Study plan

Name of study plan: Quantum Informatics

Faculty/Institute/Others:
Department:
Branch of study guaranteed by the department: Welcome page
Garantor of the study branch:
Program of study: Welcome page
Type of study: unknown full-time
Required credits: 122
Elective courses credits: -2
Sum of credits in the plan: 120
Note on the plan:

Name of the block: Compulsory courses in the program
Minimal number of credits of the block: 96
The role of the block: PP

Code of the group: QNI-PP
Name of the group: Compulsory courses of the Quantum Informatics
Requirement credits in the group: In this group you have to gain 96 credits
Requirement courses in the group: In this group you have to complete 12 courses
Credits in the group: 96
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
QNI-DIP	**Diploma Thesis** ***Zdeněk Muzikář***	Z	30	270ZP	L,Z	PP
QNI-KKP	**Cryptology and Quantum Computing** ***Róbert Lőrencz***	Z,ZK	6	2P+2C	Z	PP
QNI-KOS	**Quantum Optical Communications and Networks** *Leoš Boháč, Igor Jex, Stanislav Zvánovec* ***Igor Jex*** *Igor Jex (Gar.)*	Z,ZK	6	2P+2C	L	PP
QNI-QC1	**Quantum Computation 1** *Marcel Jiřina, Ivo Petr* ***Marcel Jiřina*** *Marcel Jiřina (Gar.)*	Z,ZK	6	2P+2C	Z	PP
QNI-QC2	**Quantum Computing 2** *Ivo Petr, Aurél Gábor Gábris* ***Aurél Gábor Gábris*** *Aurél Gábor Gábris (Gar.)*	Z,ZK	6	2P+2C	L	PP
QNI-LOM	**Linear Optimization and Methods** *Dušan Knop* ***Dušan Knop*** *Dušan Knop (Gar.)*	Z,ZK	5	2P+1C	Z	PP
QNI-MPR	**Master Project** *Zdeněk Muzikář* ***Zdeněk Muzikář*** *Zdeněk Muzikář (Gar.)*	Z	7		Z,L	PP
QNI-MQI	**Mathematics for Quantum Informatics** *Štěpán Starosta, Tomáš Kalvoda* ***Štěpán Starosta*** *Štěpán Starosta (Gar.)*	Z,ZK	6	2P+2C	Z	PP
QNI-PPS	**Programming of parallel systems** ***Pavel Tvrdík***	Z,ZK	6	2P+2C	L	PP
QNI-TIN	**Information Theory** *Pavel Hrabák* ***Pavel Hrabák*** *Pavel Hrabák (Gar.)*	Z,ZK	6	2P+2C	L	PP
QNI-CPX	**Complexity Theory** *Dušan Knop, Ondřej Suchý* ***Dušan Knop*** *Dušan Knop (Gar.)*	Z,ZK	6	3P+1C	Z	PP
QNI-UKT	**Introduction to Quantum Theory** *Martin Štefaňák* ***Martin Štefaňák*** *Martin Štefaňák (Gar.)*	Z,ZK	6	2P+2C	Z	PP

Characteristics of the courses of this group of Study Plan: Code=QNI-PP Name=Compulsory courses of the Quantum Informatics

QNI-DIP	Diploma Thesis	Z	30

Independent work of the student under the guidance of the thesis supervisor. Teaching is based on individual consultations with the thesis supervisor or other consultants. The scope of teaching 30 ECTS (i.e. about 900 hours) includes consultations, preparation of theoretical and practical parts of the thesis, writing, preparation for defence and defence of the thesis before the commission. The course supervisor guarantees the quality of the Masters thesis assignment and its compliance with the graduate profile.

QNI-KKP	Cryptology and Quantum Computing	Z,ZK	6

The course covers methods and algorithms of cryptology and their relation to quantum computing. In the first introductory lectures, students will be introduced to the basic principles and algorithms of cryptography. Following these topics, students will be introduced to basic cryptanalytic methods. Then some cryptanalytic algorithms running on quantum computers will be presented. In this context, the problem of security of related cryptographic schemes will be discussed. The next lectures will be devoted to post-quantum algorithms. The last lectures deal with cryptosystems using quantum phenomena.

QNI-KOS	Quantum Optical Communications and Networks	Z,ZK	6

The course focuses on the basic principles and technologies for building and using quantum networks. Students will learn about the key components of quantum networks, including quantum repeaters, routers and switches, and their role in creating a scalable quantum Internet. Emphasis will be placed on quantum cryptography systems. Students will also learn the fundamentals of optics, optical networks, and classical cryptography as they relate to quantum key distribution (QKD) and quantum networks. The course will cover types and architectures of QKD systems (including practical implementation of quantum protocols) according to international standards, key generation and distribution in these systems, and integration of QKD with classical communication systems. Students will also have the opportunity to explore satellite and FSO QKD systems and integrated quantum photonics and electronics.

QNI-QC1	Quantum Computation 1	Z,ZK	6

The course introduces the student to basic principles of quantum computation and shows the difference between classical and quantum mechanics. Quantum computation uses quantum circuits, which will be demonstrated in the Qiskit SDK. The course will gradually introduce the student to such concepts the state of a quantum system and its visualization, measurements, basic gates and their composition, and the so-called entanglement. The student will be introduced to the BB84 and E91 protocols as demonstrations of the properties of quantum states. The course will also cover quantum teleportation, quantum oracle queries, the Deutsch-Jozsa algorithm, the quantum Fourier transform, the phase estimation algorithm, and the Shor algorithm.

QNI-QC2	Quantum Computing 2	Z,ZK	6

Quantum Computing 2 focuses on advanced quantum algorithms and their implementations: the Grover algorithm and its applications, quantum algorithms solving linear algebra problems, HHL for solving systems of linear equations. In the course we also introduce students to variational methods and error correction.

QNI-LOM	Linear Optimization and Methods	Z,ZK	5

Students learn the applications of optimization methods in computer science, economics, and industry. They are aware of practical importance of linear and integer programming. They are able to work with optimization software and are familiar with languages used in programming of that software. They get skills in formalization of optimization problems in computer science (such as scheduling of tasks to processors, analysis of network flows), distribution and allocation of resources (transportation problems, travelling salesman problems, etc.), issues from economics, and modelling of conflicts via the game theory. They get an overview of computational complexity of optimization problems. They get orientation in algorithms in linear programming.

QNI-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.

QNI-MQI	Mathematics for Quantum Informatics	Z,ZK	6

Linear algebra on finite dimensional spaces with scalar product, Hilbert spaces, Dirac's bra-ket formalism, normal, Hermitian and unitary operators, operator spectrum, orthonormalization, diagonalization, matrix exponential, tensor product of vector spaces and operators. Discrete Fourier transform and fast Fourier transform.

QNI-PPS	Programming of parallel systems	Z,ZK	6

Nowadays, multi-core processors and GPU accelerators have become common components of computing clusters and high-performance computing systems, so knowledge and skills related to parallel programming are essential for every computer scientist. The aim of this course is to introduce students to the architectures and programming methods of parallel computers with shared memory, GPU accelerators, or with distributed memory. To effectively use these modern computing systems, it is essential to combine parallelization techniques at all three levels. Students will gain knowledge of the relevant programming models, languages and environments. They will become familiar with fundamental parallel algorithms and be able to analyze the limitations, efficiency, and scalability of parallel solutions to selected problems on high-performance computing systems. In addition to the necessary theory in lectures, students will gain practical experience and skills in programming in OpenMP, CUDA and MPI environments.

QNI-TIN	Information Theory	Z,ZK	6

The course focuses on the mathematical description of a random message source, its coding and transmission of the source through a noisy channel. The coding problem is addressed probabilistically, the relation of the mean length of the optimal code with the entropy and entropy rate of the random source is emphasized. In the case of the noisy channel we focus on the set of typical sequences and its appropriate coding by self-correcting codes. The course includes a reminder of necessary concepts such as conditional distributions, goodness-of-fit and independence tests, and an introduction to random chains.

QNI-CPX	Complexity Theory	Z,ZK	6

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.

