Anexa 39
H.S. 17/30.01.2025

Pt aviz CA şi aprobare SUO
Prorector MA,

CURRICULUM

Valid from academic year 2024-2025

UNIVERSITY OF ORADEA

Doctoral School of Engineering Sciences
Belnded Intensive Programme (BIP) - Introduction to Mathematical and Computational Modelling for Sustainability
Duration of studies / no. of credits: ***3 months / 6 credits***

APROBAT ÎN ŞEDINŢA DE SENAT
DIN DATA DE
30.IAN. 2025
Preşedinte:
Conf.univ.dr. Vasile-Aurel CĂUŞ

1. MISSION OF THE STUDY PROGRAMME (BIP) - Introduction to Mathematical and Computational Modelling for Sustainability

This 6ECTS BiP will give an introduction to mathematical and computational modelling techniques for application in developing understanding and supporting sustainable decision making in health, environmental, societal, and industrial systems. The programme is designed for students at the Masters or Doctoral level who wish to develop these skills for application in research projects aligned to the EU Green research themes. This programme prioritises high-level strategic thinking in the design and analysis of modelling paradigms and how they can be applied for effective decision making. Interpersonal skills together with technical skills are central to the learning outcomes.

The aim of this Summer School is to provide students with the basics of mathematical and computational modeling techniques with applicability in developing digital models and supporting sustainable decision making in the health, environmental, societal and industrial domains. The program is designed for students at Master or PhD level who wish to develop these skills to apply them in research projects aligned to the EU GREEN research themes. This programme prioritizes high-level strategic thinking in the design and analysis of modelling paradigms and how they can be applied for effective decision-making. Interpersonal skills, together with technical skills, are essential for learning outcomes.

2. OBJECTIVES OF THE STUDY PROGRAMME (BIP) - Introduction to Mathematical and Computational Modelling for Sustainability

- Familiarization with fundamental approaches to mathematical and computational modeling methods, techniques and tools, including differential equations, machine learning/AI, finite difference/element/volumetric methods, cellular automata and optimization algorithms.
- Develop awareness of methods that may be suitable for different types of research problems, together with the potential benefits, challenges and limitations of each approach
- Develop skills in application of these methods to real-world multidisciplinary research problems aligned to the EU Green themes
- Develop student transferable skills in group working and communication;
- Help to create a culture of international and cross-discipline collaboration in postgraduate research at the EU Green institutions

Postgraduate students will develop skills in translating broad-ranging real-world problems in a mathematical/computational framework and be familiar with fundamental tools in analysing models for problem solving, particularly in the context of sustainability. Students can be from any discipline but should normally have completed at least 5 ECTS relevant to Mathematics/Statistics at undergraduate level. The programme will focus on familiarity with different methods, their potential applications and their limitations and will enable students to select specific topics for further in-depth study.

3. COMPETENCES THAT GRADUATES WILL OBTAIN UPON THE COMPLETION OF STUDIES

Professional competences:

- Become familiar with:
  - Different applications and benefits of mathematical/computational models. Stochastic vs Deterministic, Continuous vs Discrete etc.
  - Real world relationships based on rates of change and their mathematical formulation
  - Basic concepts in the numerical solution of partial differential equations (PDEs)
  - Markov Chains and their applications
  - Cellular automata models (CA) and their applications
  - Probability as a framework for quantiying uncertainty, Monte Carlo methods
  - Supervised and unsupervised learning approaches
  - Problem modelization with constraints, declarative programming
  - Problem modelization with relations expressed as constraints
- Become aware of:
  - The modelling process. Challenges and limitations in the development and use of models. Importance of model verification and validation strategy
  - How interactions within a complex system can be modelled as a system of Ordinary Differential Equations (ODEs)
  - How to develop and use basic methods for numerical solution of partial differential equations
  - How a Markov Chain is formulated and identify the main problems to solve
  - How real world systems can be translated into a CA model framework
  - Probability distributions, state transitions, Monte Carlo simulations
  - Different types of data; the difference between classification and regression
  - The difference between a decision variable, and a standard computer science variable
  - The impact of the solution landscape on the search process
- Analyze:
  - Model performance (quantitative and qualitative), usefulness in the context of the problem to be solved
  - Behaviour of model vs behaviour of the real world system, validity of assumptions/hypotheses
  - Properties for different methods for partial differential equations
  - Properties of a Markov Chain
  - Properties of a CA model
  - Parameter uncertainty, model predictive uncertainty
  - Bias-variance tradeoffs
  - Possible decision variables and constraints
  - Adequate heuristics
- Assess:
  - Nature of the the problem to be solved, the goal of the modelling task
  - Parameter Uncertainty and Model predictive uncertainty, system stability
  - Deficiencies and limitations of the considered methods
  - Limitations of Markov Chains to model certain problems
  - Limitations of CA to model certain problems
  - Limitations of Monte Carlo methods
  - Complexity and dimension of a machine learning problem
  - Difficulty of a problem
  - Adequacy of different metaheuristics
- Know how:
  - To approach model formulation and data gathering. How to approach solving a model and to verify and interpret the solution

