# Study plan

## Name of study plan: Master Specialization Digital Business Engineering, 2023

Faculty/Institute/Others:
Department:
Branch of study guaranteed by the department: Welcome page
Garantor of the study branch:
Program of study: Informatics
Type of study: Follow-up master full-time
Required credits: 106
Elective courses credits: 14
Sum of credits in the plan: 120
Note on the plan:

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Name of the block: Compulsory courses in the program
Minimal number of credits of the block: 56
The role of the block: PP

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Code of the group: NIE-DBE-PP.23
Name of the group: Compulsory Courses of Master Study Program for Students of Specialization Dig. Business Engineerng
Requirement credits in the group: In this group you have to gain 56 credits
Requirement courses in the group: In this group you have to complete 5 courses
Credits in the group: 56
Note on the group:

| Code | Name of the course / Name of the group of courses *(in case of groups of courses the list of codes of their members)* *Tutors,* ***authors*** *and guarantors (gar.)* | Completion | Credits | Scope | Semester | Role |
|---|---|---|---|---|---|---|
| NIE-KOP | **Combinatorial Optimization** *Petr Fišer, Jan Schmidt* ***Petr Fišer*** *Petr Fišer (Gar.)* | Z,ZK | 6 | 3P+1C | Z | PP |
| NIE-DIP | **Diploma Thesis** *Zdeněk Muzikář* ***Zdeněk Muzikář*** *Zdeněk Muzikář (Gar.)* | Z | 30 | 270ZP | L,Z | PP |
| NIE-MPI | **Mathematics for Informatics** *Francesco Dolce* ***Štěpán Starosta*** *Štěpán Starosta (Gar.)* | Z,ZK | 7 | 3P+2C | Z | PP |
| NIE-PDP | **Parallel and Distributed Programming** *Pavel Tvrdík* ***Pavel Tvrdík*** *Pavel Tvrdík (Gar.)* | Z,ZK | 6 | 2P+2C | L | PP |
| NIE-VSM | **Selected statistical Methods** *Petr Novák* ***Pavel Hrabák*** *Pavel Hrabák (Gar.)* | Z,ZK | 7 | 4P+2C | L | PP |

**Characteristics of the courses of this group of Study Plan: Code=NIE-DBE-PP.23 Name=Compulsory Courses of Master Study Program for Students of Specialization Dig. Business Engineerng**

| | | | |
|---|---|---|---|
| NIE-KOP | Combinatorial Optimization | Z,ZK | 6 |
| The students will gain knowledge and understanding necessary deployment of combinatorial heuristics at a professional level. They will be able not only to select and implement but also to apply and evaluate heuristics for practical problems. | | | |
| NIE-DIP | Diploma Thesis | Z | 30 |
| NIE-MPI | Mathematics for Informatics | Z,ZK | 7 |
| The course focuses on selected topics from general algebra with emphasis on finite structures used in computer science. It includes topics from multi-variate analysis, smooth optimization, and multi-variate integration. The third large topic is computer arithmetics and number representation in a computer along with error manipulation. The last topic includes selected numerical algorithm and their stability analysis. The topics are completed with the demonstration of applications in computer science. The course focuses on clear presentation and argumentation. | | | |
| NIE-PDP | Parallel and Distributed Programming | Z,ZK | 6 |
| 21st century in computer architectures is primarily influenced by the shift of the Moore's law into parallelization of CPUs at the level of computing cores. Parallel computing systems are becoming a ubiquitous commodity and parallel programming becomes the basic paradigm of development of efficient applications for these platforms. Students get acquainted with architectures of parallel and distributed computing systems, their models, theory of interconnection networks and collective communication operations, and languages and environments for parallel programming of shared and distributed memory computers. They get acquianted with fundamental parallel algorithms and on selected problems, they will learn the techniques of design of efficient and scalable parallel algorithms and methods of performance evaluation of their implementations. The course includes a semester project of practical programming in OpenMP and MPI for solving a particular nontrivial problem. | | | |
| NIE-VSM | Selected statistical Methods | Z,ZK | 7 |
| Summary of probability theory; Multivariate normal distribution; Entropy and its application to coding; Statistical tests: T-tests, goodness of fit tests, independence test; Random processes - stacionarity; Markov chains and limiting properties; Queuing theory | | | |

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Name of the block: Compulsory courses in the specialization
Minimal number of credits of the block: 30
The role of the block: PS

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Code of the group: NIE-DBE-PS.23
Name of the group: Compulsory Courses of Master Study Specialisation Digital Business Engineering
Requirement credits in the group: In this group you have to gain 30 credits
Requirement courses in the group: In this group you have to complete 5 courses
Credits in the group: 30
Note on the group:

| Code | Name of the course / Name of the group of courses *(in case of groups of courses the list of codes of their members)* *Tutors,* ***authors*** *and guarantors (gar.)* | Completion | Credits | Scope | Semester | Role |
|---|---|---|---|---|---|---|
| DA-DRS | **Digital Risk And Security (DA-DRS)** ***Michal Valenta*** | Z,ZK | 6 | 30KP+30KC | Z | PS |
| DA-DMI | **Data Mining** ***Michal Valenta*** | Z,ZK | 6 | 30KP+30KC | Z,L | PS |
| DD-DIN | **Digital innovation** ***Michal Valenta*** | ZK | 6 | | Z | PS |
| DD-DSG | **Digital strategy and governance** ***Michal Valenta*** | ZK | 6 | 2P+2C | Z | PS |
| DD-SMN | **Strategic management** ***Michal Valenta*** | ZK | 6 | 4P+0C | Z | PS |

**Characteristics of the courses of this group of Study Plan: Code=NIE-DBE-PS.23 Name=Compulsory Courses of Master Study Specialisation Digital Business Engineering**

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|---|---|---|---|
| DA-DRS | Digital Risk And Security (DA-DRS) | Z,ZK | 6 |

Information technology has become crucial in the growth, sustainability and support of enterprises. However, the pervasive use of technologies also incurs many business risks, anging from abuse, cybercrime, fraud, errors and ommissions. The objective of this course is to understand and analyse IT related business risks and and how these risks can be translated into an appropiate information risk management and security strategy and action plan. In the course, will first discuss the basics of IT Risk, Information Security, and some of the general and specific standards and frameworks to address them. Next, we will elaborate on the IT risk management and IT security functions in an organisation. Specific attention will be given to risk assessment methods, both qualitative and quantitative. The theoretical knowledge will be applied in a group project, where students will conduct a risk assessment in a real organisation, and present the results to the responsible managers. Guarantor and teacher: MSc. Steven De Haes, Ph.D.

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| DA-DMI | Data Mining | Z,ZK | 6 |

In the past decade, weve witnessed a huge increase in the amount of data being captured and stored. In these large datasets very useful knowledge is present, though often concealed in the vastness of the data. With data mining techniques patterns are automatically revealed from such large datasets. First, data mining techniques and applications are discussed. Next, we will go into popular predictive and descriptive data mining techniques, with applications in marketing and risk management. Also, analyses such as social network analysis, text mining, process mining, and Big Data will be looked at. Basic programming skills in Python will be learnt. The learned concepts, techniques and programming language will be applied and evaluated with a real-life case. Teaching takes place at University of Antwerpen. See the web page
https://www.uantwerpen.be/en/study/programmes/all-programmes/digital-business-engineering/about-the-programme/study-programme/

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| DD-DIN | Digital innovation | ZK | 6 |

This course focuses on innovation in the context of the digital, software-intensive economy. Starting from a broader perspective on innovation, both mainstream theories and thinking on innovation, as well as alternative views from challengers, are discussed. This includes omnipresent innovation models in which IT-related innovations are adopted by startups and scaleups (eg. blockchains or drones) and making them available in certain business domains, which requires agility and speed of development at the software level. Also, disruptive innovation, where existing value chains are challenged, is discussed with its requirement for new levels of productivity in software development. Leading theories are discussed and illustrated with local and international cases using guest lectures. Students of a master double degree specialisation Digital Business Engineering will attend this course during their stay at the partner university Antwerp.

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| DD-DSG | Digital strategy and governance | ZK | 6 |

The course provides a complete and comprehensive overview of what digital governance entails and how it can be applied in practice. The course is organized around the following three main themes: concepts and practices of digital governance, the impact of digital governance on business/IT strategic and operational alignment, and the notion of digital value and risk. The course is based on the teacher's knowledge obtained in applied research projects on the relationship between digital governance practices and digital value. To support the student in understanding and absorbing the material provided, the course uses short assignments and case studies. Students of a master double degree specialisation Digital Business Engineering will attend this course during their stay at the partner university Antwerp

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| DD-SMN | Strategic management | ZK | 6 |

In the first part of the course, the different concepts and perspectives of strategic management are analyzed. The basic characteristics of strategic thinking are being analyzed. Then the importance of mission/vision, as the starting point in strategic thinking, is being discussed. This is being linked to the broader concept of sustainability / corporate social responsibility. The remaining parts focus on the three basic dimensions of strategy: (1) the strategy content: business level strategy, corporate level strategy, and network level strategy (2) the strategy process: strategic formation, strategic change, and strategic innovation, (3) the strategy context: the industry context, the organizational context, and the international context. In each of the different chapters, the fundamental strategic management paradoxes are situated and evaluated in the strategic management theory. Attention is also given to some strategic management tools which can be used to manage the strategy process. Students of a master double degree specialisation Digital Business Engineering will attend this course during their stay at the partner university Antwerp

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Name of the block: Elective vocational courses in the branch/specialization
Minimal number of credits of the block: 0
The role of the block: VO

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Code of the group: NIE-DBE-VO.23

Name of the group: Elective Vocational Courses for Master Specializations Except Digital Bussiness Engineering
Requirement credits in the group:
Requirement courses in the group:
Credits in the group: 0
Note on the group:

| Code | Name of the course / Name of the group of courses *(in case of groups of courses the list of codes of their members)* *Tutors,* ***authors*** *and guarantors (gar.)* | Completion | Credits | Scope | Semester | Role |
|---|---|---|---|---|---|---|
| NI-ADM | **Data Mining Algorithms** *Rodrigo Augusto Da Silva Alves, Pavel Kordík, Daniel Vašata* ***Daniel Vašata*** *Pavel Kordík (Gar.)* | Z,ZK | 5 | 2P+1C | L | VO |
| NI-AIB | **Algorithms of Information Security** *Martin Jureček, Olha Jurečková, Róbert Lórencz* ***Martin Jureček*** *Róbert Lórencz (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-ADP | **Architecture and Design patterns** *Jan Kurš, Jan Zimolka, Tomáš Chvosta, Jiří Borský, Filip Křikava* ***Jan Kurš*** *Filip Křikava (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-AM1 | **Middleware Architectures 1** *Tomáš Vitvar, Jaroslav Kuchař* ***Jaroslav Kuchař*** *Tomáš Vitvar (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-AM2 | **Middleware Architectures 2** *Tomáš Vitvar, Jaroslav Kuchař* ***Jaroslav Kuchař*** *Tomáš Vitvar (Gar.)* | Z,ZK | 5 | 2P+1C | L | VO |
| NI-BML | **Bayesian Methods for Machine Learning** *Kamil Dedecius, Ondřej Tichý* ***Ondřej Tichý*** *Kamil Dedecius (Gar.)* | KZ | 5 | 2P+1C | L | VO |
| NI-BVS | **Embedded Security** *Martin Novotný* ***Martin Novotný*** *Martin Novotný (Gar.)* | Z,ZK | 5 | 2P+2C | L | VO |
| NI-BKO | **Error Control Codes** *Pavel Kubalík* ***Pavel Kubalík*** *Pavel Kubalík (Gar.)* | Z,ZK | 5 | 2P+1C | L | VO |
| NI-DSV | **Distributed Systems and Computing** *Pavel Tvrdík* ***Jan Fesl*** *Pavel Tvrdík (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-DDW | **Web Data Mining** *Jaroslav Kuchař, Milan Dojčinovski* ***Jaroslav Kuchař*** *Jaroslav Kuchař (Gar.)* | Z,ZK | 5 | 2P+1C | L | VO |
| NI-EPC | **Effective C++ programming** *Daniel Langr* ***Daniel Langr*** *Daniel Langr (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-EVY | **Efficient Text Pattern Matching** *Jan Holub* ***Jan Holub*** *Jan Holub (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-FME | **Formal Methods and Specifications** *Stefan Ratschan* ***Stefan Ratschan*** *Stefan Ratschan (Gar.)* | Z,ZK | 5 | 2P+1C | L | VO |
| NI-GEN | **Code Generators** *Petr Máj, Jan Janoušek* ***Petr Máj*** *Jan Janoušek (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-GAK | **Graph theory and combinatorics** *Michal Opler* ***Tomáš Valla*** *Tomáš Valla (Gar.)* | Z,ZK | 5 | 2P+2C | L | VO |
| NI-HWB | **Hardware Security** *Jiří Buček* ***Jiří Buček*** *Jiří Buček (Gar.)* | Z,ZK | 5 | 2P+2C | L | VO |
| NI-KOD | **Data Compression** *Jan Holub* ***Jan Holub*** *Jan Holub (Gar.)* | Z,ZK | 5 | 2P+1C | L | VO |
| NI-MKY | **Mathematics for Cryptology** *Martin Jureček, Róbert Lórencz* ***Róbert Lórencz*** *Róbert Lórencz (Gar.)* | Z,ZK | 5 | 3P+1C | L | VO |
| NI-MVI | **Computational Intelligence Methods** *Pavel Kordík* ***Pavel Kordík*** *Pavel Kordík (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-MEP | **Modelling of Enterprise Processes** *Robert Pergl, Marek Suchánek* ***Robert Pergl*** *Robert Pergl (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-MPJ | **Modelling of Programming Languages** ***Jan Vitek*** | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-MTI | **Modern Internet Technologies** *Alexandru Moucha, Viktor Černý* ***Alexandru Moucha*** *Alexandru Moucha (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-NUR | **User Interface Design** *Josef Pavlíček* ***Josef Pavlíček*** *Josef Pavlíček (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-NON | **Nonlinear Continuous Optimization and Numerical Methods** *Jaroslav Kruis* ***Jaroslav Kruis*** *Jaroslav Kruis (Gar.)* | Z,ZK | 5 | 2P+1C | Z,L | VO |
| NI-NSS | **Normalized Software Systems** *Robert Pergl, Marek Suchánek, Jan Verelst* ***Robert Pergl*** *Robert Pergl (Gar.)* | ZK | 5 | 2P | L | VO |
| NI-OSY | **Operating Systems and Systems Programming** *Petr Zemánek, Tomáš Martinec* ***Petr Zemánek*** *Petr Zemánek (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-BUI | **Business Informatics** *Petra Pavlíčková* ***Petra Pavlíčková*** *Petra Pavlíčková (Gar.)* | Z,ZK | 5 | 2P+2C | L | VO |
| NI-PIS | **Enterprise Information Systems** *Martin Závrbský, Martin Mach, Vlastimil Jinoch, Martin Hasaj* ***David Buchtela*** *David Buchtela (Gar.)* | Z,ZK | 5 | 2P+1C | L | VO |
| NI-KRY | **Advanced Cryptology** *Róbert Lórencz, Jiří Buček* ***Jiří Buček*** *Róbert Lórencz (Gar.)* | Z,ZK | 5 | 2P+2C | Z | VO |

