference method, the general scheme of interactive optimization methods.
Introduction to Evolutionary Multiple Objective Optimization: evolutionary optimization, goals in evolutionary MOO, various population models, fitness assignment procedures, preserving elitism, diversity preservation, famous MOO methods: NSGA-II, SPEA2, SMS-EMOA, MOEA/D.

Teaching methods

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

Bibliography

Basic
1. A. Ishizaka, P. Nemery, Multi-criteria Decision Analysis: Methods and Software, Wiley, 2013.

2. M.J. Osborne, An Introduction to Game Theory. Oxford University Press, 2004.
3. J. Branke, K. Deb, K. Miettinen, R. Słowiński, Multiobjective Optimization: Interactive and Evolutionary Approaches. Springer, Berlin, 2008.
4. J. Fürnkranz, E. Hüllermeier, Preference Learning. Springer, Berlin, 2010.
Additional
1. S. Corrente, S. Greco, M. Kadziński, R. Słowiński, Robust ordinal regression in preference learning and ranking, Machine Learning 93 (2), 381-422, 2013.
2. M. Cinelli, M. Kadziński, M. Gonzalez, R. Słowiński, How to support the application of multiple criteria decision analysis? Let us start with a comprehensive taxonomy, Omega 96, 102261, 2020.
3. M. Cinelli, M. Kadziński, G. Miebs, M. Gonzalez, R. Słowiński, Recommending Multiple Criteria Decision Analysis Methods with A New Taxonomy-based Decision Support System, European Journal of Operational Research, 2022.
4. M. Kadziński, S. Greco, R. Słowiński, Robust ordinal regression for dominance-based rough set approach to multiple criteria sorting, Information Sciences 283, 211-228, 2014.
5. MK. Tomczyk, M. Kadziński, Decomposition-based interactive evolutionary algorithm for multiple objective optimization, IEEE Transactions on Evolutionary Computation 24 (2), 320-334, 2019.

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