QNI-UKT	Introduction to Quantum Theory	Z,ZK	6

interpretation of quantum theory are explained using simple models mainly from finite-dimensional quantum mechanics. Emphasis is placed on further applications of quantum theory to information processing and communication. Possible physical realizations of a qubit, description of multipartite systems, quantum entanglement and its applications are discussed. The course concludes with a description of continuous quantum systems in infinite-dimensional Hilbert spaces, in particular the linear harmonic oscillator as a description of the mode of a quantized electromagnetic field.

Name of the block: Elective vocational courses in the branch/specialization
Minimal number of credits of the block: 6
The role of the block: VO

Code of the group: QNI-PV-ENG
Name of the group: Compulsory elective english courses of the program Quantum Informatics
Requirement credits in the group: In this group you have to gain at least 6 credits (at most 165)
Requirement courses in the group:
Credits in the group: 6
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-KRY	**Advanced Cryptology** *Róbert Lórencz, Jiří Buček* ***Jiří Buček*** *Róbert Lórencz (Gar.)*	Z,ZK	5	2P+2C	Z	VO

NIE-PDB	**Advanced Database Systems** *Martin Svoboda* ***Martin Svoboda*** *Martin Svoboda (Gar.)*	Z,ZK	5	2P+1C	Z	VO
NIE-PIS	**Advanced Information Systems**	Z,ZK	5	2P+1C	L	VO
NIE-AIB	**Algorithms of Information Security** *Martin Jureček* ***Martin Jureček*** *Martin Jureček (Gar.)*	Z,ZK	5	2P+1C	Z	VO
NIE-ADP	**Architecture and Design patterns** *Marek Bělohoubek, Jiří Borský, Jan Kurš* ***Jan Kurš*** *Jan Kurš (Gar.)*	Z,ZK	5	2P+1C	Z	VO
NIE-SIM	**Digital Circuit Simulation and Verification**	Z,ZK	5	2P+1C	L	VO
NIE-DSV	**Distributed Systems and Computing** *Pavel Tvrdík, Peter Macejko* ***Peter Macejko*** *Pavel Tvrdík (Gar.)*	Z,ZK	5	2P+1C	Z	VO
NIE-EPC	**Effective C++ programming** *Daniel Langr* ***Daniel Langr*** *Daniel Langr (Gar.)*	Z,ZK	5	2P+1C	Z	VO
NIE-EHW	**Embedded Hardware** *Jan Schmidt* ***Jan Schmidt*** *Jan Schmidt (Gar.)*	Z,ZK	5	2P+1C	Z	VO
NIE-BVS	**Embedded Security** ***Martin Novotný***	Z,ZK	5	2P+2C	L	VO
NIE-ESW	**Embedded Software** *Miroslav Skrbek, Hana Kubátová* ***Miroslav Skrbek*** *Hana Kubátová (Gar.)*	Z,ZK	5	2P+1C	Z	VO
NIE-BKO	**Error Control Codes** ***Pavel Kubalík***	Z,ZK	5	2P+1C	L	VO
NIE-FME	**Formal Methods and Specifications** ***Stefan Ratschan***	Z,ZK	5	2P+1C	L	VO
NIE-GPU	**GPU Architectures and Programming** ***Ivan Šimeček***	Z,ZK	5	2P+1C	L	VO
NIE-HWB	**Hardware Security** ***Jiří Buček***	Z,ZK	5	2P+2C	L	VO
NIE-MKY	**Mathematics for Cryptology** ***Róbert Lórencz***	Z,ZK	5	3P+1C	L	VO
NIE-AM1	**Middleware Architectures 1** *Milan Dojčinovski, Tomáš Vitvar, Jaroslav Kuchař* ***Jaroslav Kuchař*** *Tomáš Vitvar (Gar.)*	Z,ZK	5	2P+1C	Z	VO
NIE-MTI	**Modern Internet Technologies** *Alexandru Moucha, Viktor Černý* ***Alexandru Moucha*** *Alexandru Moucha (Gar.)*	Z,ZK	5	2P+1C	Z	VO
NIE-MCC	**Multicore CPU Computing** *Daniel Langr, Ivan Šimeček* ***Ivan Šimeček*** *Ivan Šimeček (Gar.)*	Z,ZK	5	2P+1C	Z	VO
NIE-SIB	**Network Security** ***Simona Fornůsek***	Z,ZK	5	2P+1C	L	VO
NIE-NSS	**Normalized Software Systems** ***Robert Pergl***	ZK	5	2P	L	VO
NIE-REV	**Reverse Engineering** *Josef Kokeš* ***Josef Kokeš*** *Josef Kokeš (Gar.)*	Z,ZK	5	1P+2C	Z	VO
NIE-SBF	**System Security and Forensics** *Jiří Buček, Tomáš Zahradnický, Marián Svetlík, Simona Fornůsek* ***Simona Fornůsek*** *Simona Fornůsek (Gar.)*	Z,ZK	5	2P+1C	Z	VO
NIE-TES	**Systems Theory** *Jiří Vyskočil, Stefan Ratschan, Tomáš Kolárik* ***Stefan Ratschan*** *Stefan Ratschan (Gar.)*	Z,ZK	5	2P+1C	Z	VO
NIE-TSP	**Testing and Reliability** *Petr Fišer* ***Petr Fišer*** *Petr Fišer (Gar.)*	Z,ZK	5	2P+2C	Z	VO
NIE-NUR	**User Interface Design** *Josef Pavlíček* ***Josef Pavlíček*** *Josef Pavlíček (Gar.)*	Z,ZK	5	2P+1C	Z	VO
NIE-VCC	**Virtualization and Cloud Computing** ***Tomáš Vondra***	Z,ZK	5	2P+1C	L	VO

Characteristics of the courses of this group of Study Plan: Code=QNI-PV-ENG Name=Compulsory elective english courses of the program Quantum Informatics

NIE-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.

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-PIS	Advanced Information Systems	Z,ZK	5

Students learn the notion of business process logic and its formalization, with business process roles, business rules, and data processing, with the notion of service oriented company, enterprise services and service solution of business logic. They get acquainted with these notions also for the other types of ISs. They learn about agility and adaptivity and using of artificial intelligence methods for implementation of these ideas in ISs. They understand modern object-oriented methodologies for modelling of business processes, business rules, processed data, and enterprise ISs. They will get the rules and technologies for successful implementation of IS.

NIE-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.

NIE-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.			
NIE-SIM	Digital Circuit Simulation and Verification	Z,ZK	5
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 today recent verification methods, too.			
NIE-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.			
NIE-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.			
NIE-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.			
NIE-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.			
NIE-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.			
NIE-BKO	Error Control Codes	Z,ZK	5
The course expands the basic knowledge of security codes used in current systems for error detection and correction. It provides the necessary mathematical theory and principles of linear, cyclic codes and codes for the correction of multiple errors, clusters of errors and whole syllables (bytes). Students will also learn how to implement these detections and corrections for different types of transmissions (parallel, serial) when storing data in memory and when transmitting over telecommunication channels.			
NIE-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.			
NIE-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.			
NIE-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.			
NIE-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.			
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-MTI	Modern Internet Technologies	Z,ZK	5
Students learn advanced networking technologies and protocols for both local area networks and wide area networks. They get acquainted with routing techniques and transfer technologies of modern internet, including multimedia data transfer, with various types of network virtualization, and with last-mile security.			
NIE-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 memory, which are today the most common computing nodes of powerful computer systems. Students will gain knowledge of architecturally specific optimization techniques used to reduce the decrease in computing power due to the widening performance 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.			
NIE-SIB	Network Security	Z,ZK	5
The students will gain theoretical and practical knowledge and experience in the area of current security threats in computer networks, specifically about detection and defense. The course explains basic pricipals of security monitoring, packet-based and flow-based analysis, in order to detect anomalies and suspicious network traffic. The course focuses on explanation and practical examples of various mechanisms of securing network infrastructure and detection in real time. The course covers general principals of handling detected security events (i.e. incident handling and incident response).			
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.			

NIE-REV	Reverse Engineering	Z,ZK	5
Students will learn fundamentals of reverse engineering of computer software (methods of executing and initializing programs, organization of executable files, work with third-party libraries). Special attention will be paid to C ++. Students will also become familiar with the principles of debugging tools, disassemblers and obfuscation methods. Finally, the course will focus on code compression and decompression and executable file reconstruction.			
NIE-SBF	System Security and Forensics	Z,ZK	5
Students will be introduced to various aspects of system security (principles of endpoint security, principles of security policies, security models, authentication concepts). Students will also learn about forensic analysis as a tool for investigating security incidents (techniques used by malicious software or attackers, forensic analysis techniques, and the importance of memory or file system artifacts for attack analysis and detection).			
NIE-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.			
NIE-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.			
NIE-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.			
NIE-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).			

