DOCTORAL (PHD) STUDIES

COURSE UNIT DESCRIPTION

Course unit title	Scientific areas	Faculty	Institute, department
Fundamental methods of informatics and informatics engineering science	Informatics (N 009) Informatics engineering (T 007)	Faculty of Mathematics and Informatics	Institute of Data Science and Digital Technologies, Institute of Computer Science

Study method	Number of credits	Study method	Number of credits
Lectures	1 (autumn)	Consultations	1
Individual works	4	Seminars	1

Summary

The course aim is to familiarize doctoral students with the most important fundamental methods of informatics and computer engineering, which must be known to any scientist working in the fields of informatics or computer engineering.

Main topics:

1. Set theory (*Julius Žilinskas*)
   - Background of set theory; Relations
   - *Practical task*: operations with sets
2. Graph theory (*Julius Žilinskas*)
   - Definitions and properties of graphs; Problems and algorithms on graphs
   - *Practical task*: example problem on graphs
3. Optimization theory (*Julius Žilinskas*)
   - Formulation of optimization problems, classification of optimization problems; Linear programming; Unconstrained optimization; Nonlinear programming
   - *Practical task*: solution of a given example optimization problem
4. Complexity theory (*Julius Žilinskas*)
   - Complexity of algorithms; NP-completeness
   - *Practical task*: proof of NP-completeness of a given problem
6. Analysis of digital signals (*Gintautas Tamulevičius*)
   - Signal definition, input and digitization, signal and sequence correlation, convolution, analysis of signals and time sequences, transforms, spectral analysis

   Practical task: analysis of signals and time sequences
7. Machine learning (*Virginijus Marcinkevičius*)
   - Basic concepts. Types of machine learning systems: supervised/unsupervised learning, batch and online learning, instance-based and model-based learning. Main challenges of machine learning

   Practical task: Get familiar with data: data visualization, filtering, normalization, enrichment, anomaly detection and repair
8. Data mining (*Olga Kurasova*)

- Data scales, knowledge discovery in databases, data pre-processing methods, tasks and basic methods of data classification, clustering and forecasting, search of pattern and frequency sequences, visual data analysis, ethical questions of data analysis

  Practical task: data mining using one of the systems (Weka, Orange, etc.)

9. Artificial neural network (*Olga Kurasova*)
   - Concept of artificial intelligence, technologies based on artificial intelligence, concept of artificial neural networks, realtion of artificial neuron with biological, types of artificial neural networks: feed-forward neural networks, feed-back (recurrent) neural networks, multilayer perceptron and its training by error back-propagation algorithm, convolutional neural network, solving classification and prediction problems using artificial neural networks

     Practical task: to solve the classification or prediction problem using artificial neural networks using the chosen system (WEKA, R, TensorFlow, Keras, etc.)
10. Evaluation of statistical reliability of results in informatics research (*Audronė Jakaitienė*)
    - Measurement errors; parameter uncertainty; confidence intervals; significance

      Practical task: uncertainty analysis of estimated characteristics' for a selected data
11. Mathematical modelling and analysis (*Romas Baronas*)
    - Development and analysis of mathematical models, development and analysis of numerical algorithms, analysis of experimental results, obtaining and analysis of new information about simulated processes, systems and phenomena.

      Practical task: choose practical mathematical model and solve it numerically by applying suitable for this tool (MATLAB, MathCad, Maple, etc.).
11. Information systems and databases (*Romas Baronas*)
    - Principles of information systems development; conceptual, logical and physical data models; database design and implementation

      Practical task: choose an application (subject) area, develop conceptual and logical data models for the subject area, implement the logical model by creating a database.
12. Specification and verification of software-based systems (*Linas Laibinis*)
    - Overview of formal specification (modelling) languages and semantics for software-based systems, the notions of program correctness and refinement, different kinds of system properties and the methods for their formalisation and verification, the automated verification environments based on theorem proving and model checking techniques

      Practical task: in a chosen specification language, to create a formal model of a described simple software-based system and formulate the conditions for its correctness or other verification properties

Main literature

Ian Goodfellow, Yoshua Bengio, Aaron Courville. Deep Learning (2016). Prieiga internete http://www.deeplearningbook.org

William Kocay, Donald L. Kreher (2016) Graphs, Algorithms, and Optimization, Second Edition. Chapman and Hall/CRC.

Edwin K. P. Chong, Stanislaw H. Zak (2013) An Introduction to Optimization. Wiley.

R. Baronas, F. Ivanauskas, J. Kulys (2021). Mathematical Modeling of Biosensors, 2nd ed., Springer. ISBN 978-3-030-65504-4.

R. Elmasri, S.B. Navathe (2016). Fundamentals of Database Systems, 7th ed., Pearson.

https://www.cl.cam.ac.uk/teaching/0809/Semantics/notes-mono.pdf

M. J. Crawley. R Book (2013). The Second Edition. Willey https://www.cs.upc.edu/~robert/teaching/estadistica/TheRBook.pdf

Bell, S. A. (2001). A beginner's guide to uncertainty of measurement.

Gierlinski, Marek. Understanding Statistical Error : A Primer for Biologists, John Wiley & Sons, Incorporated, 2016. ProQuest Ebook Central, https://ebookcentral.proquest.com/lib/viluniv-ebooks/detail.action?docID=4529318 .
Géron, A. (2019). Hands-on machine learning with Scikit-Learn, Keras, and TensorFlow: Concepts, tools, and techniques to build intelligent systems. O'Reilly Media.
J. G. Proakis and D. Manolakis (2007). Digital Signal Processing. Pearson Prentice Hall.

Lecturer(s) (name, surname)	Science degree	Main publications
Romas Baronas	(HP) dr.	http://www.elaba.mb.vu.lt/mif/?aut=Romas+Baronas
Audronė Jakaitienė	dr.	http://www.elaba.mb.vu.lt/dmsti/?aut=Audronė+Jakaitienė
Olga Kurasova	dr.	http://www.elaba.mb.vu.lt/dmsti/?aut=Olga+Kurasova
Linas Laibinis	dr.	http://www.elaba.mb.vu.lt/mif/?aut=Linas+Laibinis
Virginijus Marcinkevičius	dr.	http://www.elaba.mb.vu.lt/dmsti/?aut=Virginius+Marcinkevičius
Gintautas Tamulevičius	dr.	http://www.elaba.mb.vu.lt/dmsti/?aut=Gintautas+Tamulevičius
Julius Žilinskas	(HP) dr.	http://www.elaba.mb.vu.lt/dmsti/?aut=Julius+Žilinskas