University of Ljubljana, Faculty of Computer and Information Science
Doctoral study programme Computer and Information Science

Elective courses BDR-RI 2019/2020

All courses are 5 ECTS. There are two types of courses available.

The **lecture** type courses are delivered as regular lectures and follow the format 15-20-15 (lectures-seminar-tutorial hours).

The **individual research** type courses are designed to introduce advanced technological breakthroughs or practical solutions in computer and information science. Students work under the supervision of the lecturer on a seminar topic that is related to the student's doctoral research topic. Each course can be selected by at most two students. The lecturer of the course must not be the advisor or co-advisor of the student selecting the course. Each student can select only one individual research course.

Lecture type courses offered in 2019/2020:

Individual research type courses offered in 2019/2020:

Incremental Learning from Data Streams

(Selected Topics in Artificial Intelligence 1, Marko Robnik Šikonja)
Lecturer: Zoran Bosnić
Course code: 63834
Course type: lectures, fall (first) semester

The goal of the proposed course is to teach students about the state-of-the-art algorithms that are used to perform learning from data streams. The course will guide the students through the major open challenges in the field (supervised learning, data compression, concept drift detection, clustering from streams, specialized evaluation statistics). With this knowledge, the students will be able to apply their machine learning skills to a specialized and useful area that is connected to the abundance of data in our everyday lives (bank/weather/financial transactions, sensor readings, etc.). The course will be organized by mixing lectures with hands-on lab exercises that the students will do in the Statistical package R. The lab exercises will include applying the acquired knowledge on their own problem and stimulating a competition between students to achieve the best possible learning results.

Linear Algebra for Machine Learning

(Selected Topics in Mathematical Methods in Computer Science 1, Polona Oblak)
Lecturer: Polona Oblak
Course code: 63828A
Course type: lectures, fall (first) semester

In this course, we will study the theory of matrices behind the basic concepts of machine learning. We will present the matrix algebra and derivations of and over matrices. These definitions are crucial to understand the optimization methods in machine learning. We will start the course with a general introduction, and then we will proceed to cover these topics: trace, norm, distance, angle, orthogonality; Kronecker product, vec operator, Hadamard product; linear systems and generalized inverses; Moore-Penrose inverse. Determinants; linear, bilinear and quadratic forms; eigenvalues and eigenvectors of matrices; matrix differentiation; polar decomposition; Hessian; minimization of a second-degree n-variable polynomial subject to linear constraints. We will conclude the course with some applications to machine learning.

Modern Cryptography and Computer Security

(Selected Topics in Mathematical Methods in Computer Science 1, Polona Oblak)
Lecturer: Aleksandar Jurišić
Course code: 63828B
Course type: lectures, fall (first) semester

This course is an introduction to modern cryptography, which provides maximum security while at the same time preserves the flexibility of digital media. It forms the foundation of Information Society (objectives: privacy, data integrity, digital authentication/signatures, digital cash, and other cryptographic protocols; it covers mathematics, computer science, electrical engineering, finances, policy, defense, etc.). We will discuss rigorous definitions of security in various situations. We will review basic mathematical problems used in cryptography and related complexity considerations. We will build more complex protocols from simpler primitives, and will prove the more complex protocols meet their security objectives.

In this course, we will study selected topics from symmetric cryptography (classical ciphers and history of cryptography, stream ciphers, Shannon theory of information, block ciphers, cryptoanalysis and statistical methods, hash functions, authentication codes, birthday paradox attacks), asymmetric (public-key) cryptography (cryptosystems, digital signatures, key agreement protocols, identification schemes, other protocols), computer and information security (security of programs, security of databases, security of OS and real time security management, security of network communications, privacy in CS, key managements, efficient and secure implementation of cryptosystems).

Predictive Analytics for Structured Data

(Selected Topics in Artificial Intelligence 2, Marko Robnik Šikonja)
Lecturer: Sašo Džeroski
Course code: 63835B
Course type: lectures, spring (second) semester

The course will introduce different tasks of structured output prediction and describe a variety of approaches for solving such tasks. The students will get to know some state-of-the-art tools for solving such tasks and examples of their use in practice. Within the course, the students will learn to apply predictive analytics methods for structured data in the context of their research.

In this course, we will study the different tasks of structured output prediction, such as multi-target classification/regression and (hierarchical) multi-label classification, predictive clustering methods (tree and rule-based) for structured output prediction, ontologies for data mining and their use for describing structured output prediction, ensemble methods for structured output prediction (tree and rule ensembles), applications of structured output prediction to different practical problems from areas such as environmental and life sciences, and image annotation and retrieval. In the practical hands-on work students will be guided through a series of methods for predicting structured outputs. They will analyse relevant data sets (from ecology and systems biology) and that represent different tasks of predicting structured outputs, e.g., multi-target regression, multi-label classification, hierarchical multi-label classification. In the last part of the course, each student will apply and test methods for predicting structured outputs on a selected relevant doctoral research problem.