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: QNI-PV
Name of the group: Compulsory elective courses of the QNI Quantum Informatics program
Requirement credits in the group: In this group you have to gain at least 20 credits (at most 63)
Requirement courses in the group: In this group you have to complete at least 4 courses (at most 12)
Credits in the group: 20
Note on the group: Beware of the knowledge prerequisite of the QNI-QML course. You can enroll only with the previous knowledge, which is discussed in the following bachelor's courses: BI-ML1.21 Strojové učení 1 BI-ML2.21 Strojové učení 2

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
QNI-AVM	**Adiabatic computing and variational methods** *Jakub Mareček* ***Jakub Mareček*** *Jakub Mareček (Gar.)*	Z,ZK	6	2P+2C	*	PV
QNI-QEC	**Quantum error correction** *Václav Potoček, Pavel Rytíř* ***Václav Potoček*** *Václav Potoček (Gar.)*	Z,ZK	5	2P+2C	Z	PV
QNI-QOM	**Quantum Optics, Metrology, Sensing and Imaging** *Igor Jex* ***Igor Jex*** *Igor Jex (Gar.)*	Z,ZK	5	2P+2C	Z	PV
QNI-QML	**Quantum machine learning** *Daniel Vašata* ***Daniel Vašata*** *Daniel Vašata (Gar.)*	Z,ZK	5	2P+1C	Z	PV
QNI-NMK	**Numerical methods for quantum computation** *Michal Beneš, Michael Valášek, Jiří Fürst* ***Tomáš Kalvoda*** *Michal Beneš (Gar.)*	Z,ZK	5	2P+2C	Z	PV
QNI-OQC	**Optical quantum computing** *Aurél Gábor Gábris* ***Aurél Gábor Gábris*** *Aurél Gábor Gábris (Gar.)*	Z,ZK	5	2P+1C	Z	PV
QNI-OPM	**Optical measurements** *Stanislav Zvánovec* ***Stanislav Zvánovec*** *Stanislav Zvánovec (Gar.)*	Z,ZK	6	2P+2C		PV
B2M17OPM	**Optical Measurements** ***Matěj Komanec***	Z,ZK	6	2P+2L	L	PV
QNI-OVV	**Optimization for Scientific Computing** *Michael Valášek* ***Michael Valášek*** *Michael Valášek (Gar.)*	Z,ZK	5	2P+1C		PV
QNI-PNM	**Parallelization of numerical methods** *Michael Valášek, Jiří Fürst, Tomáš Oberhuber* ***Jiří Fürst*** *Jiří Fürst (Gar.)*	Z,ZK	5	2P+2C		PV
QNI-PJK	**Programming languages for quantum computing** *Jan Janoušek* ***Jan Janoušek*** *Jan Janoušek (Gar.)*	Z,ZK	5	2P+1C	L	PV
B2M17VOT	**Fiber Optic Technology** *Stanislav Zvánovec, Matěj Komanec, Jan Šístek* ***Stanislav Zvánovec*** *Stanislav Zvánovec (Gar.)*	Z,ZK	6	2P+2L	Z	PV

QNI-VOT	**Fiber Optic Technology** *Stanislav Zvánovec* ***Stanislav Zvánovec*** *Stanislav Zvánovec (Gar.)*	Z,ZK	6	2P+2C		PV
QNI-PON	**Selected Topics in Optimization and Numerical mathematics** *Štěpán Starosta, Daniel Vašata, Karel Klouda* ***Karel Klouda*** *Karel Klouda (Gar.)*	Z,ZK	5	2P+1C	L	PV

Characteristics of the courses of this group of Study Plan: Code=QNI-PV Name=Compulsory elective courses of the QNI Quantum Informatics program

QNI-AVM	Adiabatic computing and variational methods	Z,ZK	6

The course introduces adiabatic computing and variational quantum algorithms (VQA). We start with a broad introduction to variational methods in physical chemistry (e.g., for calculating ground state of small molecules) and a recapitulation of advances in theoretical computer science (computational complexity and problems such as MAXCUT). We will present the EQA Conjecture and the unique games conjecture. We will present the adiabatic theorem and quantum speedup by quantum annealing (QA). We will build up an understanding of variational quantum algorithms by introducing and analysing, in turn, Variational quantum eigensolver (VQE), Quantum Approximate Optimization Algorithm (QAOA), and their Warm-started variants. As applications, we will highlight variational solvers for systems of linear equations and variational solvers for Markowitz portfolio management, with some discussion of the challenges in benchmarking of VQA.

QNI-QEC	Quantum error correction	Z,ZK	5

In this course, we will build a theory for the construction of quantum error-correcting codes. In the introductory part, necessary chapters from the classical theory will be summarized, atop of which we then present the quantum analogy. We will show how coherently stored quantum information can be made robust to loss and noise. We conclude the course by arriving at the principle of fault tolerance, based on which quantum computers are able to continuously correct errors arising at runtime and thus achieve correct results even with erroneous bits, gates or measurements.

QNI-QOM	Quantum Optics, Metrology, Sensing and Imaging	Z,ZK	5

Students are given an introduction to the quantum theory of light and related fundamental principles with an emphasis on practical aspects. They acquire the theoretical and experimental foundations for the development of specifically quantum mechanical approaches to metrology and imaging in quantum computing and communications. Specific problems discussed include elementary processes with photons (absorption, emission, stimulated emission), interference, entanglement, non-classical phenomena with photons, methods of suppressing optical aberrations and dispersion. The various techniques are explained theoretically and also using experiments that demonstrate these principles in practice.

QNI-QML	Quantum machine learning	Z,ZK	5

The aim of the course is to introduce students to quantum machine learning. Students will first learn theoretically and practically about the quantum representation of classical data. Next, they will explore kernel methods, the quantum SVM model, and the use of quantum variational methods in supervised learning scenarios. The course will also introduce quantum neural networks and quantum generative adversarial models in unsupervised learning scenarios. The primary focus of the course is quantum algorithms for classical data. The exercises will use the pandas and qiskit libraries for Python to work with data and models.

QNI-NMK	Numerical methods for quantum computation	Z,ZK	5

The course is devoted to numerical solution of boundary-value problems and intial-boundary-value problems for ordinary and partial differential equations. It explains finite-difference, finite-element and finite-volume methods for elliptic, parabolic and hyperbolic partial differential equations. Students are introduced to the recent advances in methods solving the mentioned problems.

QNI-OQC	Optical quantum computing	Z,ZK	5

The course covers the basic theoretical methods and concepts for optical quantum computing, complemented by on hands-on exercise and applications using quantum programming libraries, Strawberry Fields and Piquasso. Theoretical concepts include measurement-based quantum computation, Gaussian Boson Sampling, and quantum supremacy. Applications feasible on current and near-term hardware include recent generative and discriminative machine-learning algorithms, as well as molecular vibration simulations.

QNI-OPM	Optical measurements	Z,ZK	6

The aim of this course is to acquaint students with optical measurement methods from the detection of microparticles, non-regulation and surface breaches, through the use of fiber optics in areas where it is not possible to use standard electronic sensors, or in places with increased risk of explosion and in hospitals, lidars used in intelligent transport infrastructures, to macroscopic sensing (remote sensing) of the Earth, atmosphere and space. The inclusion of these measurement methods requires in particular an understanding of the physical mechanisms on which they are based, as well as knowledge of measurement procedures and specifics in data processing and reconstruction.

B2M17OPM	Optical Measurements	Z,ZK	6
QNI-OVV	Optimization for Scientific Computing	Z,ZK	5

The content of the course is an explanation of numerical methods for solving nonlinear optimization, convex optimization, stochastic optimization, optimal control, applications for QC, genetic and evolutionary programming, machine learning, deep neural networks. Students are also introduced to modern trends in solving these problems.

QNI-PNM	Parallelization of numerical methods	Z,ZK	5

The content of the course is an explanation of numerical methods for solving mathematical models with a focus on their parallelization and the use of these methods in QC. Students are also introduced to modern trends in the field of solving these problems.