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| NI-PAS | **Advanced Aspects of Business**<br>*David Buchtela, Štěpánka Havlíková, Dominik Vítek, Jiří Maršál, Jana Soukupová, Zdeněk Kučera* ***David Buchtela*** *Zdeněk Kučera (Gar.)* | Z,ZK | 4 | 2P+1C | Z | VO |
| NI-PDB | **Advanced Database Systems**<br>*Michal Valenta, Yelena Trofimova* ***Michal Valenta*** *Michal Valenta (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-GPU | **GPU Architectures and Programming**<br>*Ivan Šimeček* ***Ivan Šimeček*** *Ivan Šimeček (Gar.)* | Z,ZK | 5 | 2P+1C | L | VO |
| NI-PDD | **Data Preprocessing**<br>*Marcel Jiřina* ***Marcel Jiřina*** *Marcel Jiřina (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-REV | **Reverse Engineering**<br>*Josef Kokeš* ***Josef Kokeš*** *Josef Kokeš (Gar.)* | Z,ZK | 5 | 1P+2C | Z | VO |
| NI-RUN | **Runtime Systems**<br>*Filip Křikava* ***Filip Křikava*** *Filip Křikava (Gar.)* | Z,ZK | 5 | 2P+1C | L | VO |
| NI-SWE | **Semantic Web and Knowledge Graphs**<br>*Milan Dojčinovski, Jakub Klímek* ***Milan Dojčinovski*** *Milan Dojčinovski (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-SIM | **Digital Circuit Simulation and Verification**<br>*Martin Kohlík* ***Martin Kohlík*** *Martin Kohlík (Gar.)* | Z,ZK | 5 | 2P+1C | L | VO |
| NI-SIB | **Network Security**<br>*Jiří Dostál, Martin Šutovský, Martin Holec, Simona Fornůsek* ***Simona Fornůsek*** *Jiří Dostál (Gar.)* | Z,ZK | 5 | 2P+1C | L | VO |
| NI-SCR | **Statistical Analysis of Time Series**<br>*Kamil Dedecius* ***Kamil Dedecius*** *Kamil Dedecius (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-SYP | **Parsing and Compilers**<br>*Jan Janoušek* ***Jan Janoušek*** *Jan Janoušek (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-SBF | **System Security and Forensics**<br>*Simona Fornůsek, Marián Svetlík* ***Simona Fornůsek*** *Róbert Lórencz (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-DSS | **Decision Support Systems**<br>*Robert Pergl, Petra Pavlíčková, David Buchtela* ***David Buchtela*** *Robert Pergl (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-TES | **Systems Theory**<br>*Stefan Ratschan, Jiří Vyskočil* ***Stefan Ratschan*** *Stefan Ratschan (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-TSP | **Testing and Reliability**<br>*Petr Fišer* ***Martin Daňhel*** *Petr Fišer (Gar.)* | Z,ZK | 5 | 2P+2C | Z | VO |
| NI-TSW | **Software Product Development**<br>*Petra Pavlíčková* ***Petra Pavlíčková*** *Petra Pavlíčková (Gar.)* | KZ | 4 | 1P+2C | Z | VO |
| NI-UMI | **Artificial intelligence**<br>*Pavel Surynek* ***Pavel Surynek*** *Pavel Surynek (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-EHW | **Embedded Hardware**<br>*Jan Schmidt* ***Jan Schmidt*** *Jan Schmidt (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-ESW | **Embedded Software**<br>*Miroslav Skrbek, Hana Kubátová* ***Miroslav Skrbek*** *Hana Kubátová (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-VCC | **Virtualization and Cloud Computing**<br>*Jan Fesl, Tomáš Vondra* ***Tomáš Vondra*** *Tomáš Vondra (Gar.)* | Z,ZK | 5 | 2P+1C | L | VO |
| NI-APR | **Selected Methods for Program Analysis**<br>*Filip Křikava* ***Filip Křikava*** *Filip Křikava (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-PON | **Selected Topics in Optimization and Numerical mathematics**<br>*Štěpán Starosta, Daniel Vašata, Karel Klouda* ***Daniel Vašata*** *Štěpán Starosta (Gar.)* | Z,ZK | 5 | 2P+1C | L | VO |
| NI-VMM | **Retrieval from Multimedia**<br>*Tomáš Skopal, Jiří Novák* ***Jaroslav Kuchař*** *Tomáš Skopal (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |
| NI-MCC | **Multicore CPU Computing**<br>*Daniel Langr, Ivan Šimeček* ***Ivan Šimeček*** *Ivan Šimeček (Gar.)* | Z,ZK | 5 | 2P+1C | Z | VO |

**Characteristics of the courses of this group of Study Plan: Code=NIE-DBE-VO.23 Name=Elective Vocational Courses for Master Specializations Except Digital Bussiness Engineering**

| | | | |
|---|---|---|---|
| NI-ADM | Data Mining Algorithms | Z,ZK | 5 |

The course focuses on algorithms used in the fields of machine learning and data mining. However, this is not an introductory course, and the students should know machine learning basics. The emphasis is put on advanced algorithms (e.g., gradient boosting) and non-basic kinds of machine learning tasks (e.g., recommendation systems) and models (e.g., kernel methods).

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| NI-AIB | Algorithms of Information Security | Z,ZK | 5 |

Students will get acquainted with the algorithms of secure key generation and cryptographic error (not only biometric) data processing. Furthermore, students will learn the mathematical principles of cryptographic protocols (identification, authentication, and signature schemes). Another part of the course is dedicated to malware detection and the use of machine learning in detection systems. The last topic includes practical steganographic methods and attacks on steganographic systems.

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| NI-ADP | Architecture and Design patterns | Z,ZK | 5 |

The objective of this course is to provide students with both work knowledge about the underlying foundations of object-oriented design and analysis as well as with understanding of the challenges, issues, and tradeoffs of advanced software design. In the first part of the course, the students will refresh and deepen their knowledge of object-oriented programming and get familiar with the commonly used object-oriented design patterns that represent the best practices for solving common software design problems. In the second part the students will be introduced to the principles of software architecture design and analysis. This includes the classical architectural styles, component based systems, and some advanced software architectures used in large-scale distributed systems.

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| NI-AM1 | Middleware Architectures 1 | Z,ZK | 5 |

Students will study new trends, concepts, and technologies in the area of service-oriented architectures. The will gain an overview of information system architecture, web service architecture and aplication servers. The will also study principles and technologies for middleware focused on application integrations, asynchronous communications and high availability of applications.

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| NI-AM2 | Middleware Architectures 2 | Z,ZK | 5 |

Students will learn new trends and technologies on the Web including theoretical foundations. They will gain an overview of Web application architectures, concepts and technologies for microservices, distrubuted cache and databases, smart contracts, realtime communication and web security.

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| NI-BML | Bayesian Methods for Machine Learning | KZ | 5 |
| The subject is focused on practical use of basic Bayesian modeling methods in the dynamically evolving machine learning theory. In particular, it studies the construction of appropriate models providing description of real phenomena, as well as their subsequent use, e.g., for forecasting of future evolution or learning about the hidden variables (true object position from noisy observations etc.). The emphasis is put on understanding of explained principles and methods and their practical adoption. For this purpose, a number of real world examples and applications will be presented to students, for instance, 2D/3D object tracking, radiation source term estimation, or separation in medical imaging. The students will try to solve some of them. | | | |
| NI-BVS | Embedded Security | Z,ZK | 5 |
| Students gain basic knowledge in selected topics of cryptography and cryptanalysis. The course focuses particularly on efficient implementations of cryptographic primitives in hardware and software (in embedded systems). Students gain a good overview of functionality of (hardware) cryptographic accelerators, smart cards, and resources for securing internal functions of computer systems. | | | |
| NI-BKO | Error Control Codes | Z,ZK | 5 |
| The goal of the course is to present various ways to detect or correct individual errors and burst errors in data stored into memories or transmitted via channels. | | | |
| NI-DSV | Distributed Systems and Computing | Z,ZK | 5 |
| Students are introduced to methods for coordination of processes in distributed environment characterised by nondeterministic time responses of computing processes and communication channels. They learn basic algorithms that assure correctness of computations realized by a group of loosely coupled processes and mechanisms that support high availability of both data and services, and safety in case of failures. | | | |
| NI-DDW | Web Data Mining | Z,ZK | 5 |
| Students will learn latest methods and technologies for web data acquisition, analysis and utilization of the discovered knowledge. Students will gain an overview of Web mining techniques for Web crawling, Web structure analysis, Web usage analysis, Web content mining and information extraction. Students will also gain an overview of most recent developments in the field of social web and recommendation systems. | | | |
| NI-EPC | Effective C++ programming | Z,ZK | 5 |
| Students learn how to use the modern features of contemporary versions of the C++ programming language for software development. The course focuses on programming effectivity and efficiency in the form of writing maintainable and portable source code and creating correct programs with low memory and processor time requirements. | | | |
| NI-EVY | Efficient Text Pattern Matching | Z,ZK | 5 |
| Students get knowledge of efficient algorithms for text pattern matching. They learn to use so called succinct data structures that are efficient in both access time and memory complexity. They will be able to use the knowledge in design of applications that utilize pattern matching. | | | |
| NI-FME | Formal Methods and Specifications | Z,ZK | 5 |
| Students are able to describe semantics of software formally and to use sound reasoning for construction of correct software. They learn to use some software tools that allow to prove basic properties of software. | | | |
| NI-GEN | Code Generators | Z,ZK | 5 |
| Advanced techniques of translating programs written in high-level programming languages are essential for understanding the field of systems programming. This primarily involves understanding the algorithms and techniques used to translate more complex programming constructs of modern languages employed in systems programming. Students will become familiar with both the theoretical and practical aspects of implementing the back-end of optimizing compilers for programming languages. | | | |
| NI-GAK | Graph theory and combinatorics | Z,ZK | 5 |
| The goal of the class is to introduce the most important topics in graph theory, combinatorics, combinatorial structures, discrete models and algorithms. The emphasis will be not only on undestanding the basic principles but also on applications in problem solving and algorithm design. The topics include: generating functions, selected topics from graph and hypergraph coloring, Ramsey theory, introduction to probabilistic method, properties of various special classes of graphs and combinatorial structures. The theory will be also applied in the fields of combinatorics on words, formal languages and bioinformatics. | | | |
| NI-HWB | Hardware Security | Z,ZK | 5 |
| The course provides the knowledge needed for the analysis and design of computer systems security solutions. Students get an overview of safeguards against abuse of the system using hardware means. They will be able to safely use and integrate hardware components into systems and test them for resistance to attacks. Students will gain knowledge about the cryptographic accelerators, PUF, random number generators, smart cards, biometric devices, and devices for internal security functions of the computer. | | | |
| NI-KOD | Data Compression | Z,ZK | 5 |
| Students are introduced to the basic principles of data compression. They will learn the necessary theoretical background and get an overview of data compression methods being used in practice. The overview covers principles of integer coding and of statistical, dictionary, and context data compression methods. In addition, students learn the fundamentals of lossy data compression methods used in image, audio, and video compression. | | | |
| NI-MKY | Mathematics for Cryptology | Z,ZK | 5 |
| Students will gain deeper knowledge of algebraic procedures solving the most important mathematical problems concerning the security of ciphers. In particular, the course focuses on the problem of solving a system of polynomial equations over a finite field, the problem of factorization of large numbers and the problem of discrete logarithm. The problem of factorization will also be solved on elliptic curves. Students will further become familiar with modern encryption systems based on lattices. | | | |
| NI-MVI | Computational Intelligence Methods | Z,ZK | 5 |
| Students will understand methods and techniques of computational intelligence that are mostly nature-inspired, parallel by nature, and applicable to many problems. They will learn how these methods work and how to apply them to problems related to data mining, control, intelligen games, optimizations, etc. | | | |
| NI-MEP | Modelling of Enterprise Processes | Z,ZK | 5 |
| The subject is focused on introduction to the discipline of Enterprise Engineering. Students learn the importance of a proper methodological approach for (re)engineering and implementation of processes, organisation structures and information support in big enterprises and institutions. | | | |
| NI-MPJ | Modelling of Programming Languages | Z,ZK | 5 |
| The analysis, transformation, and code generation processes depend on the semantics of the language; in particular, they are correct if they preserve the semantics of the language. This course explores the semantics of programming languages. The students will learn the language models with emphasis on functional languages, students are expected to understand the basics of the lambda calculus and here get acquainted with the advanced lambda calculus. The students also get hands-on-experience with semantic modeling and execution tools. | | | |
| NI-MTI | Modern Internet Technologies | Z,ZK | 5 |
| SYNOPSIS The subject "Modern Internet Technologies" is designed on four major pillars of networking: 1. Unified Communication and Collaboration - A single network, oriented on TCP/IP is able to carry whatever types of protocols for whatever purposes. This architecture is able to be protocol independent and carries voice, video and data to achieve seamless integrated services. 2. Design of Extremely Scalable Networks - This provides the insights of network architectures which can accommodate hundreds of millions of users and billions of devices. Thus, there is a paradigm switch from LANs (Local Area Networks) to SPs (Service Providers). 3. Traffic Segregation, Traffic Matching and Traffic Prioritisation - These technologies allow service providers to create private channels of communication between customers, with guaranteed parameters (bandwidth, delay, jitter, type of protocol). 4. Acceleration Technologies - They allow traffic to be carried at the optimal speed and allow for graceful degradation of service parameters in case of failures. | | | |
| NI-NUR | User Interface Design | Z,ZK | 5 |
| Students will understand the theorical background of human-computer interaction and user interface (UI) design, will learn formal description of UIs, formal user models, the fundamental notions and procesures. They get acquainted with graphical, speech, and multimodal UIs. Thanks to the gained knowledge, the students will be able to design advanced UIs. | | | |

