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

Elective courses BDR-RI 2022/2023

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 introduce advanced technological breakthroughs or practical solutions in computer and information science. Students work under the lecturer's supervision on a seminar topic 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 2022/2023:

Individual research type courses offered in 2022/23:

Advanced Algorithms for Search and Planning

(Selected Topics in Artificial Intelligence 1, Zoran Bosnić)
Lecturer: Ivan Bratko
Course code: 63834A
Course type: lectures, fall (first) semester

The course covers advanced algorithms for the following problem-solving paradigms: state-space search, symbolic search, planning based on means-ends analysis (mostly approaches to partial order planning) and planning under uncertainty. The course assumes introductory knowledge of search and planning algorithms in AI (uninformed search, bestfirst search, and planning principles based on preconditions and effects of actions). The course includes advanced versions and extensions of search and planning algorithms, their theoretical properties, implementations and practical projects in combinatorial optimisation and robot programming. The course includes home assignments in experimentation with existing or own implementations of heuristic search on practical problems (with own ideas for heuristics), and a project in robot planning (or a planning problem of a student's choice, possibly related to the topics of their doctoral research).

Machine Learning for Language and Graphs

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

The course presents a collection of advanced machine learning topics used in representation learning and explainable artificial intelligence with focus on natural language processing, natural language understanding, knowledge graphs, and multi-relational learning. In particular, it addresses embedding techniques and deep learning approaches for texts and graphs. In this context it also covers ideas from ensemble learning and explainable artificial intelligences. The course covers relevant problems from knowledge graphs, computational linguistics and text mining, e.g., processing of linked data, learning multi-relational data, word sense disambiguation, topic detection, and specifics of morphologically rich languages. The course requires students to apply machine learning methods on graph and language processing tasks, preferably in the context of their research work.

INFOSEC of Socio-Technical Systems

(Selected Topics in Computer and Information Science, Tomaž Curk)
Lecturer: David Modic
Course code: 63818A
Course type: lectures, fall (first) semester

In this course, we will briefly discuss the foundations of informational security (INFOSEC), define socio-technical systems, discover ethics and laws as they pertain to cybersec kill-chain, and penetration testing activities. Our focus will be on the so-called soft INFOSEC skills. Some of the topics that will be covered include: Open Source Intelligence Gathering; Social engineering; phishing; intelligence gathering toolkits; and the psychology of effective manipulation, and security in general. An operational understanding of the Internet and familiarity with computers is a bonus. There will be a certain amount of practical work required and active participation in the course will be mandatory. The course is open to PhD students from any infosec related field (upon confirmation). Previous years have thought us that there is also strong interest from masters and undergraduate students, who are welcome to audit the course upon confirmation from the module convenor.

Heterogeneous Computing Platforms (IR)

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

In this course, we will deal with state-of-the-art platforms and technologies, which present a prevaling 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, preferably integrated into the high-performance computing system. For a selected application related to their doctoral thesis, they will have to recognize a suitable platform and then implement and evaluate the chosen application on it. In this course, we will study the speed-up of complex algorithms on modern hardware architectures, how to combine CPU and custom FPGA circuits to excel computation, and how to analyze the effect of number representation (fixed point, half-precision) to reduce computational cost and save energy.

Low-Power Hardware Designs for Next-Generation Signal Processing and Machine Learning Applications (IR)

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

The need to support various signal and media processing and recognition applications on energy-constrained mobile computing devices has steadily grown. There has been a growing interest in hardware neural networks in recent years, which express many benefits over conventional software models, mainly in applications where speed, cost, reliability, or energy efficiency are of great importance. Deep Neural Networks (DNN) are, presently, the most popular application models. Multilayered networks, characterized by many hidden layers and vast amounts of data to be trained, demand specialized, high-performance, low-power hardware architectures. DNN training and inference are computation-intensive processes: training requires high throughput, whereas inference needs a low latency.

In the last few years, FPGAs and GPUs vendors engaged in a race to offer the best hardware platform that runs computationally intensive algorithms quickly and efficiently. These algorithms' standard hardware implementations require many resources, power and time-consuming arithmetic operations (mainly multiplication). Hence the goal is to reduce the size and power consumption of internal arithmetic units. In particular, for large DNNs to run in real-time on resource-constrained systems, it is crucial to simplify/approximate tensor cores since they are usually responsible for the significant area, power and latency costs. One option to achieve this goal is to replace the complex exact arithmetic 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 a small accuracy loss.

In the course, we will study the importance of low-power hardware designs, evaluate the accuracy of media processing algorithms and DNNs based on approximate computing, evaluate power reduction in approximate circuits and investigate training-time methodologies to compensate for the decrease of accuracy. During the course, the students will implement various circuits in FPGAs/45nm CMOS and evaluate them in terms of speed, area, and power consumption.

Selected Topics in Analysis of Sound Signals (IR)

(Selected Topics in Software Development 1, Matija Marolt)
Lecturer: Matija Marolt
Course code: 63832
Course type: individual research course, fall (first) semester

Students will have the opportunity to explore the use of different methods for pattern recognition and machining learning (for example, deep neural networks) to solve the problems that we encounter when analyzing sound signals, such as identification of events in sound recordings, classification of sound recordings, transcription of music, detection of samples in music, etc. In the course of the semester, students will develop their own algorithm for solving a problem and send it to one of the evaluation campaigns (e.g., Mirex or DCASE), where its performance can be compared with approaches developed by other researchers (mostly doctoral students) around the world.

Selected Topics from Computer Graphics and Visualization (IR)

(Selected Topics in Software Development 1, Matija Marolt)
Lecturer: Ciril Bohak
Course code: 63832B
Course type: individual research course, fall (first) semester

Students will get to know the current methods and technologies in the field of three-dimensional computer graphics. Emphasis will be given to rendering different types of data: volumetric data, point clouds, mesh geometry, and logically defined geometry in the fields of medicine, biology, geodesy, and high energy physics. Because the rendered data can be very large, emphasis will also be given to application of appropriate algorithms and data structures for fast and real-time rendering, implementation of techniques on graphic processors and remote rendering. The students will get to know the benefits of modern graphics libraries (Vulkan, WebGPU) for addressing these challenges. In addition to the techniques, the students will also get acquainted with the different ways of visualizing such data, how to utilize different deep learning tools on the data for visualization preparation or visual parameter estimation and how to select suitable visualization method for an individual domain. Students will have an opportunity to collaborate and interact with other students and staff from one of the world's best Visual computing groups in the world at KAUST.