QNI-PJK	Programming languages for quantum computing	Z,ZK	5

Computational models for quantum computing: quantum Turing machine, QRAM, lambda calculus with qubits. Higher programming languages for quantum computation: imperative languages (Silq), functional languages (QML, Quipper).). In the seminars the student will learn the basics of programming in the higher programming language Silq.

B2M17VOT	Fiber Optic Technology	Z,ZK	6

The aim of the course is to introduce mechanisms of propagation of optical waves in optical fibers and fiber components. Furthermore, the optical measuring techniques and measuring methods for the characterization of optical fibers will be presented. Lectures include both the design and methodology of measuring transmission parameters for optical communication systems such as numerical aperture, attenuation, dispersion, and measurement of basic characteristics of active and passive elements of optical communication systems - connectors, splices, couplers, refractive indices etc.

QNI-VOT	Fiber Optic Technology	Z,ZK	6

The aim of the course is to introduce the mechanisms of optical wave propagation in optical fibres and fibre components. Furthermore, the knowledge of optical measurement techniques and measurement methods for the characterisation of optical fibres. The content includes both methodologies for measuring design and transmission parameters for optical communication systems such as numerical aperture, attenuation, dispersion, as well as measurements of basic characteristics of active and passive elements of optical communication systems - connectors, couplers, coupling elements, refractive indices.

QNI-PON	Selected Topics in Optimization and Numerical mathematics	Z,ZK	5

Students will be introduced to special optimization problems that arise in the field of machine learning and artificial intelligence and will extend the basic knowledge of continuous optimization acquired in previous studies. They will also learn about the details of implementing solutions to these problems on a computer and related mathematical concepts, especially from numerical linear algebra.

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

Code of the group: QNI-V
Name of the group: Purely Elective Master's Courses in the programu Quantum Informatics
Requirement credits in the group:
Requirement courses in the group:
Credits in the group: 0
Note on the group: In addition to the courses listed here, you can enroll as an elective any course that is offered within your study program and form of study that you did not enroll as a compulsory subject in the program/branch/specialization or a compulsory elective course.Courses of this group that a student has completed in the bachelor study at CTU cannot be re-completed.

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-ATH	**AlgorithmicTheories of Games** ***Tomáš Valla***	Z,ZK	4	2P+2C	L	v
NI-AFP	**Applied Functional Programming** ***Robert Pergl***	KZ	5	2P+1C	L	v
NI-VGA	**Video Games Architecture** *Radek Richtr, Jan Matoušek* ***Jan Matoušek*** *Radek Richtr (Gar.)*	Z,ZK	5	2P+1C	Z	v
NI-APH	**Architecture of computer games**	Z,ZK	4	2P+1C	Z	v
NI-BPS	**Wireless Computer Networks** ***Alexandru Moucha***	Z,ZK	4	2P+1C	L	v
NI-CTF	**Capture The Flag** *Jakub Bartoň, Jiří Dostál, Vojtěch Novák, Ladislav Marko* ***Jiří Dostál*** *Jiří Dostál (Gar.)*	KZ	4	3C	Z	v
NI-DPH	**Game Design**	Z,ZK	5	2P+1C	L	v
NI-DSW	**Design Sprint** *Michal Manda, Ondřej Brém* ***Michal Manda*** *David Pešek (Gar.)*	Z	2	30B	Z	v
NI-PSD	**Public Services Design** ***David Pešek***	KZ	4	1P+2C		v
FITE-DIF	**Differential equations** *Ondřej Bouchala, Antonella Marchesiello, Jan Valdman* ***Tomáš Kalvoda*** *Ondřej Bouchala (Gar.)*	Z,ZK	5	2P+2C	L	v
NI-DID	**Digital drawing**	Z	2	4C	Z,L	v
NI-DZO	**Digital Image Processing**	Z,ZK	4	2P+1C	L	v
NI-DDM	**Distributed Data Mining**	KZ	4	3C	L	v
NI-PAM	**Efficient Preprocessing and Parameterized Algorithms** ***Ondřej Suchý***	Z,ZK	4	2P+1C	L	v
NI-EVY	**Efficient Text Pattern Matching** *Jan Holub* ***Jan Holub*** *Jan Holub (Gar.)*	Z,ZK	5	2P+1C	Z	v
NI-ESC	**Experimental Project Course** *Ondřej Brém* ***Ondřej Brém*** *Ondřej Brém (Gar.)*	KZ	8	0P+3R+5C	L	v
NI-GLR	**Games and reinforcement learning**	Z,ZK	4	2P+2C	L	v
NI-GEN	**Code Generators** *Petr Máj* ***Petr Máj*** *Jan Janoušek (Gar.)*	Z,ZK	5	2P+1C	Z	v
NI-GNN	**Graph Neural Networks**	Z,ZK	4	1P+1C	L	v
NI-GAK	**Graph theory and combinatorics** ***Tomáš Valla***	Z,ZK	5	2P+2C	L	v
NI-GRI	**Grid Computing** *André Sopczak, Petr Fiedler* ***Pavel Tvrdík*** *André Sopczak (Gar.)*	Z,ZK	5	2P+1C	Z	v
NI-HCM	**Mind Hacking** *Marcel Jiřina, Josef Holý* ***Marcel Jiřina*** *Marcel Jiřina (Gar.)*	ZK	5	2P+1C	Z	v
NI-HSC	**Side-Channel Analysis in Hardware** *Vojtěch Miškovský, Petr Socha* ***Petr Socha*** *Vojtěch Miškovský (Gar.)*	Z,ZK	4	2P+2C	Z	v
NI-HMI2	**History of Mathematics and Informatics** *Alena Šolcová* ***Alena Šolcová*** *Alena Šolcová (Gar.)*	ZK	3	2P+1C	Z	v
NI-IBE	**Information Security**	ZK	2	2P	Z	v
NI-IVS	**Intelligent embedded systems** ***Miroslav Skrbek***	KZ	4	1P+3C	L	v
NI-IKM	**Internet and Classification Methods**	Z,ZK	4	1P+1C	L	v
NI-IAM	**Internet and Multimedia**	Z,ZK	4	2P+1C	L	v
NI-IOT	**Internet of Things**	Z,ZK	4	2P+1C	L	v
FITE-EHD	**Introduction to European Economic History** *Tomáš Evan* ***Tomáš Evan*** *Tomáš Evan (Gar.)*	Z,ZK	3	2P+1C	L	v
NI-KTH	**Combinatorial Theories of Games** ***Tomáš Valla***	Z,ZK	4	2P+1C	L	v
NI-KOD	**Data Compression** ***Jan Holub***	Z,ZK	5	2P+1C	L	v