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|---|---|---|---|
| NI-NON | Nonlinear Continuous Optimization and Numerical Methods | Z,ZK | 5 |
| Students will be introduced to nonlinear continuous optimization, principles of the most popular methods of optimization and applications of such methods to real-world problems. They will also learn the finite element method and the finite difference method used for solving ordinary and partial differential equations in engineering. They will learn to solve systems of linear algebraic equations that arise from discretization of the continuous problems by direct and iterative algorithms. They will also learn to implement these algorithms sequentially as well as in parallel. | | | |
| NI-NSS | Normalized Software Systems | ZK | 5 |
| Students will learn the foundations of normalized systems theory that studies the evolvability of modular structures based on concepts from engineering, such as stability from system theory and entropy from thermodynamics. Students will understand a set of principles that indicate where violations of stability and entropy-related issues occur in any given software architecture. In the second part of the course, students learn how to construct software architectures using a set of 5 design patterns called elements. These elements provide the core functionality of information systems in terms of storing data, executing actions, workflows, connectors, and triggers, while handling violations of the stability and entropy-related principles. This knowledge allows students to realize new levels of evolvability in software architectures. | | | |
| NI-OSY | Operating Systems and Systems Programming | Z,ZK | 5 |
| The course covers system programming in UNIX environment. Emphasis is given on kernel development with focus on kernel architecture and kernel data structures. Key topics are: process management, memory management, file operations and architecture of modern file systems, device drivers and network programming.The course also addresses kernel development process, upgrades of existing kernels, kernel booting, debugging using dynamic instrumentation, and techniques to guarantee portability. Specifics of kernel architecture in embedded and real-time operating systems are also discussed. Theoretical and general principles are demonstrated on the LINUX kernel. Within labs, students will work on projects focused on development of LINUX kernel modules. | | | |
| NI-BUI | Business Informatics | Z,ZK | 5 |
| The aim of the course is to focus on operational, tactical and strategic management of business informatics. Students will gain knowledge in the areas of business process management, ICT services and architectures in enterprise informatics. They will also learn about the principles, models and standards (ITIL, COBIT) in IT management, and lifecycle management of ICT services and resource management (sourcing). Students will learn the process of creating and implementing information strategy, IT Governance, the importance of ICT for business and the context of information strategy with global business strategy. They will also gain knowledge in the areas of economic IT management, revenue and investment management, IT investment evaluation and human resources management in IT (roles CIO, CEO, CFO). | | | |
| NI-PIS | Enterprise Information Systems | Z,ZK | 5 |
| The course is focused on the current IT requirements of large companies in the Czech Republic (Top 100). The basis is Data management, storage of big data (BigData) and their use in BI (Business Intelligence). The principles of solving the overall architecture of information systems in the banking, insurance and telecommunications sectors will be explained on real examples. Furthermore, students will get acquainted with the life cycle of information systems in the company / organization and its impact on the business strategy of the company. Students will be acquainted with technologies that have proven themselves in the elimination of basic risks in the planning, implementation and operation of information systems in the company / organization. | | | |
| NI-KRY | Advanced Cryptology | Z,ZK | 5 |
| Students will learn the essentials of cryptanalysis and the mathematical principles of constructing symmetric and asymmetric ciphers. They will know the mathematical principles of random number generators. They will have an overview of cryptanalysis methods, elliptic curve cryptography and quantum cryptography, which they can apply to the integration of their own systems or to the creation of their own software solutions. | | | |
| NI-PAS | Advanced Aspects of Business | Z,ZK | 4 |
| The aim of the course is to provide students with advanced (compared to the bachelor's degree) knowledge and skills needed to establish and run their own business or business management, especially in law, administration (necessary steps and documents), business economics, foreign trade and related aspects. | | | |
| NI-PDB | Advanced Database Systems | Z,ZK | 5 |
| Students orient themselves in problems of evaluation and optimization of SQL queries. The next part of the course deals with new concepts of database machines (so called NoSQL databases), with the related new data models (XML, graph databases, column databases) and languages for working with them (XQuery, XPath, CYPHER, Gremlin). The last part of the course deals with performance evaluation of database machines. | | | |
| NI-GPU | GPU Architectures and Programming | Z,ZK | 5 |
| Students will gain knowledge of the internal architecture of modern massively parallel GPU processors. They will learn to program them mainly in the CUDA programming environment, which is already a widespread programming technology of GPU processors. As an integral part of the effective computational use of these hierarchical computational structures, students will also learn optimization programming techniques and methods of programming multiprocessor GPU systems. | | | |
| NI-PDD | Data Preprocessing | Z,ZK | 5 |
| Students learn to prepare raw data for further processing and analysis. They learn what algorithms can be used to extract information from various data sources, such as images, texts, time series, etc., and learn the skills to apply these theoretical concepts to solve specific problems in individual projects - e.g., extraction of characteristics from images or from web pages. | | | |
| NI-REV | Reverse Engineering | Z,ZK | 5 |
| Students will get acquainted with the essentials of reverse engineering of computer software. They will learn how processes start and what happens before and after the main function is called. Students will understand how executable files are organized and how they interact with 3rd party libraries. Another part of the course is dedicated to reverse engineering of applications written in C++. Students will also understand principles of disassemblers and obfuscation techniques. A part of the course will also be dedicated to debuggers: how debuggers and debugging work and which methods can be used to detect it. One of the lectures will be dedicated to the latest trends on the computer malware scene. The focus of the course is on the seminars, where students will solve practically oriented tasks from the real world. | | | |
| NI-RUN | Runtime Systems | Z,ZK | 5 |
| This course is an introduction to the world of virtual machines (VM) for high-level programming languages. There are two goals: Give you hands-on experience in design and implementation of a compiler and a VM from scratch, including Abstract Syntax Tree (AST) interpretation Byte code (BC) design and interpretation AST to BC compilation Memory management Just-in-time compilation and some optimization techniques Through a series of guest lectures, introduce you to various advanced topics and implementations of real-world VMs, including Dynamic optimizations, speculations, and deoptimizations Language implementation frameworks Read-world VMs | | | |
| NI-SWE | Semantic Web and Knowledge Graphs | Z,ZK | 5 |
| The students will learn the most recent concepts and technologies of the Semantic Web. The course will provide an overview of the Semantic Web technologies, methods and best practices for modelling, integration, publishing, querying and consumption of semantic data. The students will also gain skills in creation of knowledge graphs and their systematic quality assurance. | | | |
| NI-SIM | Digital Circuit Simulation and Verification | Z,ZK | 5 |
| The aim of the course is to acquaint the students with principles of digital circuit simulation at RTL (Register Transfer Level) and TLM (Transaction Level Modeling) levels and with the properties of proper tools. The course covers recent verification methods, too. | | | |
| NI-SIB | Network Security | Z,ZK | 5 |
| NI-SCR | Statistical Analysis of Time Series | Z,ZK | 5 |
| The course deals with the practical use of the basic time series modelling theory in engineering tasks, ranging from economics (stock exchange prices, employment) and industrial problems (modelling of signals and processes) to computer networks (network components load, attacks detection). The students learn to select a convenient process model, estimate its parameters, analyze its properties and use it for forecasting of future or intermediate values. The stress is put on understanding and adoption of the main principles based on practical real-world examples. Both the lab classes and the lectures exploit freely available software packages in order to provide easy and straightforward transfer of students' knowledge from the academic to the real world. | | | |

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| NI-SYP | Parsing and Compilers | Z,ZK | 5 |
| The module builds upon the knowledge of fundamentals of automata theory, formal language and formal translation theories. Students gain knowledge of various variants and applications of LR parsing and are introduced to special applications of parsers, such as incremental and parallel parsing. | | | |
| NI-SBF | System Security and Forensics | Z,ZK | 5 |
| Students will get familiar with aspects of system security (principles of end station security, principles of security policies, security models, authentication concepts). Furthermore, students will get familiar with forensic analysis as a tool for investigating security incidents (techniques used by malicious software/attackers and forensic analysis techniques and the importance of operating system/operating system artifacts or file system for attack analysis and detection). | | | |
| NI-DSS | Decision Support Systems | Z,ZK | 5 |
| The aim of the course is to provide students with knowledge and skills in decision support systems, their classification (Powerova), selected principles of data-oriented, model-oriented and knowledge-oriented decision support systems. Students will also gain knowledge of multicriterial decision-making methods and game theory. They will also learn about the principles of conceptually and ontologically oriented decision support systems and the basics of distribution, optimization and evolution methods and algorithms. | | | |
| NI-TES | Systems Theory | Z,ZK | 5 |
| Today, humankind has the ability to develop systems of incredible complexity (e.g., trains, microprocessors, airplanes, nuclear power plants). However, the costs of managing this complexity and of ensuring the correct behavior of a given system have become critical. A key technique for mastering this complexity is the usage of models that describe only those aspects of the systems that are important for the task at hand, and automated tools for analyzing those models. This subject will present theory and algorithms that form the basis for the modeling and analysis of complex systems. | | | |
| NI-TSP | Testing and Reliability | Z,ZK | 5 |
| Students will gain knowledge about circuit testing and about methods for increasing reliability and security. They will get practical skills to be able to prepare a test set with the help of the intuitive path sensitization and to use an ATPG for automatic test generation. They will be able to design easily testable circuits and systems with built-in-self-test equipment. They will be able to compute, analyze, and control the reliability and availability of the designed circuits. | | | |
| NI-TSW | Software Product Development | KZ | 4 |
| The course is presented in Czech. | | | |
| NI-UMI | Artificial intelligence | Z,ZK | 5 |
| The course covers search and inference algorithms in major formal paradigms used in artificial intelligence such as logic theories, constraint programming and automated planning. The main principles and practical applications of discussed techniques will be illustrated. | | | |
| NI-EHW | Embedded Hardware | Z,ZK | 5 |
| The course brings basic laws that govern digital design and basic techniques to use them. It deals with both large and small scale systems. This is the base of advanced embedded systems, that profit from their specialized structure for effective computation and acceleration. Design of fast custom computing machines is discussed, including standardized means of internal communication, parallelism extraction and utilization in special structures and system architectures. | | | |
| NI-ESW | Embedded Software | Z,ZK | 5 |
| Embedded software course acquainted students with the specifics of software development for embedded systems. The course covers the areas from the basic techniques of programming in C language and code optimizations, through typical areas as the reliable software development, embedded operating systems, signal processing, up to sophisticated techniques combined with artificial intelligence. | | | |
| NI-VCC | Virtualization and Cloud Computing | Z,ZK | 5 |
| Students will gain knowledge of architectures of large computer systems that are used in data centers and computer infrastructure of companies and organizations. They will get acquainted with virtualization principles, tools and technologies that serve to facilitate and automate configuration, testing and monitoring, and to efficiently operate and optimize the performance parameters of modern computer systems. Theoretically and practically, they will get acquainted with containerization as the most effective technology today for the management of complex computer systems and with specific technologies of cloud systems. Finally, they will learn the principles and gain practical skills in the use of modern integration and development tools (Continuous integration and development). | | | |
| NI-APR | Selected Methods for Program Analysis | Z,ZK | 5 |
| This course introduces you to program analysis, i.e., the automated reasoning about the behavior of a computer program. We will cover static and dynamic analysis. In Static Analysis, we will look at the art of reasoning about computer programs without running them. We will look at the analyses for program understanding, optimizations, error detection. In Dynamic Analysis, we will look at the analyses considering individual program runs using a concrete environment and inputs. | | | |
| NI-PON | Selected Topics in Optimization and Numerical mathematics | Z,ZK | 5 |
| The course focuses on optimization problems that appear in the field of machine learning and artificial intelligence. Students broaden their knowledge of continuous optimization obtained in the course Mathematics for informatics. The methods are explained and described along with the details on how they are implemented on computers. Hence, the relevant concepts of numerical matematics, mainly numerical linear algebra, are explained too. | | | |
| NI-VMM | Retrieval from Multimedia | Z,ZK | 5 |
| The student obtains general knowledge regarding interfaces of portals providing multimedia content, the principles of similarity search, the methods of feature extraction from multimedia objects, indexing, and structure of distributed search engines. | | | |
| NI-MCC | Multicore CPU Computing | Z,ZK | 5 |
| Students will get acquainted in detail with hardware support and programming technologies for the creation of parallel multithreaded computations on multicore processors with shared and virtually shared memories, which are today the most common computing nodes of powerful (super)computer systems. Students will gain knowledge of architecturally specific optimization techniques used to reduce the performance drop due to the widening gap between the computational requirements of multi-core CPUs and memory interface throughput. On specific non-trivial multithreaded programs, students will also learn the basics of the art of creating these applications. | | | |

Name of the block: Compulsory elective courses
Minimal number of credits of the block: 20
The role of the block: PV

Code of the group: NIE-DBE-PVA.23
Name of the group: Compulsory Elective Courses for Master DBE Specialization A - Normalized Systems Theory
Requirement credits in the group: In this group you have to gain at least 5 credits (at most 9)
Requirement courses in the group: In this group you have to complete 1 course
Credits in the group: 5
Note on the group:

| Code | Name of the course / Name of the group of courses *(in case of groups of courses the list of codes of their members)* *Tutors,* ***authors*** *and guarantors (gar.)* | Completion | Credits | Scope | Semester | Role |
|---|---|---|---|---|---|---|
| NIE-NSS | **Normalized Software Systems** *Robert Pergl, Marek Suchánek, Jan Verelst* ***Robert Pergl*** *Robert Pergl (Gar.)* | ZK | 5 | 2P | L | PV |
| DA-SEA | **Software Engineering And Architecture** ***Michal Valenta*** | Z,ZK | 9 | 3P+3C+3S | Z,L | PV |

**Characteristics of the courses of this group of Study Plan: Code=NIE-DBE-PVA.23 Name=Compulsory Elective Courses for Master DBE Specialization A - Normalized Systems Theory**

| | | | |
|---|---|---|---|
| NIE-NSS | Normalized Software Systems | ZK | 5 |

Students will learn the foundations of normalized systems theory that studies the evolvability of modular structures based on concepts from engineering, such as stability from system theory and entropy from thermodynamics. Students will understand a set of principles that indicate where violations of stability and entropy-related issues occur in any given software architecture. In the second part of the course, students learn how to construct software architectures using a set of 5 design patterns called elements. These elements provide the core functionality of information systems in terms of storing data, executing actions, workflows, connectors, and triggers, while handling violations of the stability and entropy-related principles. This knowledge allows students to realize new levels of evolvability in software architectures.

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|---|---|---|---|
| DA-SEA | Software Engineering And Architecture | Z,ZK | 9 |

Basic software engineering structures, practices, and patterns are explained in a realistic software engineering environment using the Java progarmming language. Practical assignments complement these lectures. Basic software architecture structures, practices, and patterns are explained and discussed, including various aspects of evolvability. Video lectures and a practical assignment deepen this. Teaching takes place at University of Antwerpen. See the web page https://www.uantwerpen.be/en/study/programmes/all-programmes/digital-business-engineering/about-the-programme/study-programme/

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Code of the group: NIE-DBE-PVB.23
Name of the group: Compulsory Elective Courses for Master Double degree Specialization DBE B - Engineering and Ethics
Requirement credits in the group: In this group you have to gain at least 3 credits (at most 6)
Requirement courses in the group: In this group you have to complete at least 1 course ( at most 2)
Credits in the group: 3
Note on the group:

| Code | Name of the course / Name of the group of courses *(in case of groups of courses the list of codes of their members)* *Tutors,* ***authors*** *and guarantors (gar.)* | Completion | Credits | Scope | Semester | Role |
|---|---|---|---|---|---|---|
| DD-DSE | **Data science and ethics** ***Michal Valenta*** | ZK | 3 | | Z | PV |
| DA-ESB | **Ethical And Sustainable Business** ***Michal Valenta*** | ZK | 3 | 30KP | Z | PV |

**Characteristics of the courses of this group of Study Plan: Code=NIE-DBE-PVB.23 Name=Compulsory Elective Courses for Master Double degree Specialization DBE B - Engineering and Ethics**

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|---|---|---|---|
| DD-DSE | Data science and ethics | ZK | 3 |

Ethics tell us about right and wrong. The course will provide an overview of key: (1) concepts, related to privacy, discrimination, transparency, and explainability, (2) techniques to assess and improve on these aspects, and (3) cautionary tales that motivate the importance thereof. The consideration of data science ethics is crucial for any data-driven company, as will be motivated by ample cautionary tales. With a wide range of cases, the large implications of new data science technologies on ethics will be discussed. These include online tracking, medical records, Facebook data, Internet censorship, big data, privacy engineering, and Artificial Intelligence. Data scientists and business managers are not inherently unethical, but at the same time not trained to think this through neither. This course aims to address this important gap. Students of a master double degree specialisation Digital Business Engineering will attend this course during their stay at the partner university Antwerp