Advanced Topics in Network Science

(Selected Topics in Artificial Intelligence 2, Marko Robnik Šikonja)
Lecturer: Lovro Šubelj
Course code: 63835A
Course type: lectures, spring (second) semester

This course will first introduce the language of networks and review the fundamental concepts and techniques for the analysis of large real-world networks. In the main part of the course, the students will learn about selected advanced topics in network science with special emphasis on the practical applicability of the presented approaches. The topics will include node metrics, groups and patterns, large-scale network structure, network sampling, comparison, modeling, mining, inference, visualization and dynamics. The last part of the course will be devoted to invited talks on network science from the perspective of mathematicians, physicists, social scientists and other.

The objective of the course is not to give a comprehensive theoretical discussion or in-depth review on any of the topics, but to present a rich set of network science tools that students could use in their own doctoral research work. The latter will be the main part of the coursework. Except for a clearly identified doctoral topic, there are no specific prerequisites for the course. However, the students will benefit from a solid knowledge in graph theory, probability theory and linear algebra, good programming skills in a language of their choice, and familiarity with research work and scientific writing.

Contemporary Approaches to Algorithm Design

(Selected Topics in Architectures and Algorithms 1, Borut Robič)
Lecturers: Borut Robič, Jurij Mihelič
Course code: 63824
Course type: lectures, spring (second) semester

In this course, we will study the main contemporary approaches to the design of algorithms. These approaches include various analysis techniques, design methods and computation models. The students will learn how to apply algorithm engineering (which aims to bridge the gap between theory and practice), use multi-level memory hierarchy and design cache-oblivious algorithms, speed up exact exponential algorithms (e.g., by branching techniques), design parameterized algorithms (algorithms that take advantage of specific inputs bound to a parameter), design approximation algorithms (fast algorithms that return approximate results of good quality), design randomized algorithms (fast algorithms that return uncertain results of good confidence), design quantum algorithms (algorithms that integrate quantum reality into computation). Finally, we will describe the concept of the realistic (as opposed to the worst-case) complexity of algorithms and computational problems.

Heterogeneous Computing Platforms

(Selected Topics in Computer Systems 1, Miha Mraz)
Lecturer: Uroš Lotrič
Course code: 63830A
Course type: individual research, fall (first) semester

The aim of this course is to deal with the state-of-the-art platforms and technologies, which present an important direction in ensuring enough computing performance for increasing computational requirements. Students will work with different types of hardware accelerators like GPU, FPGA, multicore CPU, and their combinations. For a selected problem, related to their doctoral thesis, they will have to recognize an interesting platform and then implement and evaluate their problem on it.

In this course, we will study the speed-up of complex algorithms on modern hardware, how to combine CPU and custom FPGA circuits, programmed in OpenCL, and how to analyse the effect of number representation to reduce computational cost and save energy.

Approximate Arithmetic for Media Processing and (C)NNs

(Selected Topics in Computer Systems 1, Miha Mraz)
Lecturer: Patricio Bulić
Course code: 63830B
Course type: individual research, spring (second) semester

The need to support various signal and media processing and recognition applications on energy-constrained mobile computing devices has steadily grown. In recent years there has been a growing interest in hardware neural networks, which express many benefits over conventional software models, mainly in applications where speed, cost, reliability, or energy efficiency are of great importance.

The standard hardware implementations of these algorithms and (convolutional) neural networks require many resource-, power- and time-consuming arithmetic (mainly multiplication) operations thus the goal is to reduce the size and power consumption of arithmetic circuits. In particular, in order for large (C)NNs to run in real-time on resource-constrained systems, it is of crucial importance to simplify/approximate MAC units, since they are usually responsible for significant area, power and latency costs. One option to achieve this goal is to replace the complex exact multiplying circuits with simpler, approximate ones. Approximate computing forms a design alternative that exploits the intrinsic error resilience of various applications and produces energy-efficient circuits with small accuracy loss.

In the course, we will study the importance of low-power, low-memory solutions, evaluate accuracy of media processing algorithms and CNNs based on approximate computing, evaluate power reduction in approximate circuits and investigate training-time methodologies to compensate for the reduction in accuracy. During the course, the students will implement various circuits in FPGAs and evaluate them in terms of speed, area and power consumption.