NI-FMT	**Finite model theory**	Z,ZK	4	2P+1C	L	v
NI-CCC	**Creative Coding and Computational Art** *Radek Richtr, Ondřej Brém, Jiří Šebele, Josef Kortan* ***Josef Kortan*** *Radek Richtr (Gar.)*	KZ	4	1P+2C	Z,L	v
NI-KYB	**Cybernality**	ZK	5	2P	Z	v
NI-LSM2	**Statistical Modelling Lab** *Kamil Dedecius* ***Kamil Dedecius*** *Kamil Dedecius (Gar.)*	KZ	5	3C	Z,L	v
NI-MPL	**Managerial Psychology** *Jan Fiala* ***Jan Fiala*** *Jan Fiala (Gar.)*	ZK	2	2P	Z,L	v
NI-MSI	**Mathematical Structures in Computer Science**	Z,ZK	4	2P+1C	L	v
NI-MZI	**Mathematics for data science** ***Štěpán Starosta***	Z,ZK	4	2P+1C	L	v
FIT-ITI	**Modern IT infrastructure** *Jan Fesl, Ivan Šimeček, Tomáš Vondra* ***Ivan Šimeček*** *Ivan Šimeček (Gar.)*	Z,ZK	5	2P+1C	Z,L	v
NI-MOP	**Modern Object-Oriented Programming in Pharo** *Jan Blizničenko* ***Robert Pergl*** *Robert Pergl (Gar.)*	KZ	4	3C	Z	v
NI-NLM	**Neural Language Models**	Z	5	2P+1C	L	v
NI-NMU	**New media in art and design** *Zdeněk Svejkovský* ***Zdeněk Svejkovský*** *Zdeněk Svejkovský (Gar.)*	ZK	3	2P+0C	Z	v
NI-OLI	**Linux Drivers**	Z,ZK	4	2P+2C	L	v
NI-ARI	**Computer arithmetic** *Pavel Kubalík* ***Pavel Kubalík*** *Pavel Kubalík (Gar.)*	Z,ZK	4	2P+1C	Z,L	v
NI-PG1	**Computer Grafics 1** ***Radek Richtr***	ZK	4	2P+1C	L	v
NI-EDW	**Enterprise Data Warehouse Systems**	Z,ZK	5	1P+1C	L	v
NI-PVR	**Advanced Virtual Reality** *Petr Pauš* ***Petr Pauš*** *Petr Pauš (Gar.)*	KZ	4	2P+1C	Z	v
QNI-PMO	**Advanced Optimization Methods / Conic Optimization** *Jakub Mareček* ***Jakub Mareček*** *Jakub Mareček (Gar.)*	Z,ZK	6	2P+2C	Z	v
NI-AML	**Advanced machine learning**	Z,ZK	5	2P + 1C	L	v
NI-IOS	**Advanced techniques in iOS applications**	KZ	4	2P+2C	L	v
NI-APT	**Advanced Program Testing** *Pierre Donat-Bouillud* ***Pierre Donat-Bouillud*** *Pierre Donat-Bouillud (Gar.)*	Z,ZK	5	2P+1C	Z	v
NI-PVS	**Advanced embedded systems** ***Miroslav Skrbek***	Z,ZK	4	2P+2C	Z	v
NI-DNP	**Advanced .NET**	Z,ZK	4	2P+1C	L	v
NI-PYT	**Advanced Python**	KZ	4	3C	Z	v
FIT-ACM1	**Programming Practices 1** ***Tomáš Valla*** *Tomáš Valla (Gar.)*	KZ	5	4C	L	v
FIT-ACM2	**Programming Practices 2** ***Ondřej Suchý*** *Ondřej Suchý (Gar.)*	KZ	5	4C	Z	v
FIT-ACM3	**Programming Practices 3** ***Ondřej Suchý*** *Ondřej Suchý (Gar.)*	KZ	5	4C	L	v
FIT-ACM4	**Programming Practices 4** ***Ondřej Suchý*** *Ondřej Suchý (Gar.)*	KZ	5	4C	Z	v
FIT-ACM5	**Programming Practices 5** ***Ondřej Suchý*** *Ondřej Suchý (Gar.)*	KZ	5	4C	L	v
FIT-ACM6	**Programming Practices 6** ***Ondřej Suchý*** *Ondřej Suchý (Gar.)*	KZ	5	4C	L	v
NI-GOL	**Programming of distributed systems in GO** *Jaroslav Kříž, Róbert Selvek* ***Jaroslav Kříž*** *Jaroslav Kříž (Gar.)*	KZ	5	0P+3C	Z	v
NI-PSL	**Programming in Scala**	Z,ZK	4	2P+1C	Z	v
NI-RUB	**Programming in Ruby** *Cyril Černý* ***Cyril Černý*** *Cyril Černý (Gar.)*	KZ	4	3C	Z	v
NI-ROZ	**Pattern Recognition** *Michal Haindl* ***Michal Haindl*** *Michal Haindl (Gar.)*	Z,ZK	5	2P+1C	Z	v
NI-RUN	**Runtime Systems** ***Filip Křikava***	Z,ZK	5	2P+1C	L	v
NI-PLS1	**Programming Language Seminar** *Pierre Donat-Bouillud, Filip Křikava* ***Pierre Donat-Bouillud*** *Pierre Donat-Bouillud (Gar.)*	Z	2	0P+1C	Z	v
NI-PLS2	**Programming Language Seminar** *Pierre Donat-Bouillud, Filip Křikava* ***Pierre Donat-Bouillud*** *Pierre Donat-Bouillud (Gar.)*	Z	2	0P+1C	L	v
NI-PLS3	**Programming Language Seminar** ***Pierre Donat-Bouillud***	Z	2	0P+1C	Z	v
NI-PLS4	**Programming Language Seminar** ***Pierre Donat-Bouillud***	Z	2	0P+1C	L	v
NI-SCE1	**Computer Engineering Seminar Master I** *Hana Kubátová* ***Miroslav Skrbek*** *Hana Kubátová (Gar.)*	Z	4	2C	L,Z	v

NI-SCE2	**Computer Engineering Seminar Master II** ***Hana Kubátová***	Z	4	2C	L,Z	v
NI-SZ1	**Knowledge Engineering Seminar Master I** ***Pavel Kordík***	Z	4	2C	L,Z	v
NI-SZ2	**Knowledge Engineering Seminar Master II** ***Pavel Kordík***	Z	4	2C	L,Z	v
NI-MLP	**Machine Learning in Practice** *Jan Hučín* ***Daniel Vašata*** *Daniel Vašata (Gar.)*	Z,ZK	5	2P+1C	Z	v
NI-SLA	**Sublinear algorithms** *Dušan Knop* ***Dušan Knop*** *Dušan Knop (Gar.)*	Z,ZK	5	2P+1C	Z	v
FIT-SEP	**World Economy and Business** *Tomáš Evan* ***Tomáš Evan*** *Tomáš Evan (Gar.)*	Z,ZK	4	2P+2C	L	v
NI-SEP	**World Economy and Business** ***Tomáš Evan***	Z,ZK	4	2P+1C	Z,L	v
NI-SYP	**Parsing and Compilers** *Jan Janoušek* ***Jan Janoušek*** *Jan Janoušek (Gar.)*	Z,ZK	5	2P+1C	Z	v
NI-TVR	**Virtual Reality Technology** *Tomáš Nováček* ***Tomáš Nováček*** *Tomáš Nováček (Gar.)*	Z,ZK	3	1P+1C	L,Z	v
NI-TS1	**Theoretical Seminar Master I** *Dušan Knop, Ondřej Suchý, Michal Opler, Tomáš Valla* ***Tomáš Valla*** *Tomáš Valla (Gar.)*	Z	4	2C	Z	v
NI-TS2	**Theoretical Seminar Master II** ***Tomáš Valla***	Z	4	2C	L	v
NI-TS3	**Theoretical Seminar Master III** ***Tomáš Valla***	Z	4	2C	Z	v
NI-TS4	**Theoretical Seminar Master IV** ***Tomáš Valla***	Z	4	2C	L	v
NI-TKA	**Category Theory**	Z,ZK	4	2P+1C	L	v
NI-TNN	**Theory of Neural Networks**	Z,ZK	5	2P+1C	L	v
FIT-TOP	**Academic writing** *Tomáš Nováček, Petr Kroha* ***Tomáš Nováček*** *Petr Kroha (Gar.)*	Z	2	10B	Z	v
NI-DVG	**Introduction to Discrete and Computational Geometry**	Z,ZK	5	2P+1C	L	v
NI-VOL	**Elections** ***Dušan Knop***	Z,ZK	5	2P+1C	L	v
QNI-PON	**Selected Topics in Optimization and Numerical mathematics** *Štěpán Starosta, Daniel Vašata, Karel Klouda* ***Karel Klouda*** *Karel Klouda (Gar.)*	Z,ZK	5	2P+1C	L	v
NI-VYC	**Computability**	Z,ZK	4	2P+2C	L	v
NI-VPR	**Research Project** *Štěpán Starosta* ***Štěpán Starosta*** *Štěpán Starosta (Gar.)*	Z	5		Z,L	v
FITE-SEP	**World Economy and Business** *Tomáš Evan* ***Tomáš Evan*** *Tomáš Evan (Gar.)*	Z,ZK	4	2P+2C	Z	v
NI-ZS10	**Master internship abroad for 10 credits** ***Zdeněk Muzikář*** *Zdeněk Muzikář (Gar.)*	Z	10		Z,L	v
NI-ZS20	**Master internship abroad for 20 credits** ***Zdeněk Muzikář*** *Zdeněk Muzikář (Gar.)*	Z	20		Z,L	v
NI-ZS30	**Master internship abroad for 30 credits** ***Zdeněk Muzikář*** *Zdeněk Muzikář (Gar.)*	Z	30		Z,L	v

Characteristics of the courses of this group of Study Plan: Code=QNI-V Name=Purely Elective Master's Courses in the programu Quantum Informatics

QNI-PON	Selected Topics in Optimization and Numerical mathematics	Z,ZK	5

Students will be introduced to special optimization problems that arise in the field of machine learning and artificial intelligence and will extend the basic knowledge of continuous optimization acquired in previous studies. They will also learn about the details of implementing solutions to these problems on a computer and related mathematical concepts, especially from numerical linear algebra.