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|---|---|---|---|
| DA-ESB | Ethical And Sustainable Business | ZK | 3 |

This course covers corporate responsibility, morality and sustainability. It has three main parts: Part 1: Ethics and morality in business History of ethics in business Origins, stakeholder theory, basic philosophy Utilitarianism vs Kantian approaches Behavioural economic. Part 2: Corporate responsibility and sustainability in theory Shared value creation, social profit, social entrepreneurship Sustainable HR Circular Economy Green Deal and CSRD New business models for sustainability. Part 3: Corporate responsibility and sustainability in practice Implementing sustainability in the value chain of a company: products, operations, organisation and HR How to apply a management approach to sustainability. Teaching takes place at University Antwerpen. See the web page https://www.uantwerpen.be/en/study/programmes/all-programmes/digital-business-engineering/about-the-programme

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Code of the group: NIE-DBE-PV1.23
Name of the group: Compulsory Elective Courses for Master Specialization DBE - Modern Technology
Requirement credits in the group: In this group you have to gain at least 5 credits (at most 25)
Requirement courses in the group: In this group you have to complete at least 1 course ( at most 5)
Credits in the group: 5
Note on the group:

| Code | Name of the course / Name of the group of courses *(in case of groups of courses the list of codes of their members)* *Tutors,* ***authors*** *and guarantors (gar.)* | Completion | Credits | Scope | Semester | Role |
|---|---|---|---|---|---|---|
| NIE-PDB | **Advanced Database Systems** *Martin Svoboda* ***Martin Svoboda*** *Martin Svoboda (Gar.)* | Z,ZK | 5 | 2P+1C | Z | PV |

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|---|---|---|---|---|---|---|
| DD-ZUM | **Artificial Intelligence Fundamentals**<br>*Pavel Surynek* ***Pavel Surynek*** *Pavel Surynek (Gar.)* | Z,ZK | 5 | 2P+2C | L | PV |
| NIE-BLO | **Blockchain**<br>*Róbert Lórencz, Josef Gattermayer, Marek Bielik, Jakub Růžička* ***Josef Gattermayer*** *Róbert Lórencz (Gar.)* | Z,ZK | 5 | 1P+2C | Z | PV |
| NIE-AM1 | **Middleware Architectures 1**<br>*Tomáš Vitvar, Jaroslav Kuchař, Milan Dojčinovski* ***Jaroslav Kuchař*** *Tomáš Vitvar (Gar.)* | Z,ZK | 5 | 2P+1C | Z | PV |
| NIE-SWE | **Semantic Web and Knowledge Graphs**<br>*Milan Dojčinovski* ***Milan Dojčinovski*** *Milan Dojčinovski (Gar.)* | Z,ZK | 5 | 2P+1C | Z | PV |

**Characteristics of the courses of this group of Study Plan: Code=NIE-DBE-PV1.23 Name=Compulsory Elective Courses for Master Specialization DBE - Modern Technology**

| | | | |
|---|---|---|---|
| NIE-PDB | Advanced Database Systems | Z,ZK | 5 |

Students orient themselves in problems of evaluation and optimization of SQL queries. The next part of the course deals with new concepts of database machines (so called NoSQL databases), with the related new data models (XML, graph databases, column databases) and languages for working with them (XQuery, XPath, CYPHER, Gremlin). The last part of the course deals with performance evaluation of database machines. This course is equivalent to the course MIE-PDB.

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| DD-ZUM | Artificial Intelligence Fundamentals | Z,ZK | 5 |

Students are introduced to the fundamental problems in the Artificial Intelligence, and the basic methods for their solving. It focuses mainly on the classical tasks from the areas of state space search, multi-agent systems, game theory, planning, and machine learning. Modern soft-computing methods, including the evolutionary algorithms and the neural networks, will be presented as well. This course is only for students of the double degree program with the University of Antwerp. Other students are not allowed to enrol this course, enrol the BIE-ZUM course instead.

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|---|---|---|---|
| NIE-BLO | Blockchain | Z,ZK | 5 |

Students will understand the foundations of blockchain technology, smart contract programming, and gain an overview of most notable blockchain platforms. They will be able to design, code and deploy a secure decentralized application, and assess whether integration of a blockchain is suitable for a given problem. The course places an increased emphasis on the relationship between blockchains and information security. It is concluded with a defense of a research or applied semester project, which prepares the students for implementing or supervising implementation of blockchain-based solutions in both academia and business.

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|---|---|---|---|
| NIE-AM1 | Middleware Architectures 1 | Z,ZK | 5 |

Students will study new trends, concepts, and technologies in the area of service-oriented architectures. The will gain an overview of information system architecture, web service architecture and aplication servers. The will also study principles and technologies for middleware focused on application integrations, asynchronous communications and high availability of applications. This course replaces the course MIE-MDW.

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|---|---|---|---|
| NIE-SWE | Semantic Web and Knowledge Graphs | Z,ZK | 5 |

The students will learn the most recent concepts and technologies of the Semantic Web. The course will provide an overview of the Semantic Web technologies, methods and best practices for modelling, integration, publishing, querying and consumption of semantic data. The students will also gain skills in creation of knowledge graphs and their systematic quality assurance.

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Code of the group: NIE-DBE-PVC.23
Name of the group: Compulsory Elective Courses for Master Specialization DBE C - Master Project
Requirement credits in the group: In this group you have to gain at least 7 credits (at most 16)
Requirement courses in the group: In this group you have to complete at least 1 course ( at most 2)
Credits in the group: 7
Note on the group: A FIT student who wants to complete two programs and obtain two degrees (Duble Degree DBE) must enroll in addition to the DA-IPR course (instead of NIE-MPR) enrolled in two other courses at the University of Anwerp: - Engineering & design science methodologies - Empirical research in MIS

| **Code** | **Name of the course / Name of the group of courses**<br***(in case of groups of courses the list of codes of their members)***<br>*Tutors,* ***authors*** *and guarantors (gar.)* | **Completion** | **Credits** | **Scope** | **Semester** | **Role** |
|---|---|---|---|---|---|---|
| DA-IPR | **Integration project digital business engineering**<br>***Michal Valenta*** | Z | 9 | 30KP | L | PV |
| NIE-MPR | **Master Project**<br>***Zdeněk Muzikář*** *Zdeněk Muzikář (Gar.)* | Z | 7 | | Z,L | PV |

**Characteristics of the courses of this group of Study Plan: Code=NIE-DBE-PVC.23 Name=Compulsory Elective Courses for Master Specialization DBE C - Master Project**

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|---|---|---|---|
| DA-IPR | Integration project digital business engineering | Z | 9 |

This is typically a study followed by a thesis. Teaching takes place at University Antwerpen. Contact Information: Jan Verelst jan.verelst@uantwerpen.be Dieter Van Nuffel dieter.vannuffel@uantwerpen.be See the web page https://www.uantwerpen.be/en/study/programmes/all-programmes/digital-business-engineering/about-the-programme/study-programme/

| | | | |
|---|---|---|---|
| NIE-MPR | Master Project | Z | 7 |

1. At the beginning of the semester, a student reserves her/his final thesis topic and gets together with its supervisor. Together they decide on partial tasks that should be carried out during the semester. If the requirements they agreed upon are met, the supervisor awards the student an assessment for the course MI-MPR at the end of the semester. 2. The external supervisor enters the information on granting the credit using the form "Granting credit from the external supervisor of the final thesis" (http://fit.cvut.cz/student/studijni/formulare). The completed and signed form must be delivered in person or by email to the SZZ coordinator, who will arrange for the credit to be granted. 3. If the FT topic that the student has reserved is rather general, the immediate tasks the supervisor assigns to the student for the upcoming semester should aim at fine-tuning the FT topic so that the FTT will be complete and approvable at the end of the semester.

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Name of the block: Elective courses
Minimal number of credits of the block: 0
The role of the block: V

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Code of the group: NIE-DBE-V-ANT
Name of the group: Elective courses from University of Antverpen
Requirement credits in the group:
Requirement courses in the group:
Credits in the group: 0
Note on the group: Any courses offered by the University of Antwerpen during stay there

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Code of the group: NIE-V.21
Name of the group: Purely elective master's courses
Requirement credits in the group:
Requirement courses in the group:
Credits in the group: 0
Note on the group:

| Code | Name of the course / Name of the group of courses *(in case of groups of courses the list of codes of their members)* *Tutors,* ***authors*** *and guarantors (gar.)* | Completion | Credits | Scope | Semester | Role |
|---|---|---|---|---|---|---|
| NIE-BLO | **Blockchain** *Róbert Lórencz, Josef Gattermayer, Marek Bielik, Jakub Růžička* ***Josef Gattermayer*** *Róbert Lórencz (Gar.)* | Z,ZK | 5 | 1P+2C | Z | v |
| NIE-CPX | **Complexity Theory** *Dušan Knop, Ondřej Suchý* ***Dušan Knop*** *Dušan Knop (Gar.)* | Z,ZK | 5 | 3P+1C | Z | v |
| NIE-VYC | **Computability** *Jan Starý* ***Jan Starý*** *Jan Starý (Gar.)* | Z,ZK | 4 | 2P+2C | L | v |
| NIE-MVI | **Computational Intelligence Methods** *Pavel Kordík, Miroslav Čepek* ***Pavel Kordík*** *Pavel Kordík (Gar.)* | Z,ZK | 5 | 2P+1C | Z | v |
| NIE-ARI | **Computer arithmetic** *Pavel Kubalík* ***Pavel Kubalík*** *Pavel Kubalík (Gar.)* | Z,ZK | 4 | 2P+1C | Z,L | v |
| NIE-SCE1 | **Computer Engineering Seminar Master I** *Hana Kubátová* ***Hana Kubátová*** *Hana Kubátová (Gar.)* | Z | 4 | 2C | Z | v |
| NIE-SCE2 | **Computer Engineering Seminar Master II** *Hana Kubátová* ***Hana Kubátová*** *Hana Kubátová (Gar.)* | Z | 4 | 2C | L | v |
| NI-DSW | **Design Sprint** *Ondřej Brém, Michal Manda* ***Michal Manda*** *David Pešek (Gar.)* | Z | 2 | 30B | Z | v |
| NI-DID | **Digital drawing** *Denisa Nováčková, Eliška Novotná* ***Denisa Nováčková*** *Denisa Nováčková (Gar.)* | Z | 2 | 4C | Z,L | v |
| NIE-EVY | **Efficient Text Pattern Matching** *Jan Holub* ***Jan Holub*** *Jan Holub (Gar.)* | Z,ZK | 5 | 2P+1C | Z | v |
| NI-GLR | **Games and reinforcement learning** ***Juan Pablo Maldonado Lopez*** | Z,ZK | 4 | 2P+2C | L | v |
| NI-GRI | **Grid Computing** *André Sopczak, Petr Fiedler* ***Pavel Tvrdík*** *André Sopczak (Gar.)* | Z,ZK | 5 | 2P+1C | Z | v |
| NIE-HMI | **History of Mathematics and Informatics** *Alena Šolcová* ***Alena Šolcová*** *Alena Šolcová (Gar.)* | Z,ZK | 3 | 2P+1C | Z | v |
| NIE-DVG | **Introduction to Discrete and Computational Geometry** *Maria Saumell Mendiola* ***Maria Saumell Mendiola*** *Maria Saumell Mendiola (Gar.)* | Z,ZK | 5 | 2P+1C | L | v |
| FITE-EHD | **Introduction to European Economic History** ***Tomáš Evan*** | Z,ZK | 3 | 2P+1C | L | v |
| MIE-MZI | **Mathematics for data science** ***Štěpán Starosta*** | Z,ZK | 4 | 2P+1C | L | v |
| NIE-AM2 | **Middleware Architectures 2** *Milan Dojčinovski* ***Milan Dojčinovski*** *Milan Dojčinovski (Gar.)* | Z,ZK | 5 | 2P+1C | L | v |
| NIE-OSY | **Operating Systems and Systems Programming** *Petr Zemánek* ***Petr Zemánek*** *Petr Zemánek (Gar.)* | Z,ZK | 5 | 2P+1C | Z | v |
| NIE-PAM | **Parameterized Algorithms** *Ondřej Suchý* ***Ondřej Suchý*** *Ondřej Suchý (Gar.)* | Z,ZK | 4 | 2P+1C | L | v |
| NIE-SYP | **Parsing and Compilers** *Jan Janoušek* ***Jan Janoušek*** *Jan Janoušek (Gar.)* | Z,ZK | 5 | 2P+1C | Z | v |
| NIE-ROZ | **Pattern Recognition** *Michal Haindl* ***Michal Haindl*** *Michal Haindl (Gar.)* | Z,ZK | 5 | 2P+1C | Z | v |
| NIE-PML | **Personalized Machine Learning** *Rodrigo Augusto Da Silva Alves* ***Karel Klouda*** *Rodrigo Augusto Da Silva Alves (Gar.)* | Z,ZK | 5 | 2P+1C | Z | v |
| NI-AML | **Advanced machine learning** *Rodrigo Augusto Da Silva Alves, Zdeněk Buk, Miroslav Čepek, Petr Šimánek, Vojtěch Rybář* ***Miroslav Čepek*** *Miroslav Čepek (Gar.)* | Z,ZK | 5 | 2P + 1C | L | v |
| NIE-PDL | **Practical Deep Learning** *Martin Barus, Yauhen Babakhin* ***Karel Klouda*** *Karel Klouda (Gar.)* | KZ | 5 | 2P+1C | Z | v |

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|---|---|---|---|---|---|---|
| FIT-ACM1 | **Programming Practices 1**<br>***Tomáš Valla*** | KZ | 5 | 4C | L | v |
| FIT-ACM2 | **Programming Practices 2**<br>***Ondřej Suchý*** | KZ | 5 | 4C | Z | v |
| FIT-ACM3 | **Programming Practices 3**<br>***Ondřej Suchý*** | KZ | 5 | 4C | L | v |
| FIT-ACM4 | **Programming Practices 4**<br>***Ondřej Suchý*** | KZ | 5 | 4C | Z | v |
| FIT-ACM5 | **Programming Practices 5**<br>***Ondřej Suchý*** | KZ | 5 | 4C | L | v |
| FIT-ACM6 | **Programming Practices 6**<br>***Ondřej Suchý*** | KZ | 5 | 4C | L | v |
| NIE-VPR | **Research Project**<br>*Štěpán Starosta* ***Štěpán Starosta*** *Štěpán Starosta (Gar.)* | Z | 5 | | Z,L | v |
| NIE-SWE | **Semantic Web and Knowledge Graphs**<br>*Milan Dojčinovski* ***Milan Dojčinovski*** *Milan Dojčinovski (Gar.)* | Z,ZK | 5 | 2P+1C | Z | v |
| MI-SCE1 | **Computer Engineering Seminar Master I**<br>***Hana Kubátová*** | Z | 4 | 2C | L,Z | v |
| NIE-HSC | **Side-Channel Analysis in Hardware**<br>*Vojtěch Miškovský, Petr Socha* ***Vojtěch Miškovský*** *Vojtěch Miškovský (Gar.)* | Z,ZK | 4 | 2P+2C | Z | v |
| NIE-DDW | **Web Data Mining**<br>*Milan Dojčinovski* ***Milan Dojčinovski*** *Milan Dojčinovski (Gar.)* | Z,ZK | 5 | 2P+1C | L | v |
| NIE-BPS | **Wireless Computer Networks**<br>*Alexandru Moucha* ***Alexandru Moucha*** *Alexandru Moucha (Gar.)* | Z,ZK | 4 | 2P+1C | L | v |
| NIE-SEP | **World Economy and Business**<br>***Tomáš Evan*** | Z,ZK | 4 | 2P+1C | Z | v |
| FITE-SEP | **World Economy and Business**<br>***Tomáš Evan*** | Z,ZK | 4 | 2P+2C | Z | v |

**Characteristics of the courses of this group of Study Plan: Code=NIE-V.21 Name=Purely elective master's courses**

| | | | |
|---|---|---|---|
| NIE-BLO | Blockchain | Z,ZK | 5 |

Students will understand the foundations of blockchain technology, smart contract programming, and gain an overview of most notable blockchain platforms. They will be able to design, code and deploy a secure decentralized application, and assess whether integration of a blockchain is suitable for a given problem. The course places an increased emphasis on the relationship between blockchains and information security. It is concluded with a defense of a research or applied semester project, which prepares the students for implementing or supervising implementation of blockchain-based solutions in both academia and business.