- To simulate systems using a commonly available computer package
  - To implement numerical methods for PDEs
  - How to infer the state using standard algorithms
  - To simulate CA systems using a computer package
  - To implement Monte Carlo methods via a computer package
  - Generate models; choose performance measures; estimate the model performance
  - How to model a problem
  - How to find the decision variables and constraints
  - How to choose a single or hybrid metaheuristic
- Be able to:
  - Justify and present the approach to formulation of a model and its analysis in the context of the real-world problem to be addressed
  - Formulate systems of ODEs based on physical knowledge and communicate to a non-expert audience
  - Formulate suitable numerical methods for solving scientific and engineering problems described by PDEs
  - Implement the algorithms and adapt them to specific cases
  - Formulate CA models of some case study real-world systems
  - Formulate and simulate simple stochastic models of real-world systems
  - Implement and optimize a low dimension modeling problem
  - Model a problem
  - Improve a model, help the solver with strategies and symmetry breaking
  - Determine usefulness thresholds, choose among different metaheuristics
- Knowledge about:
  - Approaches to formulating, solving and testing models
  - Developing, simulating and analysing mathematical models of dynamic systems
  - Solving PDEs for scientific and engineering problems
  - Solving Markov Chain problems using Python
  - Developing, simulating and analysing CA models of discrete dynamic systems
  - Uncertainty and probability and how it can be managed in a modelling framework
  - Data manipulation and Machine Learning Python packages
  - Modelization languages, constraint solvers, solver fine-tuning, search parameters
- Understand how
  - Mathematical and Computational models can provide insight and predictions about systems, with an understanding of limitations and challenges
  - How a model can assist in testing hypotheses and predicting future behaviour and how data limitations can result in high uncertainty
  - To interpret the results in the context of the problem and objectives
  - How modelling errors influence the predictions
  - CA models can give insight into real world physical systems and assist in decision making
  - Stochastic modelling approaches can handle uncertainty in real-world systems and provide probabilistic outcomes
  - Quality and quantity of data influence the model
  - How a model can influence the effectiveness and efficiency of resolution, how a good strategy can influence efficiency

Transversal competences:

- Completion of professional tasks on time, rigorously and responsibly, in conditions of efficiency and effectiveness, in compliance with the ethical principles of scientific activity, rigorous application of citation rules and rejection of plagiarism and other requirements.
- Application of group communication techniques and effective teamwork, assuming various roles.

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Module	Hours				Verification	Credits	IS [hours / sem.]
	C	S	L	P			
Module 1	12		4		Ex	2	34
Overview of Modelling Differential equation based models Numerical Methods for partial differential equations							
Module 2	12		4		Ex	2	34
Finite Dynamical systems - Markov Chains Cellular automata/Agent-based models Stochastic modelling, Monte Carlo methods							
Module 3	12		4		Ex	2	34
Introduction to Machine Learning - Classification and Regression problems Constraint Modeling and Constraint solving Local Search and Metaheuristics							
TOTAL	**36**		**12**			**6**	**102**

Legend: C - Course; S - Seminar; L - Laboratory; P - Project; IS – Individual Study;Ex. – Examination

ONE CREDIT POINT REQUIERES A TOTAL OF 25 HOURS OF STUDY PROGRAM, DIDACTIC AND INDIVIDUAL ACTIVITY.

Head of Doctoral School ,
Prof.univ.dr.ing. habil. Iulian Stănășel

RECTOR,
Prof.univ.dr.ing.habil. BUNGĂU Constantin

ROMÂNIA
MINISTERUL EDUCAȚIEI ȘI CERCETĂRII
UNIVERSITATEA DIN ORADEA
RECTORAT

DEAN,
Conf.univ.dr. HULE Voichița Ionela

Universitatea din Oradea * România *
DECANAT
Facultatea de Inginerie Managerială și Tehnologică

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