NI-ATH	AlgorithmicTheories of Games	Z,ZK	4

Traditional game theory is a branch of mathematics, which has broad applications in economy, biology, politics and computer science. This theory studies the behaviour of agents (players) of a certain competitive process by designinng a mathematical model and investigating the strategies. The traditional task of classical game theory is to find the equilibria, which are the states of the game where no player wants to deviate from his strategy. Due to the recent development of computers, internet, social networks, online auctions, advertising, multiagent systems and other concepts the algorithmic point of view is gaining attention. In addition to existential questions we study the problems of efficient computation of various solution concepts. In this course we introduce the basics of game theory of many players, solution concept (usually equilibria) and methods of their computation.

NI-AFP	Applied Functional Programming	KZ	5

This course is presented in Czech. Functional programming represents one of the traditional programming paradigms. Traditional and novel functional programming languages are on the rise nowadays and the functional paradigm becomes an important construct of traditionally imperative languages (C++, C#, Java). As such, mastering this paradigm becomes a necessary competence of a software engineer: the theory and especially the practice.

NI-VGA	Video Games Architecture	Z,ZK	5

The course covers a wide range of topics, procedures and methodologies related to the development of computer games - from a technical point of view, but also from a design and philosophical point of view. In the lectures, students will be guided through the history of development, the structure of game engines, component and functional architecture typical of game development, physics, graphics, artificial intelligence and multiplayer. The exercises will then cover selected technological topics in greater detail, including ways of implementing some game mechanics, in the form of practical demonstrations.

NI-APH	Architecture of computer games	Z,ZK	4
Students will gain a basic understanding of the various issues in the field of computer games development, especially from a technical point of view, but also from design and philosophical perspective. They will get a grasp of component-oriented and functional-oriented architecture, game mechanics, decision-making processes and base components that form an integral part of most games. They will also understand the basics of pathfinding, networking and scripting and apply them in practical exercises (labs). An important part of the course is an implementation of a simple game, with a strong focus on nontrivial game mechanics.			
NI-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.			
NI-CTF	Capture The Flag	KZ	4
The course is designed to introduce students to CTF competitions and let them gain practical experience in the field of cyber security.			
NI-DPH	Game Design	Z,ZK	5
The course complements the NI-APH (Architecture of Computer Games) and BI-VHS (Virtual gaming worlds) course, while focusing primarily on game design. It is intended for people interested in deeper knowledge of the principles used for games design, such as: level design, gameplay design, character design, game mechanics design, storytelling, and game development cycle. The students will get an overview of game development from the designer's perspective, from theoretical concepts to practical implementation applied to semestral projects.			
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-PSD	Public Services Design	KZ	4
The course will introduce students to specifics of UX, Service design and development for public sector. We will look into the design and development process from the perspective of suppliers (devs and designesr) as well as clients. In small teams students will work on projects from partner organizations and will try out collaboration with client representatives. Course is aimed at students-designers as well as clients.			
FITE-DIF	Differential equations	Z,ZK	5
This course provides a foundational overview of differential equations, starting with basic motivation and examples of ODEs and progressing to essential solution methods like separation of variables. Key theorems on existence and uniqueness establish when solutions can be guaranteed. Linear and system-based ODEs are covered with methods like characteristic polynomial analysis, followed by examples of non-linear models such as predator-prey and epidemiological models to showcase real-world applications. Finally, an introduction to partial differential equations (PDEs) extends these concepts to multi-variable contexts. The course will also cover numerical methods for solving ODEs and PDEs, including implicit and explicit Euler methods, Runge-Kutta methods, and finite element methods for both ODEs and PDEs.			
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-DZO	Digital Image Processing	Z,ZK	4
This course presents a comprehensive overview of modern methods for interactive editing of digital images and video. It mainly deals with practical algorithms that are both easy to implement and have an interesting theoretical basis. Visually attractive applications provide better understanding of basic theoretical background that is also valuable outside the domain of digital image processing. This course will introduce algorithms solving the following practical applications: edge-aware editing, tone mapping, HDR compression, de-blurring in frequency domain, abstraction, hybrid images, gradient domain editing, seamless image stitching and cloning, digital photo-montage, color-to-gray conversion, context enhancement, interactive as-rigid-as-possible image deformation, free-form image registration, texture synthesis, interactive segmentation, colorization, painting, adding depth, alpha matting.			
NI-DDM	Distributed Data Mining	KZ	4
Course focuses on state-of-the-art approaches for distributed data mining and parallelization of machine learning algorithms. Students will gain hands on experience with large scale data processing framework Apache Spark and with existing distributed DM / ML algorithms. They will learn principles of their parallel implementations and will be capable to propose approaches to parallelize other algorithms. The course is prezented in czech language.			
NI-PAM	Efficient Preprocessing and 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.			
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-ESC	Experimental Project Course	KZ	8
"The Design Project course offers a holistic exploration of the design process, providing students with a well-rounded understanding of the principles, methodologies, and tools used in designing technology-driven solutions that are user-centric and industry-relevant. Throughout the semester, students will work on real-world design projects, collaborate with industry experts, and learn to integrate theory with practical application. Through a hands-on, project-based learning approach, students will develop their skills in user-centered design and user experience evaluation, as well as gain experience working in a team to design and prototype a functional solution."			
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.			
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-GNN	Graph Neural Networks	Z,ZK	4
The course introduces students to advanced artificial intelligence techniques for working with graphs. Lectures will focus on the latest graph neural networks for creating vector representations of nodes, edges and entire graphs. The techniques discussed cover various types of graphs, including time-varying graphs. The last part of the course also covers graph generation and interpretability of graph neural networks. In the exercises, students will try out selected techniques and problems.			