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|---|---|---|---|
| NIE-SWE | Semantic Web and Knowledge Graphs | Z,ZK | 5 |

The students will learn the most recent concepts and technologies of the Semantic Web. The course will provide an overview of the Semantic Web technologies, methods and best practices for modelling, integration, publishing, querying and consumption of semantic data. The students will also gain skills in creation of knowledge graphs and their systematic quality assurance.

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|---|---|---|---|
| NIE-CPX | Complexity Theory | Z,ZK | 5 |

Students will learn about the fundamental classes of problems in the complexity theory and different models of algoritms and about implications of the theory concerning practical (in)tractability of difficult problems.

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| NIE-VYC | Computability | Z,ZK | 4 |

Classical theory of recursive functions and effective computability.

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| NIE-MVI | Computational Intelligence Methods | Z,ZK | 5 |

Students will understand the basic methods and techniques of computational intelligence, which are based on traditional artificial intelligence, are parallel in nature and are applicable to solving a wide range of problems. The subject is also devoted to modern neural networks and the ways in which they learn and neuroevolution. Students will learn how these methods work and how to apply them to problems related to data extraction, management, intelligence in games and optimisation, etc.

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| NIE-ARI | Computer arithmetic | Z,ZK | 4 |

Students will learn various data representations used in digital devices and will be able to design arithmetic operations implementation units.

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|---|---|---|---|
| NIE-SCE1 | Computer Engineering Seminar Master I | Z | 4 |

The Seminar of Computer Engineering is a (s)elective course for students who want to deal with deeper topics of digital design, reliability and resistance to failures and attacks. Students are approached individually within the subject. Each student or group of students solves some interesting topic with the selected supervisor. Part of the subject is work with scientific articles and other professional literature and/or work in KČN laboratories. The capacity of the subject is limited by the possibilities of the seminar teachers. The topics are new for each semester.

| | | | |
|---|---|---|---|
| NIE-SCE2 | Computer Engineering Seminar Master II | Z | 4 |

The Seminar of Computer Engineering is a (s)elective course for students who want to deal with deeper topics of digital design, reliability and resistance to failures and attacks. Students are approached individually within the subject. Each student or group of students solves some interesting topic with the selected supervisor. Part of the subject is work with scientific articles and other professional literature and/or work in KČN laboratories. The capacity of the subject is limited by the possibilities of the seminar teachers. The topics are new for each semester.

| | | | |
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| NI-DSW | Design Sprint | Z | 2 |

Students will work on projects using the Design Sprint method, developed by Google. THanks to this method the teams are able to go from idea to validated prototype in 5 days. During the course the students will get familiar with the method as participants. Through practical challenges they will try the whole 5 day process starting with research and finishing with testing the prototypes (plus final presentation).

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|---|---|---|---|
| NI-DID | Digital drawing | Z | 2 |

The course will introduce students to the basic principals of digital drawing and graphical design. Students will gain understanding of composition, perspective and color theory, which they will practically apply in their own design works. Students will also gain experience in drawing and painting with digital and analog tools. The course is fit for anyone who wants to practice or learn drawing and painting. The course is organized as a thematic practices covering parts of theory and practical exercise to practice gained knowledge.

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| NIE-EVY | Efficient Text Pattern Matching | Z,ZK | 5 |

Students get knowledge of efficient algorithms for text pattern matching. They learn to use so called succinct data structures that are efficient in both access time and memory complexity. They will be able to use the knowledge in design of applications that utilize pattern matching.

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|---|---|---|---|
| NI-GLR | Games and reinforcement learning | Z,ZK | 4 |

The field of reinforcement learning is very hot recently, because of advances in deep learning, recurrent neural networks and general artificial intelligence. This course is intended to give you both theoretical and practical background so you can participate in related research activities. Presented in English.

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|---|---|---|---|
| NI-GRI | Grid Computing | Z,ZK | 5 |
| Grid computing and gain knowledge about the world-wide network and computing infrastructure. | | | |
| NIE-HMI | History of Mathematics and Informatics | Z,ZK | 3 |
| The course focuses on selected topics from calculus, general algebra, number theory, numerical mathematics and logic - useful for today computer science The topics are selected for finding some relations between computer science and mathematical methods. Some examples of applications of mathematics to computer sciences will be showed. | | | |
| NIE-DVG | Introduction to Discrete and Computational Geometry | Z,ZK | 5 |
| The course intends to introduce the students to the discipline of Discrete and Computational Geometry. The main goal of the course is to get familiar with the most fundamental notions of this discipline, and to be able to solve simple algorithmic problems with a geometric component. | | | |
| FITE-EHD | Introduction to European Economic History | Z,ZK | 3 |
| The course introduces a selection of themes from the European economic history. It gives the student basic knowledge about forming of the global economy through the description of the key periods in history. As European countries have been dominant actors in this process it focuses predominantly on their roles in the economic history. From large economic area of Roman Empire to fragmentation of the Middle Ages, from destruction of WWII to the current affairs, the development of modern financial institutions is deciphered. The course does not cover detailed economic history of particular European countries but rather the impact of trade and role of particular events, institutions and organizations in history. Class meetings will consist of a mixture of lecture and discussion. | | | |
| MIE-MZI | Mathematics for data science | Z,ZK | 4 |
| In this course, the students are introduced to the domains of mathematics necessary for understanding the standard methods and algorithms used in data science. The studied topics include mainly: linear algebra (matrix factorisations, eigenvalues, diagonalization), continuous optimisation (optimisation with constraints, duality principle, gradient methods) and selected notions from probability theory and statistics. | | | |
| NIE-AM2 | Middleware Architectures 2 | Z,ZK | 5 |
| Students will learn new trends and technologies on the Web including theoretical foundations. They will gain an overview of Web application architectures, concepts and technologies for microservices, distrubuted cache and databases, smart contracts, realtime communication and web security. | | | |
| NIE-OSY | Operating Systems and Systems Programming | Z,ZK | 5 |
| This course is focused on the design and implementation of the basic components that make up modern operating systems. This includes threads, processes, switching context, virtual memory, system calls, interrupts and interactions of SW and HW using drivers. Students will learn the theory of the concept of operating system architecture with emphasis on the kernel architecture. Within the course, they will gain practical experience with the development of a small but fully functional operating system. | | | |
| NIE-PAM | Parameterized Algorithms | Z,ZK | 4 |
| There are many optimization problems for which no polynomial time algorithms are known (e.g. NP-complete problems). Despite that it is often necessary to solve these problems exactly in practice. We will demonstrate that many problems can be solved much more effectively than by naively trying all possible solutions. Often one can find a common property (parameter) of the inputs from practice-e.g., all solutions are relatively small. Parameterized algorithms exploit that by limiting the time complexity exponentially in this (small) parameter and polynomially in the input size (which can be huge). Parameterized algorithms also represent a way to formalize the notion of effective polynomial time preprocessing of the input, which is not possible in the classical complexity. Such a polynomial time preprocessing is then a suitable first step, whatever is the subsequent solution method. We will present a plethora of parameterized algorithm design methods and we will also show how to prove that for some problem (and parameter) such an algorithm (presumably) does not exist. We will also not miss out the relations to other approaches to hard problems such as moderately exponential algorithms or approximation schemes. | | | |
| NIE-SYP | Parsing and Compilers | Z,ZK | 5 |
| The module builds upon the knowledge of fundamentals of automata theory, formal language and formal translation theories. Students gain knowledge of various variants and applications of LR parsing and are introduced to special applications of parsers, such as incremental and parallel parsing. | | | |
| NIE-ROZ | Pattern Recognition | Z,ZK | 5 |
| The aim of the module is to give a systematic account of the major topics in pattern recognition with emphasis on problems and applications of the statistical approach to pattern recognition. Students will learn the fundamental concepts and methods of pattern recognition, including probability models, parameter estimation, and their numerical aspects. | | | |
| NIE-PML | Personalized Machine Learning | Z,ZK | 5 |
| Personalized machine learning (PML) is a sub-field of machine learning that aims to create models and predictions based on the unique characteristics and behaviors of individual entities. While PML is commonly used in applications such as recommender systems, which recommend items to users based on their personal interests, its principles can be applied to a wide range of other fields, including education, medicine, and chemical engineering. In this course, we will explore the latest PML methods from theoretical, algorithmic, and practical perspectives. Specifically, we will focus on cutting-edge models that are of interest to both the research and commercial communities. | | | |
| NI-AML | Advanced machine learning | Z,ZK | 5 |
| The course introduces students to selected advanced topics of machine learning and artificial intelligence. The topics present techniques in the field of recommendation systems, image processing, control and interconnection of physical laws with the field of machine learning. The aim of the exercise is to familiarize students with the methods discussed. | | | |
| NIE-PDL | Practical Deep Learning | KZ | 5 |
| This course is designed to provide students with a comprehensive understanding of Deep Learning using PyTorch, a popular open-source machine learning framework. Throughout the course, students will develop practical skills in building and training deep neural networks, using PyTorch to solve real-world problems in fields such as computer vision and natural language processing. | | | |
| FIT-ACM1 | Programming Practices 1 | KZ | 5 |
| This is a selective course for preparing talented student for representation in international programming contests. | | | |
| FIT-ACM2 | Programming Practices 2 | KZ | 5 |
| This is a selective course for preparing talented student for representation in international programming contests. | | | |
| FIT-ACM3 | Programming Practices 3 | KZ | 5 |
| This is a selective course for preparing talented student for representation in international programming contests. | | | |
| FIT-ACM4 | Programming Practices 4 | KZ | 5 |
| This is a selective course for preparing talented student for representation in international programming contests. | | | |
| FIT-ACM5 | Programming Practices 5 | KZ | 5 |
| This is a selective course for preparing talented student for representation in international programming contests. | | | |
| FIT-ACM6 | Programming Practices 6 | KZ | 5 |
| This is a selective course for preparing talented student for representation in international programming contests. | | | |
| NIE-VPR | Research Project | Z | 5 |
| 1. At the beginning of the semester, a student reserves her/his final thesis topic and gets together with its supervisor. Together they decide on partial tasks that should be carried out during the semester. If the requirements they agreed upon are met, the supervisor awards the student an assessment for the course MI-MPR at the end of the semester. 2. External Master these (MT) supervisor fills his/her assessment into the paper "Form to award assessment by an external Final theses (FT) supervisor" (for the courses BIE-BAP, MIE-MPR, MIE-DIP). Students, then, ensure that the assessment is registered into the information system (IS) by asking their internal FT opponent to award the assessment to the IS based on the confirmation of the external MT supervisor. In the case the FT opponent is external as well, the assessment will be registered to the IS by the head of the department responsible for the topic of the MT. 3. If the FT topic that the student has reserved is rather general, the immediate tasks the supervisor assigns to the student for the upcoming semester should aim at fine-tuning the FT topic so that the FTT will be complete and approvable at the end of the semester. | | | |

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|---|---|---|---|
| MI-SCE1 | Computer Engineering Seminar Master I | Z | 4 |
| The Seminar of Computer Engineering is a (s)elective course for students who want to deal with deeper topics of digital design, reliability and resistance to failures and attacks. Students are approached individually within the subject. Each student or group of students solves some interesting topic with the selected supervisor. Part of the subject is work with scientific articles and other professional literature and/or work in KČN laboratories. The capacity of the subject is limited by the possibilities of the seminar teachers. The topics are new for each semester. | | | |
| NIE-HSC | Side-Channel Analysis in Hardware | Z,ZK | 4 |
| This course is dedicated to so-called side-channel information leakage in hardware devices. It focuses on both theoretical analysis and practical attacks. Students get familiar with various kinds of side channels and they get deeper insight in power attacks. Students learn to implement various profiled and non-profiled attacks and get familiar with higher-order attacks. They also get practice in both designing the SCA countermeasures and analyzing the amount and characteristics of the side-channel information leakage. | | | |
| NIE-DDW | Web Data Mining | Z,ZK | 5 |
| Students will learn latest methods and technologies for web data acquisition, analysis and utilization of the discovered knowledge. Students will gain an overview of Web mining techniques for Web crawling, Web structure analysis, Web usage analysis, Web content mining and information extraction. Students will also gain an overview of most recent developments in the field of social web and recommendation systems. | | | |
| NIE-BPS | Wireless Computer Networks | Z,ZK | 4 |
| Students will learn about the modern technologies, protocols, and standards for wireless networks. They will understand the routing mechanisms in ad-hoc networks, multicast and broadcast mechanisms, and data flow control mechanisms. They will also learn about principles of communication in sensor networks. They get knowledge of security mechanisms for wireless networks and get skills of configuration of wireless network elements and simulation of wireless networks using suitable tools. | | | |
| NIE-SEP | World Economy and Business | Z,ZK | 4 |
| The course introduces students of technical university to the international business. It does that predominantly by comparing individual countries and key regions of world economy. Students get to know about different religions and cultures, necessary for doing business in diverse societies as well as indexes of economic freedom, corruption and economic development, which are needed for the right investment decision. Seminars help to improve on the knowledge in the form of discussions based on individual readings. It is advised to take bachelor level of this course BIE-SEP as a prerequisite. | | | |
| FITE-SEP | World Economy and Business | Z,ZK | 4 |
| The course introduces students of technical university to the international business. It does that predominantly by comparing individual countries and key regions of world economy. Students get to know about different religions and cultures, necessary for doing business in diverse societies as well as indexes of economic freedom, corruption and economic development, which are needed for the right investment decision. Seminars help to improve on the knowledge in the form of discussions based on individual readings. It is advised to take bachelor level of this course BIE-SEP as a prerequisite. | | | |