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-GRI	Grid Computing	Z,ZK	5
Grid computing and gain knowledge about the world-wide network and computing infrastructure.			
NI-HCM	Mind Hacking	ZK	5
Cognitive security is an emerging discipline that is closely related to cyber security. While the domain of cyber security is the protection of networks, information systems and assets, the domain of cognitive security is the protection of the human mind from intentional and unintentional digital manipulation. The topic of cognitive security is growing in importance in the context of information warfare, increasing digital dependence and the development of artificial intelligence, where these phenomena from the Internet environment have real societal impacts such as disruption of social cohesion, threats to democracy or war.			
NI-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.			
NI-HMI2	History of Mathematics and Informatics	ZK	3
This course is presented in Czech. Selected topics {Infinitesimal calculus, probability, number theory, general algebra, different examples of algorithms, transformations, recursive functions, eliptic curves, etc.) note on possibilities of applications of some mathematical methods in informatics and its development.			
NI-IBE	Information Security	ZK	2
Students learn information and IS/ICT security management systems (ISMS), methods for information access control, and basic norms and international standards in this area. They understand methods for management of internal and external security threats, for IS/IT security audits, and for application security testing (e.g., penetration testing).			
NI-IVS	Intelligent embedded systems	KZ	4
Intelligent embedded systems course for master's degree is focused on high-level technology embedded systems integrating artificial intelligence. The course is an advance version of the Intelligent embedded system fundamentals course for the bachelor degree. The aim of the course is to teach students humanoid robot programming and advance application development. Lectures provide basis of motion control, sensor reading, application interfaces, robot navigation and development tools. In labs, students develop advanced applications combining knowledge of various courses like nature inspired algorithms, data mining algorithms, image recognition and web technologies			
NI-IKM	Internet and Classification Methods	Z,ZK	4
In this course, the students get acquainted with classification methods used in four important internet, or generally network applications: in spam filtering, in recommendation systems, in malware detection systems and in intrusion detection systems. However, they will learn more than only how classification is performed when solving these four kinds of problems. On the background of these applications, they get an overview of the fundamentals of classification methods. The course is taught in a 2-weeks cycle with 2-hour lectures and 2-hour exercises. During the exercises, the students on the one hand implement simple examples to topics from the lectures, on the other hand consult their semester tasks.			
NI-IAM	Internet and Multimedia	Z,ZK	4
The NI-IAM course is focused on principles and modern technologies for network transmissions of audiovisual (AV) signals. The syllabus includes acquisition of AV signals (input), presentation of AV signals (output), network communication protocols, device interfaces, codecs, data formats and stereoscopy. We will look at practical use case scenarios of real-time audiovisual transmissions. Within the labs, students will practically assemble AV transmission chains using HW and SW technologies and verify the effect of various components on the quality and latency of AV transmissions. Students will learn how to build Internet infrastructure for end-to-end AV transmissions from the recording the scene up to the presentation for audience.			
NI-IOT	Internet of Things	Z,ZK	4
The subject is focused on the area of hardware and software technologies for the strongly growing computer support of various devices. Its goal is familiarization with available development elements (Raspberry Pi, Arduino Due) and with the language for efficient application development and modification (GNU Forth).			
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.			
NI-KTH	Combinatorial Theories of Games	Z,ZK	4
Traditional game theory is a branch of mathematics, which has broad applications in economy, biology, politics and computer science. This theory studies the behaviour of agents (players) of a certain competitive process by designinng a mathematical model and investigating the strategies. The traditional task of classical game theory is to find the equilibria, which are the states of the game where no player wants to deviate from his strategy. Historically, the second big development in game theory of two-player full-information combinatorial games, was by Conway, Berlekamp and Guy. They developed a theory, originally used for solving end-games in Go, into a full fledged field. The idea is to evaluate games such that otherwise incompatible games can be added, that is, played simultaneously. This led to the algrebraic approach to study combinatorial games. The third most important step is the work of Beck, who established the theory of positional games (like tic-tac-toe and hex). In analysis of these game, one cannot escape the brute-force traversal of the game tree, which is no efficient. Beck introduced the "false probabilistic method", which aims to tackhle this problem. In this course we build the foundation of the theory of combinatorial and positional games. We focus on theoretical analysis of games and building the theory, not on the programming aspects of game solving algorithms. The course requires independent work, ability to mathematically analyse, think and proof. The course is also suitable for bachelors student in the third year, who attended introduction to graph theory, as well as for PhD students looking for research topics.			
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-FMT	Finite model theory	Z,ZK	4
The aim of the course is to introduce students to the basics of finite model theory. The original motivation is the questions expressibility and verifiability of logical properties of database systems. Since its inception in the 1970s, the course has evolved rapidly and touched on many other areas of theoretical computer science, such as descriptive complexity theory, the Constraint Satisfaction Problem (CSP), the theory of algorithmic meta-theorems and combinatorics.			
NI-CCC	Creative Coding and Computational Art	KZ	4
Students work on practical tasks, get acquainted with creative and yet proven methods of visualizing various types of data. The course freely follows the basic graphics courses (MGA, BLE,) and introduces students to suitable visualization methods for traditional as well as for open data. It combines well-known visualization techniques with artistic methods using modern technologies. The aim is to create an interesting visualization project. It is planned to work closely with IPR CAMP (Center of Architecture and Metropolitan Planning) and IIM (Institute of Intermedia FEL).			

NI-KYB	Cybernality	ZK	5
Students get acquainted with the fundamentals of legislation and international activities in the area of fighting cybercrime. Students will understand the classification of attacks and have an overview of systems for computer surveillance and traffic monitoring in the cyberspace. Students will also familiarize themselves with hacker activities and behavior. The course will also discuss the cooperation of the state agencies and subjects dealing with defence of the cyberspace (especially CSIRT and CERT teams).			
NI-LSM2	Statistical Modelling Lab	KZ	5
The topic of LSM2 is advanced multiple target tracking (MTT). This domain covers simultaneous tracking of multiple targets using radar under the presence of clutter, or video tracking. We aim at the state-of-the-art filters, in particular the PHD (Probability Hypothesis Density) and PMBM (Poisson Multi-Bernoulli) filters.			
NI-MPL	Managerial Psychology	ZK	2
NI-MSI	Mathematical Structures in Computer Science	Z,ZK	4
Mathematical semantics of programming languages. Data types as continous lattices, Scott topology. Procedures as continuous mappings. The Scott model of lambda calculus. Introduction to category theory.			
NI-MZI	Mathematics for data science	Z,ZK	4
In this course, students are introduced to those fields of mathematics that are necessary for understanding 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.			
FIT-ITI	Modern IT infrastructure	Z,ZK	5
with a very limited and time-invariable range of software or hardware, this subject tries to explain the issue as a whole and in the context of the time. A modern data or computing center is understood here as a complex whole, the individual parts of which must be reconciled from different aspects of the view using current technologies. The proposed solution should thus be capable of continuous and economically optimal operation.			
NI-MOP	Modern Object-Oriented Programming in Pharo	KZ	4
Object-oriented programming is currently one of the most widespread paradigms of software creation, especially enterprise information systems, where its ability to natural abstraction is used to build complex modern applications. In this course, we build on the knowledge acquired in the course BI-OOP and aim to further deepen the skills of design and implementation of object systems in modern pure object system Pharo (https://pharo.org). The course focuses on individual approach to students, their development needs and areas of interest. In addition to deepening object programming skills, which are generally applicable in other OO languages, students will also gain the opportunity to work on interesting projects and OO technologies in terms of semestral work with the possibility of cooperation with practice and related bachelor, diploma, postgraduate our direct involvement in the Pharo Consortium.			
NI-NLM	Neural Language Models	Z	5
In this course, students will learn the technical foundations of the Transformer architecture as well as the practical aspects of using language models. The goal of the course is to teach students how to use language models to solve problems, make informed risk assessments, and work critically with the scientific literature.			
NI-NMU	New media in art and design	ZK	3
The course introduces students to the issue of using new media in artistic and design work. Key topics are moving image, internet, computer game and sound. The main goal is to familiarize the student with the largest possible range of creative approaches in new media. The subject emphasizes dialogue with students, especially in lectures devoted to specific art projects.			
NI-OLI	Linux Drivers	Z,ZK	4
The Linux operating system is an important operating system for personal computer and also for embedded systems. Systems on chip and combining powerful processors and FPGAs increase the variability of peripheral subsystems requiring specific software drivers. This course is an advanced course in the Linux driver development for master's students. The course provides knowledge of Linux operating system architecture, principles of development of various types drivers, including practical experience.			
NI-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.			
NI-PG1	Computer Grafics 1	ZK	4
The course builds on graphic courses (mainly BI-PGA and BI-PGR) and the knowledge from these courses is deepened by state-of-the-art knowledge. The course is designed for those interested in advanced computer graphics. Students will gain practical knowledge with realistic texturing and raytracing methods. An integral part of the course is the study of scientific articles and their subsequent implementation. The course will be followed by a course PG2 supplementing the knowledge of PG1 on other areas and topics of computer graphics.			
NI-EDW	Enterprise Data Warehouse Systems	Z,ZK	5
The Enterprise Data Warehouses course focuses on the area of business intelligence. Students will be introduced to business intelligence methods and will gain practical knowledge not only in designing warehouses and various architectures, but also their deployment and maintenance. This course also includes an introduction to the area of reporting and data visualization.			
NI-PVR	Advanced Virtual Reality	KZ	4
The course introduces advanced parts of the virtual reality. It is a continuation of the already running graphic objects, especially the creation of 3D models in Blender, and among other things, it introduces students to their application in virtual reality. Lectures will focus on virtual reality technology, its use in various applications and will also deal with creating applications in available 3D engines (mainly Unity3D). The course is freely connected with the subject VHS (virtual game worlds), students will be able to apply the knowledge gained in this subject in virtual reality, or directly create a complex game for VR.			
QNI-PMO	Advanced Optimization Methods / Conic Optimization	Z,ZK	6
Motivating examples. Conic optimization: Convex cones, Primal and dual conic problems, Spectrahedra and LMIs, Spectrahedral shadows, SDP duality, Numerical SDP solvers, Exact SDP solvers. Finite-dimensional polynomial optimization: Measures and moments, Riesz functional, moment and localizing matrices, Lasserres hierarchy, Global optimum recovery, Software interfaces, Back to the motivating examples. Infinite-dimensional polynomial optimization. Extensions to time-varying coefficients. The motivating examples revisited.			
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-IOS	Advanced techniques in iOS applications	KZ	4
Students will learn the latest trends in mobile development technologies for iOS platform. Class covers advanced topics, students need to know all the basics from the beginners class BI-IOS.			
NI-APT	Advanced Program Testing	Z,ZK	5
Testing a program is essential to ensure that a program respects its specification, that changes do not introduce regressions or security issues. The goal of the course is to present advanced program testing techniques, beyond writing unit tests, especially fuzzing and symbolic execution.			
NI-PVS	Advanced embedded systems	Z,ZK	4
The course is focused on ARM processors and microcontrollers and their usage in wide range of applications. The course includes a series of advanced topics like security support, working with mass storage devices, motor control, system control and industrial communication. The students obtain both theoretical and also practical experiences with embedded systems.			
NI-DNP	Advanced .NET	Z,ZK	4
Students will acquire an overview of platform .NET and will gain knowledge about technologies ASP.NET Core, Entity Framework Core, .NET MAUI (WPF, UWP), Blazor and also will get notions of Azure DevOps and GIT. Students will get practical experience in semestral work where they will create a client-server application utilizing technologies ASP.NET Core, Entity Framework Core and (Blazor, .NET MAUI or WPF) and also Azure DevOps and GIT.			