## List of courses of this pass:

| Code | Name of the course | Completion | Credits |
|---|---|---|---|
| DA-DMI | Data Mining | Z,ZK | 6 |
| In the past decade, weve witnessed a huge increase in the amount of data being captured and stored. In these large datasets very useful knowledge is present, though often concealed in the vastness of the data. With data mining techniques patterns are automatically revealed from such large datasets. First, data mining techniques and applications are discussed. Next, we will go into popular predictive and descriptive data mining techniques, with applications in marketing and risk management. Also, analyses such as social network analysis, text mining, process mining, and Big Data will be looked at. Basic programming skills in Python will be learnt. The learned concepts, techniques and programming language will be applied and evaluated with a real-life case. Teaching takes place at University of Antwerpen. See the web page https://www.uantwerpen.be/en/study/programmes/all-programmes/digital-business-engineering/about-the-programme/study-programme/ | | | |
| DA-DRS | Digital Risk And Security (DA-DRS) | Z,ZK | 6 |
| Information technology has become crucial in the growth, sustainability and support of enterprises. However, the pervasive use of technologies also incurs many business risks, anging from abuse, cybercrime, fraud, errors and ommissions. The objective of this course is to understand and analyse IT related business risks and and how these risks can be translated into an appropiate information risk management and security strategy and action plan. In the course, will first discuss the basics of IT Risk, Information Security, and some of the general and specific standards and frameworks to address them. Next, we will elaborate on the IT risk management and IT security functions in an organisation. Specific attention will be given to risk assessment methods, both qualitative and quantitative. The theoretical knowledge will be applied in a group project, where students will conduct a risk assessment in a real organisation, and present the results to the responsible managers. Guarantor and teacher: MSc. Steven De Haes, Ph.D. | | | |
| DA-ESB | Ethical And Sustainable Business | ZK | 3 |
| This course covers corporate responsibility, morality and sustainability. It has three main parts: Part 1: Ethics and morality in business History of ethics in business Origins, stakeholder theory, basic philosophy Utilitarianism vs Kantian approaches Behavioural economic. Part 2: Corporate responsibility and sustainability in theory Shared value creation, social profit, social entrepreneurship Sustainable HR Circular Economy Green Deal and CSRD New business models for sustainability. Part 3: Corporate responsibility and sustainability in practice Implementing sustainability in the value chain of a company: products, operations, organisation and HR How to apply a management approach to sustainability. Teaching takes place at University Antwerpen. See the web page https://www.uantwerpen.be/en/study/programmes/all-programmes/digital-business-engineering/about-the-programme | | | |
| DA-IPR | Integration project digital business engineering | Z | 9 |
| This is typically a study followed by a thesis. Teaching takes place at University Antwerpen. Contact Information: Jan Verelst jan.verelst@uantwerpen.be Dieter Van Nuffel dieter.vannuffel@uantwerpen.be See the web page https://www.uantwerpen.be/en/study/programmes/all-programmes/digital-business-engineering/about-the-programme/study-programme/ | | | |
| DA-SEA | Software Engineering And Architecture | Z,ZK | 9 |
| Basic software engineering structures, practices, and patterns are explained in a realistic software engineering environment using the Java progarmming language. Practical assignments complement these lectures. Basic software architecture structures, practices, and patterns are explained and discussed, including various aspects of evolvability. Video lectures and a practical assignment deepen this. Teaching takes place at University of Antwerpen. See the web page https://www.uantwerpen.be/en/study/programmes/all-programmes/digital-business-engineering/about-the-programme/study-programme/ | | | |
| DD-DIN | Digital innovation | ZK | 6 |
| This course focuses on innovation in the context of the digital, software-intensive economy. Starting from a broader perspective on innovation, both mainstream theories and thinking on innovation, as well as alternative views from challengers, are discussed. This includes omnipresent innovation models in which IT-related innovations are adopted by startups and scaleups (eg. blockchains or drones) and making them available in certain business domains, which requires agility and speed of development at the software level. Also, disruptive innovation, where existing value chains are challenged, is discussed with its requirement for new levels of productivity in software development. Leading theories are discussed and illustrated with local and international cases using guest lectures. Students of a master double degree specialisation Digital Business Engineering will attend this course during their stay at the partner university Antwerp. | | | |

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|---|---|---|---|
| DD-DSE | Data science and ethics | ZK | 3 |
| Ethics tell us about right and wrong. The course will provide an overview of key: (1) concepts, related to privacy, discrimination, transparency, and explainability, (2) techniques to assess and improve on these aspects, and (3) cautionary tales that motivate the importance thereof. The consideration of data science ethics is crucial for any data-driven company, as will be motivated by ample cautionary tales. With a wide range of cases, the large implications of new data science technologies on ethics will be discussed. These include online tracking, medical records, Facebook data, Internet censorship, big data, privacy engineering, and Artificial Intelligence. Data scientists and business managers are not inherently unethical, but at the same time not trained to think this through neither. This course aims to address this important gap. Students of a master double degree specialisation Digital Business Engineering will attend this course during their stay at the partner university Antwerp | | | |
| DD-DSG | Digital strategy and governance | ZK | 6 |
| The course provides a complete and comprehensive overview of what digital governance entails and how it can be applied in practice. The course is organized around the following three main themes: concepts and practices of digital governance, the impact of digital governance on business/IT strategic and operational alignment, and the notion of digital value and risk. The course is based on the teacher's knowledge obtained in applied research projects on the relationship between digital governance practices and digital value. To support the student in understanding and absorbing the material provided, the course uses short assignments and case studies. Students of a master double degree specialisation Digital Business Engineering will attend this course during their stay at the partner university Antwerp | | | |
| DD-SMN | Strategic management | ZK | 6 |
| In the first part of the course, the different concepts and perspectives of strategic management are analyzed. The basic characteristics of strategic thinking are being analyzed. Then the importance of mission/vision, as the starting point in strategic thinking, is being discussed. This is being linked to the broader concept of sustainability / corporate social responsibility. The remaining parts focus on the three basic dimensions of strategy: (1) the strategy content: business level strategy, corporate level strategy, and network level strategy (2) the strategy process: strategic formation, strategic change, and strategic innovation, (3) the strategy context: the industry context, the organizational context, and the international context. In each of the different chapters, the fundamental strategic management paradoxes are situated and evaluated in the strategic management theory. Attention is also given to some strategic management tools which can be used to manage the strategy process. Students of a master double degree specialisation Digital Business Engineering will attend this course during their stay at the partner university Antwerp | | | |
| DD-ZUM | Artificial Intelligence Fundamentals | Z,ZK | 5 |
| Students are introduced to the fundamental problems in the Artificial Intelligence, and the basic methods for their solving. It focuses mainly on the classical tasks from the areas of state space search, multi-agent systems, game theory, planning, and machine learning. Modern soft-computing methods, including the evolutionary algorithms and the neural networks, will be presented as well. This course is only for students of the double degree program with the University of Antwerp. Other students are not allowed to enrol this course, enrol the BIE-ZUM course instead. | | | |
| FIT-ACM1 | Programming Practices 1 | KZ | 5 |
| This is a selective course for preparing talented student for representation in international programming contests. | | | |
| FIT-ACM2 | Programming Practices 2 | KZ | 5 |
| This is a selective course for preparing talented student for representation in international programming contests. | | | |
| FIT-ACM3 | Programming Practices 3 | KZ | 5 |
| This is a selective course for preparing talented student for representation in international programming contests. | | | |
| FIT-ACM4 | Programming Practices 4 | KZ | 5 |
| This is a selective course for preparing talented student for representation in international programming contests. | | | |
| FIT-ACM5 | Programming Practices 5 | KZ | 5 |
| This is a selective course for preparing talented student for representation in international programming contests. | | | |
| FIT-ACM6 | Programming Practices 6 | KZ | 5 |
| This is a selective course for preparing talented student for representation in international programming contests. | | | |
| FITE-EHD | Introduction to European Economic History | Z,ZK | 3 |
| The course introduces a selection of themes from the European economic history. It gives the student basic knowledge about forming of the global economy through the description of the key periods in history. As European countries have been dominant actors in this process it focuses predominantly on their roles in the economic history. From large economic area of Roman Empire to fragmentation of the Middle Ages, from destruction of WWII to the current affairs, the development of modern financial institutions is deciphered. The course does not cover detailed economic history of particular European countries but rather the impact of trade and role of particular events, institutions and organizations in history. Class meetings will consist of a mixture of lecture and discussion. | | | |
| FITE-SEP | World Economy and Business | Z,ZK | 4 |
| The course introduces students of technical university to the international business. It does that predominantly by comparing individual countries and key regions of world economy. Students get to know about different religions and cultures, necessary for doing business in diverse societies as well as indexes of economic freedom, corruption and economic development, which are needed for the right investment decision. Seminars help to improve on the knowledge in the form of discussions based on individual readings. It is advised to take bachelor level of this course BIE-SEP as a prerequisite. | | | |
| MI-SCE1 | Computer Engineering Seminar Master I | Z | 4 |
| The Seminar of Computer Engineering is a (s)elective course for students who want to deal with deeper topics of digital design, reliability and resistance to failures and attacks. Students are approached individually within the subject. Each student or group of students solves some interesting topic with the selected supervisor. Part of the subject is work with scientific articles and other professional literature and/or work in KČN laboratories. The capacity of the subject is limited by the possibilities of the seminar teachers. The topics are new for each semester. | | | |
| MIE-MZI | Mathematics for data science | Z,ZK | 4 |
| In this course, the students are introduced to the domains of mathematics necessary for understanding the standard methods and algorithms used in data science. The studied topics include mainly: linear algebra (matrix factorisations, eigenvalues, diagonalization), continuous optimisation (optimisation with constraints, duality principle, gradient methods) and selected notions from probability theory and statistics. | | | |
| NI-ADM | Data Mining Algorithms | Z,ZK | 5 |
| The course focuses on algorithms used in the fields of machine learning and data mining. However, this is not an introductory course, and the students should know machine learning basics. The emphasis is put on advanced algorithms (e.g., gradient boosting) and non-basic kinds of machine learning tasks (e.g., recommendation systems) and models (e.g., kernel methods). | | | |
| NI-ADP | Architecture and Design patterns | Z,ZK | 5 |
| The objective of this course is to provide students with both work knowledge about the underlying foundations of object-oriented design and analysis as well as with understanding of the challenges, issues, and tradeoffs of advanced software design. In the first part of the course, the students will refresh and deepen their knowledge of object-oriented programming and get familiar with the commonly used object-oriented design patterns that represent the best practices for solving common software design problems. In the second part the students will be introduced to the principles of software architecture design and analysis. This includes the classical architectural styles, component based systems, and some advanced software architectures used in large-scale distributed systems. | | | |
| NI-AIB | Algorithms of Information Security | Z,ZK | 5 |
| Students will get acquainted with the algorithms of secure key generation and cryptographic error (not only biometric) data processing. Furthermore, students will learn the mathematical principles of cryptographic protocols (identification, authentication, and signature schemes). Another part of the course is dedicated to malware detection and the use of machine learning in detection systems. The last topic includes practical steganographic methods and attacks on steganographic systems. | | | |

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| NI-AM1 | Middleware Architectures 1 | Z,ZK | 5 |
| Students will study new trends, concepts, and technologies in the area of service-oriented architectures. The will gain an overview of information system architecture, web service architecture and aplication servers. The will also study principles and technologies for middleware focused on application integrations, asynchronous communications and high availability of applications. | | | |
| NI-AM2 | Middleware Architectures 2 | Z,ZK | 5 |
| Students will learn new trends and technologies on the Web including theoretical foundations. They will gain an overview of Web application architectures, concepts and technologies for microservices, distrubuted cache and databases, smart contracts, realtime communication and web security. | | | |
| NI-AML | Advanced machine learning | Z,ZK | 5 |
| The course introduces students to selected advanced topics of machine learning and artificial intelligence. The topics present techniques in the field of recommendation systems, image processing, control and interconnection of physical laws with the field of machine learning. The aim of the exercise is to familiarize students with the methods discussed. | | | |
| NI-APR | Selected Methods for Program Analysis | Z,ZK | 5 |
| This course introduces you to program analysis, i.e., the automated reasoning about the behavior of a computer program. We will cover static and dynamic analysis. In Static Analysis, we will look at the art of reasoning about computer programs without running them. We will look at the analyses for program understanding, optimizations, error detection. In Dynamic Analysis, we will look at the analyses considering individual program runs using a concrete environment and inputs. | | | |
| NI-BKO | Error Control Codes | Z,ZK | 5 |
| The goal of the course is to present various ways to detect or correct individual errors and burst errors in data stored into memories or transmitted via channels. | | | |
| NI-BML | Bayesian Methods for Machine Learning | KZ | 5 |
| The subject is focused on practical use of basic Bayesian modeling methods in the dynamically evolving machine learning theory. In particular, it studies the construction of appropriate models providing description of real phenomena, as well as their subsequent use, e.g., for forecasting of future evolution or learning about the hidden variables (true object position from noisy observations etc.). The emphasis is put on understanding of explained principles and methods and their practical adoption. For this purpose, a number of real world examples and applications will be presented to students, for instance, 2D/3D object tracking, radiation source term estimation, or separation in medical imaging. The students will try to solve some of them. | | | |
| NI-BUI | Business Informatics | Z,ZK | 5 |
| The aim of the course is to focus on operational, tactical and strategic management of business informatics. Students will gain knowledge in the areas of business process management, ICT services and architectures in enterprise informatics. They will also learn about the principles, models and standards (ITIL, COBIT) in IT management, and lifecycle management of ICT services and resource management (sourcing). Students will learn the process of creating and implementing information strategy, IT Governance, the importance of ICT for business and the context of information strategy with global business strategy. They will also gain knowledge in the areas of economic IT management, revenue and investment management, IT investment evaluation and human resources management in IT (roles CIO, CEO, CFO). | | | |
| NI-BVS | Embedded Security | Z,ZK | 5 |
| Students gain basic knowledge in selected topics of cryptography and cryptanalysis. The course focuses particularly on efficient implementations of cryptographic primitives in hardware and software (in embedded systems). Students gain a good overview of functionality of (hardware) cryptographic accelerators, smart cards, and resources for securing internal functions of computer systems. | | | |
| NI-DDW | Web Data Mining | Z,ZK | 5 |
| Students will learn latest methods and technologies for web data acquisition, analysis and utilization of the discovered knowledge. Students will gain an overview of Web mining techniques for Web crawling, Web structure analysis, Web usage analysis, Web content mining and information extraction. Students will also gain an overview of most recent developments in the field of social web and recommendation systems. | | | |
| NI-DID | Digital drawing | Z | 2 |
| The course will introduce students to the basic principals of digital drawing and graphical design. Students will gain understanding of composition, perspective and color theory, which they will practically apply in their own design works. Students will also gain experience in drawing and painting with digital and analog tools. The course is fit for anyone who wants to practice or learn drawing and painting. The course is organized as a thematic practices covering parts of theory and practical exercise to practice gained knowledge. | | | |
| NI-DSS | Decision Support Systems | Z,ZK | 5 |
| The aim of the course is to provide students with knowledge and skills in decision support systems, their classification (Powerova), selected principles of data-oriented, model-oriented and knowledge-oriented decision support systems. Students will also gain knowledge of multicriterial decision-making methods and game theory. They will also learn about the principles of conceptually and ontologically oriented decision support systems and the basics of distribution, optimization and evolution methods and algorithms. | | | |
| NI-DSV | Distributed Systems and Computing | Z,ZK | 5 |
| Students are introduced to methods for coordination of processes in distributed environment characterised by nondeterministic time responses of computing processes and communication channels. They learn basic algorithms that assure correctness of computations realized by a group of loosely coupled processes and mechanisms that support high availability of both data and services, and safety in case of failures. | | | |
| NI-DSW | Design Sprint | Z | 2 |
| Students will work on projects using the Design Sprint method, developed by Google. THanks to this method the teams are able to go from idea to validated prototype in 5 days. During the course the students will get familiar with the method as participants. Through practical challenges they will try the whole 5 day process starting with research and finishing with testing the prototypes (plus final presentation). | | | |
| NI-EHW | Embedded Hardware | Z,ZK | 5 |
| The course brings basic laws that govern digital design and basic techniques to use them. It deals with both large and small scale systems. This is the base of advanced embedded systems, that profit from their specialized structure for effective computation and acceleration. Design of fast custom computing machines is discussed, including standardized means of internal communication, parallelism extraction and utilization in special structures and system architectures. | | | |
| NI-EPC | Effective C++ programming | Z,ZK | 5 |
| Students learn how to use the modern features of contemporary versions of the C++ programming language for software development. The course focuses on programming effectivity and efficiency in the form of writing maintainable and portable source code and creating correct programs with low memory and processor time requirements. | | | |
| NI-ESW | Embedded Software | Z,ZK | 5 |
| Embedded software course acquainted students with the specifics of software development for embedded systems. The course covers the areas from the basic techniques of programming in C language and code optimizations, through typical areas as the reliable software development, embedded operating systems, signal processing, up to sophisticated techniques combined with artificial intelligence. | | | |
| NI-EVY | Efficient Text Pattern Matching | Z,ZK | 5 |
| Students get knowledge of efficient algorithms for text pattern matching. They learn to use so called succinct data structures that are efficient in both access time and memory complexity. They will be able to use the knowledge in design of applications that utilize pattern matching. | | | |
| NI-FME | Formal Methods and Specifications | Z,ZK | 5 |
| Students are able to describe semantics of software formally and to use sound reasoning for construction of correct software. They learn to use some software tools that allow to prove basic properties of software. | | | |
| NI-GAK | Graph theory and combinatorics | Z,ZK | 5 |
| The goal of the class is to introduce the most important topics in graph theory, combinatorics, combinatorial structures, discrete models and algorithms. The emphasis will be not only on undestanding the basic principles but also on applications in problem solving and algorithm design. The topics include: generating functions, selected topics from graph and hypergraph | | | |

coloring, Ramsey theory, introduction to probabilistic method, properties of various special classes of graphs and combinatorial structures. The theory will be also applied in the fields of combinatorics on words, formal languages and bioinformatics.

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| NI-GEN | Code Generators | Z,ZK | 5 |

Advanced techniques of translating programs written in high-level programming languages are essential for understanding the field of systems programming. This primarily involves understanding the algorithms and techniques used to translate more complex programming constructs of modern languages employed in systems programming. Students will become familiar with both the theoretical and practical aspects of implementing the back-end of optimizing compilers for programming languages.

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| NI-GLR | Games and reinforcement learning | Z,ZK | 4 |

The field of reinforcement learning is very hot recently, because of advances in deep learning, recurrent neural networks and general artificial intelligence. This course is intended to give you both theoretical and practical background so you can participate in related research activities. Presented in English.

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| NI-GPU | GPU Architectures and Programming | Z,ZK | 5 |

Students will gain knowledge of the internal architecture of modern massively parallel GPU processors. They will learn to program them mainly in the CUDA programming environment, which is already a widespread programming technology of GPU processors. As an integral part of the effective computational use of these hierarchical computational structures, students will also learn optimization programming techniques and methods of programming multiprocessor GPU systems.

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| NI-GRI | Grid Computing | Z,ZK | 5 |

Grid computing and gain knowledge about the world-wide network and computing infrastructure.

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| NI-HWB | Hardware Security | Z,ZK | 5 |

The course provides the knowledge needed for the analysis and design of computer systems security solutions. Students get an overview of safeguards against abuse of the system using hardware means. They will be able to safely use and integrate hardware components into systems and test them for resistance to attacks. Students will gain knowledge about the cryptographic accelerators, PUF, random number generators, smart cards, biometric devices, and devices for internal security functions of the computer.

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| NI-KOD | Data Compression | Z,ZK | 5 |

Students are introduced to the basic principles of data compression. They will learn the necessary theoretical background and get an overview of data compression methods being used in practice. The overview covers principles of integer coding and of statistical, dictionary, and context data compression methods. In addition, students learn the fundamentals of lossy data compression methods used in image, audio, and video compression.

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| NI-KRY | Advanced Cryptology | Z,ZK | 5 |

Students will learn the essentials of cryptanalysis and the mathematical principles of constructing symmetric and asymmetric ciphers. They will know the mathematical principles of random number generators. They will have an overview of cryptanalysis methods, elliptic curve cryptography and quantum cryptography, which they can apply to the integration of their own systems or to the creation of their own software solutions.

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| NI-MCC | Multicore CPU Computing | Z,ZK | 5 |

Students will get acquainted in detail with hardware support and programming technologies for the creation of parallel multithreaded computations on multicore processors with shared and virtually shared memories, which are today the most common computing nodes of powerful (super)computer systems. Students will gain knowledge of architecturally specific optimization techniques used to reduce the performance drop due to the widening gap between the computational requirements of multi-core CPUs and memory interface throughput. On specific non-trivial multithreaded programs, students will also learn the basics of the art of creating these applications.

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| NI-MEP | Modelling of Enterprise Processes | Z,ZK | 5 |

The subject is focused on introduction to the discipline of Enterprise Engineering. Students learn the importance of a proper methodological approach for (re)engineering and implementation of processes, organisation structures and information support in big enterprises and institutions.

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| NI-MKY | Mathematics for Cryptology | Z,ZK | 5 |

Students will gain deeper knowledge of algebraic procedures solving the most important mathematical problems concerning the security of ciphers. In particular, the course focuses on the problem of solving a system of polynomial equations over a finite field, the problem of factorization of large numbers and the problem of discrete logarithm. The problem of factorization will also be solved on elliptic curves. Students will further become familiar with modern encryption systems based on lattices.

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| NI-MPJ | Modelling of Programming Languages | Z,ZK | 5 |

The analysis, transformation, and code generation processes depend on the semantics of the language; in particular, they are correct if they preserve the semantics of the language. This course explores the semantics of programming languages. The students will learn the language models with emphasis on functional languages, students are expected to understand the basics of the lambda calculus and here get acquainted with the advanced lambda calculus. The students also get hands-on-experience with semantic modeling and execution tools.

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| NI-MTI | Modern Internet Technologies | Z,ZK | 5 |

SYNOPSIS The subject "Modern Internet Technologies" is designed on four major pillars of networking: 1. Unified Communication and Collaboration - A single network, oriented on TCP/IP is able to carry whatever types of protocols for whatever purposes. This architecture is able to be protocol independent and carries voice, video and data to achieve seamless integrated services. 2. Design of Extremely Scalable Networks - This provides the insights of network architectures which can accommodate hundreds of millions of users and billions of devices. Thus, there is a paradigm switch from LANs (Local Area Networks) to SPs (Service Providers). 3. Traffic Segregation, Traffic Matching and Traffic Prioritisation - These technologies allow service providers to create private channels of communication between customers, with guaranteed parameters (bandwidth, delay, jitter, type of protocol). 4. Acceleration Technologies - They allow traffic to be carried at the optimal speed and allow for graceful degradation of service parameters in case of failures.

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| NI-MVI | Computational Intelligence Methods | Z,ZK | 5 |

Students will understand methods and techniques of computational intelligence that are mostly nature-inspired, parallel by nature, and applicable to many problems. They will learn how these methods work and how to apply them to problems related to data mining, control, intelligen games, optimizations, etc.

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| NI-NON | Nonlinear Continuous Optimization and Numerical Methods | Z,ZK | 5 |

Students will be introduced to nonlinear continuous optimization, principles of the most popular methods of optimization and applications of such methods to real-world problems. They will also learn the finite element method and the finite difference method used for solving ordinary and partial differential equations in engineering. They will learn to solve systems of linear algebraic equations that arise from discretization of the continuous problems by direct and iterative algorithms. They will also learn to implement these algorithms sequentially as well as in parallel.

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| NI-NSS | Normalized Software Systems | ZK | 5 |

Students will learn the foundations of normalized systems theory that studies the evolvability of modular structures based on concepts from engineering, such as stability from system theory and entropy from thermodynamics. Students will understand a set of principles that indicate where violations of stability and entropy-related issues occur in any given software architecture. In the second part of the course, students learn how to construct software architectures using a set of 5 design patterns called elements. These elements provide the core functionality of information systems in terms of storing data, executing actions, workflows, connectors, and triggers, while handling violations of the stability and entropy-related principles. This knowledge allows students to realize new levels of evolvability in software architectures.

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| NI-NUR | User Interface Design | Z,ZK | 5 |

Students will understand the theorical background of human-computer interaction and user interface (UI) design, will learn formal description of UIs, formal user models, the fundamental notions and procesures. They get acquainted with graphical, speech, and multimodal UIs. Thanks to the gained knowledge, the students will be able to design advanced UIs.

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| NI-OSY | Operating Systems and Systems Programming | Z,ZK | 5 |

The course covers system programming in UNIX environment. Emphasis is given on kernel development with focus on kernel architecture and kernel data structures. Key topics are: process management, memory management, file operations and architecture of modern file systems, device drivers and network programming.The course also addresses kernel development process, upgrades of existing kernels, kernel booting, debugging using dynamic instrumentation, and techniques to guarantee portability. Specifics of kernel architecture

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| | in embedded and real-time operating systems are also discussed. Theoretical and general principles are demonstrated on the LINUX kernel. Within labs, students will work on projects focused on development of LINUX kernel modules. | | |
| NI-PAS | Advanced Aspects of Business | Z,ZK | 4 |
| | The aim of the course is to provide students with advanced (compared to the bachelor's degree) knowledge and skills needed to establish and run their own business or business management, especially in law, administration (necessary steps and documents), business economics, foreign trade and related aspects. | | |
| NI-PDB | Advanced Database Systems | Z,ZK | 5 |
| | Students orient themselves in problems of evaluation and optimization of SQL queries. The next part of the course deals with new concepts of database machines (so called NoSQL databases), with the related new data models (XML, graph databases, column databases) and languages for working with them (XQuery, XPath, CYPHER, Gremlin). The last part of the course deals with performance evaluation of database machines. | | |
| NI-PDD | Data Preprocessing | Z,ZK | 5 |
| | Students learn to prepare raw data for further processing and analysis. They learn what algorithms can be used to extract information from various data sources, such as images, texts, time series, etc., and learn the skills to apply these theoretical concepts to solve specific problems in individual projects - e.g., extraction of characteristics from images or from web pages. | | |
| NI-PIS | Enterprise Information Systems | Z,ZK | 5 |
| | The course is focused on the current IT requirements of large companies in the Czech Republic (Top 100). The basis is Data management, storage of big data (BigData) and their use in BI (Business Intelligence). The principles of solving the overall architecture of information systems in the banking, insurance and telecommunications sectors will be explained on real examples. Furthermore, students will get acquainted with the life cycle of information systems in the company / organization and its impact on the business strategy of the company. Students will be acquainted with technologies that have proven themselves in the elimination of basic risks in the planning, implementation and operation of information systems in the company / organization. | | |
| NI-PON | Selected Topics in Optimization and Numerical mathematics | Z,ZK | 5 |
| | The course focuses on optimization problems that appear in the field of machine learning and artificial intelligence. Students broaden their knowledge of continuous optimization obtained in the course Mathematics for informatics. The methods are explained and described along with the details on how they are implemented on computers. Hence, the relevant concepts of numerical matematics, mainly numerical linear algebra, are explained too. | | |
| NI-REV | Reverse Engineering | Z,ZK | 5 |
| | Students will get acquainted with the essentials of reverse engineering of computer software. They will learn how processes start and what happens before and after the main function is called. Students will understand how executable files are organized and how they interact with 3rd party libraries. Another part of the course is dedicated to reverse engineering of applications written in C++. Students will also understand principles of disassemblers and obfuscation techniques. A part of the course will also be dedicated to debuggers: how debuggers and debugging work and which methods can be used to detect it. One of the lectures will be dedicated to the latest trends on the computer malware scene. The focus of the course is on the seminars, where students will solve practically oriented tasks from the real world. | | |
| NI-RUN | Runtime Systems | Z,ZK | 5 |
| | This course is an introduction to the world of virtual machines (VM) for high-level programming languages. There are two goals: Give you hands-on experience in design and implementation of a compiler and a VM from scratch, including Abstract Syntax Tree (AST) interpretation Byte code (BC) design and interpretation AST to BC compilation Memory management Just-in-time compilation and some optimization techniques Through a series of guest lectures, introduce you to various advanced topics and implementations of real-world VMs, including Dynamic optimizations, speculations, and deoptimizations Language implementation frameworks Read-world VMs | | |
| NI-SBF | System Security and Forensics | Z,ZK | 5 |
| | Students will get familiar with aspects of system security (principles of end station security, principles of security policies, security models, authentication concepts). Furthermore, students will get familiar with forensic analysis as a tool for investigating security incidents (techniques used by malicious software/attackers and forensic analysis techniques and the importance of operating system/operating system artifacts or file system for attack analysis and detection). | | |
| NI-SCR | Statistical Analysis of Time Series | Z,ZK | 5 |
| | The course deals with the practical use of the basic time series modelling theory in engineering tasks, ranging from economics (stock exchange prices, employment) and industrial problems (modelling of signals and processes) to computer networks (network components load, attacks detection). The students learn to select a convenient process model, estimate its parameters, analyze its properties and use it for forecasting of future or intermediate values. The stress is put on understanding and adoption of the main principles based on practical real-world examples. Both the lab classes and the lectures exploit freely available software packages in order to provide easy and straightforward transfer of students' knowledge from the academic to the real world. | | |
| NI-SIB | Network Security | Z,ZK | 5 |
| NI-SIM | Digital Circuit Simulation and Verification | Z,ZK | 5 |
| | The aim of the course is to acquaint the students with principles of digital circuit simulation at RTL (Register Transfer Level) and TLM (Transaction Level Modeling) levels and with the properties of proper tools. The course covers recent verification methods, too. | | |
| NI-SWE | Semantic Web and Knowledge Graphs | Z,ZK | 5 |
| | The students will learn the most recent concepts and technologies of the Semantic Web. The course will provide an overview of the Semantic Web technologies, methods and best practices for modelling, integration, publishing, querying and consumption of semantic data. The students will also gain skills in creation of knowledge graphs and their systematic quality assurance. | | |
| NI-SYP | Parsing and Compilers | Z,ZK | 5 |
| | The module builds upon the knowledge of fundamentals of automata theory, formal language and formal translation theories. Students gain knowledge of various variants and applications of LR parsing and are introduced to special applications of parsers, such as incremental and parallel parsing. | | |
| NI-TES | Systems Theory | Z,ZK | 5 |
| | Today, humankind has the ability to develop systems of incredible complexity (e.g., trains, microprocessors, airplanes, nuclear power plants). However, the costs of managing this complexity and of ensuring the correct behavior of a given system have become critical. A key technique for mastering this complexity is the usage of models that describe only those aspects of the systems that are important for the task at hand, and automated tools for analyzing those models. This subject will present theory and algorithms that form the basis for the modeling and analysis of complex systems. | | |
| NI-TSP | Testing and Reliability | Z,ZK | 5 |
| | Students will gain knowledge about circuit testing and about methods for increasing reliability and security. They will get practical skills to be able to prepare a test set with the help of the intuitive path sensitization and to use an ATPG for automatic test generation. They will be able to design easily testable circuits and systems with built-in-self-test equipment. They will be able to compute, analyze, and control the reliability and availability of the designed circuits. | | |
| NI-TSW | Software Product Development | KZ | 4 |
| | The course is presented in Czech. | | |
| NI-UMI | Artificial intelligence | Z,ZK | 5 |
| | The course covers search and inference algorithms in major formal paradigms used in artificial intelligence such as logic theories, constraint programming and automated planning. The main principles and practical applications of discussed techniques will be illustrated. | | |
| NI-VCC | Virtualization and Cloud Computing | Z,ZK | 5 |
| | Students will gain knowledge of architectures of large computer systems that are used in data centers and computer infrastructure of companies and organizations. They will get acquainted with virtualization principles, tools and technologies that serve to facilitate and automate configuration, testing and monitoring, and to efficiently operate and optimize the | | |

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| | performance parameters of modern computer systems. Theoretically and practically, they will get acquainted with containerization as the most effective technology today for the management of complex computer systems and with specific technologies of cloud systems. Finally, they will learn the principles and gain practical skills in the use of modern integration and development tools (Continuous integration and development). | | |
| NI-VMM | Retrieval from Multimedia | Z,ZK | 5 |
| | The student obtains general knowledge regarding interfaces of portals providing multimedia content, the principles of similarity search, the methods of feature extraction from multimedia objects, indexing, and structure of distributed search engines. | | |
| NIE-AM1 | Middleware Architectures 1 | Z,ZK | 5 |
| | Students will study new trends, concepts, and technologies in the area of service-oriented architectures. The will gain an overview of information system architecture, web service architecture and aplication servers. The will also study principles and technologies for middleware focused on application integrations, asynchronous communications and high availability of applications. This course replaces the course MIE-MDW. | | |
| NIE-AM2 | Middleware Architectures 2 | Z,ZK | 5 |
| | Students will learn new trends and technologies on the Web including theoretical foundations. They will gain an overview of Web application architectures, concepts and technologies for microservices, distrubuted cache and databases, smart contracts, realtime communication and web security. | | |
| NIE-ARI | Computer arithmetic | Z,ZK | 4 |
| | Students will learn various data representations used in digital devices and will be able to design arithmetic operations implementation units. | | |
| NIE-BLO | Blockchain | Z,ZK | 5 |
| | Students will understand the foundations of blockchain technology, smart contract programming, and gain an overview of most notable blockchain platforms. They will be able to design, code and deploy a secure decentralized application, and assess whether integration of a blockchain is suitable for a given problem. The course places an increased emphasis on the relationship between blockchains and information security. It is concluded with a defense of a research or applied semester project, which prepares the students for implementing or supervising implementation of blockchain-based solutions in both academia and business. | | |
| NIE-BPS | Wireless Computer Networks | Z,ZK | 4 |
| | Students will learn about the modern technologies, protocols, and standards for wireless networks. They will understand the routing mechanisms in ad-hoc networks, multicast and broadcast mechanisms, and data flow control mechanisms. They will also learn about principles of communication in sensor networks. They get knowledge of security mechanisms for wireless networks and get skills of configuration of wireless network elements and simulation of wireless networks using suitable tools. | | |
| NIE-CPX | Complexity Theory | Z,ZK | 5 |
| | Students will learn about the fundamental classes of problems in the complexity theory and different models of algoritms and about implications of the theory concerning practical (in)tractability of difficult problems. | | |
| NIE-DDW | Web Data Mining | Z,ZK | 5 |
| | Students will learn latest methods and technologies for web data acquisition, analysis and utilization of the discovered knowledge. Students will gain an overview of Web mining techniques for Web crawling, Web structure analysis, Web usage analysis, Web content mining and information extraction. Students will also gain an overview of most recent developments in the field of social web and recommendation systems. | | |
| NIE-DIP | Diploma Thesis | Z | 30 |
| NIE-DVG | Introduction to Discrete and Computational Geometry | Z,ZK | 5 |
| | The course intends to introduce the students to the discipline of Discrete and Computational Geometry. The main goal of the course is to get familiar with the most fundamental notions of this discipline, and to be able to solve simple algorithmic problems with a geometric component. | | |
| NIE-EVY | Efficient Text Pattern Matching | Z,ZK | 5 |
| | Students get knowledge of efficient algorithms for text pattern matching. They learn to use so called succinct data structures that are efficient in both access time and memory complexity. They will be able to use the knowledge in design of applications that utilize pattern matching. | | |
| NIE-HMI | History of Mathematics and Informatics | Z,ZK | 3 |
| | The course focuses on selected topics from calculus, general algebra, number theory, numerical mathematics and logic - useful for today computer science The topics are selected for finding some relations between computer science and mathematical methods. Some examples of applications of mathematics to computer sciences will be showed. | | |
| NIE-HSC | Side-Channel Analysis in Hardware | Z,ZK | 4 |
| | This course is dedicated to so-called side-channel information leakage in hardware devices. It focuses on both theoretical analysis and practical attacks. Students get familiar with various kinds of side channels and they get deeper insight in power attacks. Students learn to implement various profiled and non-profiled attacks and get familiar with higher-order attacks. They also get practice in both designing the SCA countermeasures and analyzing the amount and characteristics of the side-channel information leakage. | | |
| NIE-KOP | Combinatorial Optimization | Z,ZK | 6 |
| | The students will gain knowledge and understanding necessary deployment of combinatorial heuristics at a professional level. They will be able not only to select and implement but also to apply and evaluate heuristics for practical problems. | | |
| NIE-MPI | Mathematics for Informatics | Z,ZK | 7 |
| | The course focuses on selected topics from general algebra with emphasis on finite structures used in computer science. It includes topics from multi-variate analysis, smooth optimization, and multi-variate integration. The third large topic is computer arithmetics and number representation in a computer along with error manipulation. The last topic includes selected numerical algorithm and their stability analysis. The topics are completed with the demonstration of applications in computer science. The course focuses on clear presentation and argumentation. | | |
| NIE-MPR | Master Project | Z | 7 |
| | 1. At the beginning of the semester, a student reserves her/his final thesis topic and gets together with its supervisor. Together they decide on partial tasks that should be carried out during the semester. If the requirements they agreed upon are met, the supervisor awards the student an assessment for the course MI-MPR at the end of the semester. 2. The external supervisor enters the information on granting the credit using the form "Granting credit from the external supervisor of the final thesis" (http://fit.cvut.cz/student/studijni/formulare). The completed and signed form must be delivered in person or by email to the SZZ coordinator, who will arrange for the credit to be granted. 3. If the FT topic that the student has reserved is rather general, the immediate tasks the supervisor assigns to the student for the upcoming semester should aim at fine-tuning the FT topic so that the FTT will be complete and approvable at the end of the semester. | | |
| NIE-MVI | Computational Intelligence Methods | Z,ZK | 5 |
| | Students will understand the basic methods and techniques of computational intelligence, which are based on traditional artificial intelligence, are parallel in nature and are applicable to solving a wide range of problems. The subject is also devoted to modern neural networks and the ways in which they learn and neuroevolution. Students will learn how these methods work and how to apply them to problems related to data extraction, management, intelligence in games and optimisation, etc. | | |
| NIE-NSS | Normalized Software Systems | ZK | 5 |
| | Students will learn the foundations of normalized systems theory that studies the evolvability of modular structures based on concepts from engineering, such as stability from system theory and entropy from thermodynamics. Students will understand a set of principles that indicate where violations of stability and entropy-related issues occur in any given software architecture. In the second part of the course, students learn how to construct software architectures using a set of 5 design patterns called elements. These elements provide the core functionality of information systems in terms of storing data, executing actions, workflows, connectors, and triggers, while handling violations of the stability and entropy-related principles. This knowledge allows students to realize new levels of evolvability in software architectures. | | |

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| NIE-OSY | Operating Systems and Systems Programming | Z,ZK | 5 |
| This course is focused on the design and implementation of the basic components that make up modern operating systems. This includes threads, processes, switching context, virtual memory, system calls, interrupts and interactions of SW and HW using drivers. Students will learn the theory of the concept of operating system architecture with emphasis on the kernel architecture. Within the course, they will gain practical experience with the development of a small but fully functional operating system. | | | |
| NIE-PAM | Parameterized Algorithms | Z,ZK | 4 |
| There are many optimization problems for which no polynomial time algorithms are known (e.g. NP-complete problems). Despite that it is often necessary to solve these problems exactly in practice. We will demonstrate that many problems can be solved much more effectively than by naively trying all possible solutions. Often one can find a common property (parameter) of the inputs from practice-e.g., all solutions are relatively small. Parameterized algorithms exploit that by limiting the time complexity exponentially in this (small) parameter and polynomially in the input size (which can be huge). Parameterized algorithms also represent a way to formalize the notion of effective polynomial time preprocessing of the input, which is not possible in the classical complexity. Such a polynomial time preprocessing is then a suitable first step, whatever is the subsequent solution method. We will present a plethora of parameterized algorithm design methods and we will also show how to prove that for some problem (and parameter) such an algorithm (presumably) does not exist. We will also not miss out the relations to other approaches to hard problems such as moderately exponential algorithms or approximation schemes. | | | |
| NIE-PDB | Advanced Database Systems | Z,ZK | 5 |
| Students orient themselves in problems of evaluation and optimization of SQL queries. The next part of the course deals with new concepts of database machines (so called NoSQL databases), with the related new data models (XML, graph databases, column databases) and languages for working with them (XQuery, XPath, CYPHER, Gremlin). The last part of the course deals with performance evaluation of database machines. This course is equivalent to the course MIE-PDB. | | | |
| NIE-PDL | Practical Deep Learning | KZ | 5 |
| This course is designed to provide students with a comprehensive understanding of Deep Learning using PyTorch, a popular open-source machine learning framework. Throughout the course, students will develop practical skills in building and training deep neural networks, using PyTorch to solve real-world problems in fields such as computer vision and natural language processing. | | | |
| NIE-PDP | Parallel and Distributed Programming | Z,ZK | 6 |
| 21st century in computer architectures is primarily influenced by the shift of the Moore's law into parallelization of CPUs at the level of computing cores. Parallel computing systems are becoming a ubiquitous commodity and parallel programming becomes the basic paradigm of development of efficient applications for these platforms. Students get acquainted with architectures of parallel and distributed computing systems, their models, theory of interconnection networks and collective communication operations, and languages and environments for parallel programming of shared and distributed memory computers. They get acquianted with fundamental parallel algorithms and on selected problems, they will learn the techniques of design of efficient and scalable parallel algorithms and methods of performance evaluation of their implementations. The course includes a semester project of practical programming in OpenMP and MPI for solving a particular nontrivial problem. | | | |
| NIE-PML | Personalized Machine Learning | Z,ZK | 5 |
| Personalized machine learning (PML) is a sub-field of machine learning that aims to create models and predictions based on the unique characteristics and behaviors of individual entities. While PML is commonly used in applications such as recommender systems, which recommend items to users based on their personal interests, its principles can be applied to a wide range of other fields, including education, medicine, and chemical engineering. In this course, we will explore the latest PML methods from theoretical, algorithmic, and practical perspectives. Specifically, we will focus on cutting-edge models that are of interest to both the research and commercial communities. | | | |
| NIE-ROZ | Pattern Recognition | Z,ZK | 5 |
| The aim of the module is to give a systematic account of the major topics in pattern recognition with emphasis on problems and applications of the statistical approach to pattern recognition. Students will learn the fundamental concepts and methods of pattern recognition, including probability models, parameter estimation, and their numerical aspects. | | | |
| NIE-SCE1 | Computer Engineering Seminar Master I | Z | 4 |
| The Seminar of Computer Engineering is a (s)elective course for students who want to deal with deeper topics of digital design, reliability and resistance to failures and attacks. Students are approached individually within the subject. Each student or group of students solves some interesting topic with the selected supervisor. Part of the subject is work with scientific articles and other professional literature and/or work in KČN laboratories. The capacity of the subject is limited by the possibilities of the seminar teachers. The topics are new for each semester. | | | |
| NIE-SCE2 | Computer Engineering Seminar Master II | Z | 4 |
| The Seminar of Computer Engineering is a (s)elective course for students who want to deal with deeper topics of digital design, reliability and resistance to failures and attacks. Students are approached individually within the subject. Each student or group of students solves some interesting topic with the selected supervisor. Part of the subject is work with scientific articles and other professional literature and/or work in KČN laboratories. The capacity of the subject is limited by the possibilities of the seminar teachers. The topics are new for each semester. | | | |
| NIE-SEP | World Economy and Business | Z,ZK | 4 |
| The course introduces students of technical university to the international business. It does that predominantly by comparing individual countries and key regions of world economy. Students get to know about different religions and cultures, necessary for doing business in diverse societies as well as indexes of economic freedom, corruption and economic development, which are needed for the right investment decision. Seminars help to improve on the knowledge in the form of discussions based on individual readings. It is advised to take bachelor level of this course BIE-SEP as a prerequisite. | | | |
| NIE-SWE | Semantic Web and Knowledge Graphs | Z,ZK | 5 |
| The students will learn the most recent concepts and technologies of the Semantic Web. The course will provide an overview of the Semantic Web technologies, methods and best practices for modelling, integration, publishing, querying and consumption of semantic data. The students will also gain skills in creation of knowledge graphs and their systematic quality assurance. | | | |
| NIE-SYP | Parsing and Compilers | Z,ZK | 5 |
| The module builds upon the knowledge of fundamentals of automata theory, formal language and formal translation theories. Students gain knowledge of various variants and applications of LR parsing and are introduced to special applications of parsers, such as incremental and parallel parsing. | | | |
| NIE-VPR | Research Project | Z | 5 |
| 1. At the beginning of the semester, a student reserves her/his final thesis topic and gets together with its supervisor. Together they decide on partial tasks that should be carried out during the semester. If the requirements they agreed upon are met, the supervisor awards the student an assessment for the course MI-MPR at the end of the semester. 2. External Master these (MT) supervisor fills his/her assessment into the paper "Form to award assessment by an external Final theses (FT) supervisor" (for the courses BIE-BAP, MIE-MPR, MIE-DIP). Students, then, ensure that the assessment is registered into the information system (IS) by asking their internal FT opponent to award the assessment to the IS based on the confirmation of the external MT supervisor. In the case the FT opponent is external as well, the assessment will be registered to the IS by the head of the department responsible for the topic of the MT. 3. If the FT topic that the student has reserved is rather general, the immediate tasks the supervisor assigns to the student for the upcoming semester should aim at fine-tuning the FT topic so that the FTT will be complete and approvable at the end of the semester. | | | |
| NIE-VSM | Selected statistical Methods | Z,ZK | 7 |
| Summary of probability theory; Multivariate normal distribution; Entropy and its application to coding; Statistical tests: T-tests, goodness of fit tests, independence test; Random processes - stacionarity; Markov chains and limiting properties; Queuing theory | | | |
| NIE-VYC | Computability | Z,ZK | 4 |
| Classical theory of recursive functions and effective computability. | | | |

For updated information see http://bilakniha.cvut.cz/en/FF.html

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