NI-PYT	Advanced Python	KZ	4
The goal of this course is to learn various advanced techniques and methods in Python. The course indirectly continues where Programming in Python (BI-PYT) left of. The course is very hands-on and it has only tutorials, everything is demonstrated on examples. Classification is based on work in class as well as semestral coursework. The course is lead by external teachers from Red Hat.			
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.			
NI-GOL	Programming of distributed systems in GO	KZ	5
NI-PSL	Programming in Scala	Z,ZK	4
The course introduces the modern programming language Scala which exploits object-functional paradigm. Scala comprises advance language features - e.g.pattern matching and advance standard library. Scala enables to use of applications functional patterns e.g. H-List, Monads, etc. Scala is used by many powerful frameworks and libraries e.g. Play, Cassandra, Scalaz, etc.			
NI-RUB	Programming in Ruby	KZ	4
This course is presented in Czech.			
NI-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.			
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-PLS1	Programming Language Seminar	Z	2
The Programming Language Seminar aims to introduce students to research in programming languages. It has the format of a reading group in which we discuss scientific papers about programming languages and related fields. Participating students are expected to present a paper of their interest and actively participate in the discussions. The reading group is a joint venue between FIT and MFF CUNI. It is open to all students and researchers interested in programming languages.			
NI-PLS2	Programming Language Seminar	Z	2
The Programming Language Seminar aims to introduce students to research in programming languages. It has the format of a reading group in which we discuss scientific papers about programming languages and related fields. Participating students are expected to present a paper of their interest and actively participate in the discussions. The reading group is a joint venue between FIT and MFF CUNI. It is open to all students and researchers interested in programming languages.			
NI-PLS3	Programming Language Seminar	Z	2
The Programming Language Seminar aims to introduce students to research in programming languages. It has the format of a reading group in which we discuss scientific papers about programming languages and related fields. Participating students are expected to present a paper of their interest and actively participate in the discussions. The reading group is a joint venue between FIT and MFF CUNI. It is open to all students and researchers interested in programming languages.			
NI-PLS4	Programming Language Seminar	Z	2
The Programming Language Seminar aims to introduce students to research in programming languages. It has the format of a reading group in which we discuss scientific papers about programming languages and related fields. Participating students are expected to present a paper of their interest and actively participate in the discussions. The reading group is a joint venue between FIT and MFF CUNI. It is open to all students and researchers interested in programming languages.			
NI-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.			
NI-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.			
NI-SZ1	Knowledge Engineering Seminar Master I	Z	4
On this seminar you will present a research paper from a top institute / research group to your peers. You will learn what is being cooked in top research labs around the world. Additionally, you will learn how to properly present and read scientific papers. The work in the seminar will prepare you to attend (and profit from) top machine learning and AI conferences and summer schools, as well as FIT's own Summer Research Program (VyLet).			
NI-SZ2	Knowledge Engineering Seminar Master II	Z	4
On this seminar you will present a research paper from a top institute / research group to your peers. You will learn what is being cooked in top research labs around the world. Additionally, you will learn how to properly present and read scientific papers. The work in the seminar will prepare you to attend (and profit from) top machine learning and AI conferences and summer schools, as well as FIT's own Summer Research Program (VyLet).			
NI-MLP	Machine Learning in Practice	Z,ZK	5
Applying machine learning methods to real projects in practice involves many other necessary tasks - from understanding the intentions of the client to, ideally, technical implementation. The course guides students through all phases of a project according to the standard CRISP-DM methodology, not only theoretically but also practically. The aim is to experience real data processing and learn how to describe the whole process from exploration to evaluation of the model performance in the form of a clear and understandable report.			
NI-SLA	Sublinear algorithms	Z,ZK	5
We will introduce three methods to tackle algorithms working in sublinear space.			

FIT-SEP	World Economy and Business	Z,ZK	4
This course is presented in Czech. 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.			
NI-SEP	World Economy and Business	Z,ZK	4
This course is presented in Czech. However, there is an English variant in the program Informatics (N1801 / 4793). 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.			
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-TVR	Virtual Reality Technology	Z,ZK	3
Students will be introduced to the basic concepts of virtual reality. Techniques for displaying virtual worlds (CAVE, HMD, ...) and the possibilities of controlling virtual avatars (position tracking, hand tracking, eye tracking) will be discussed. Furthermore, the concepts of mixed and augmented reality will be introduced. Finally, ways of using virtual and augmented reality will be presented.			
NI-TS1	Theoretical Seminar Master I	Z	4
Theoretical seminar is intended for students which want to come in deeper contact with contemporary theoretical computer science. It is mostly a classical reading group. The students are treated individually and concern themselves with interesting topics from the latest research in the area. Therefore, an integral part of the course is a work with scientific papers and other scholarly literature. The capacity is limited by the the potentials of the teachers of the seminar.			
NI-TS2	Theoretical Seminar Master II	Z	4
Theoretical seminar is intended for students which want to come in deeper contact with contemporary theoretical computer science. It is mostly a classical reading group. The students are treated individually and concern themselves with interesting topics from the latest research in the area. Therefore, an integral part of the course is a work with scientific papers and other scholarly literature. The capacity is limited by the the potentials of the teachers of the seminar.			
NI-TS3	Theoretical Seminar Master III	Z	4
Theoretical seminar is intended for students which want to come in deeper contact with contemporary theoretical computer science. It is mostly a classical reading group. The students are treated individually and concern themselves with interesting topics from the latest research in the area. Therefore, an integral part of the course is a work with scientific papers and other scholarly literature. The capacity is limited by the the potentials of the teachers of the seminar.			
NI-TS4	Theoretical Seminar Master IV	Z	4
Theoretical seminar is intended for students which want to come in deeper contact with contemporary theoretical computer science. It is mostly a classical reading group. The students are treated individually and concern themselves with interesting topics from the latest research in the area. Therefore, an integral part of the course is a work with scientific papers and other scholarly literature. The capacity is limited by the the potentials of the teachers of the seminar.			
NI-TKA	Category Theory	Z,ZK	4
NI-TNN	Theory of Neural Networks	Z,ZK	5
Artificial neural networks are now the foundation of artificial intelligence and the fastest-growing area of machine learning. This course introduces their theoretical foundations. It begins with general conceptsstructure, active dynamics, and adaptive dynamics (i.e., learning). Then it covers the theoretical basis of the most common types of artificial neural networks, from the perceptron of the 1950s to the transformer of 2017. Finally, using function approximation theory, it rigorously explains the most important theoretical result: the universal approximation capability of neural networks.			
FIT-TOP	Academic writing	Z	2
Publishing is an important and required part of research activity. It is not only about obtaining research results but also about applying them in the form of publication. Writing scientific publications can be useful for students not only in their own publishing activities but also in the preparation of a bachelor's or master's thesis. In the course, students will learn how to write a scientific article, what parts such an article should have, and how the peer review process works. Students will also try their hand at presenting an article and reviewing someone else's article. The course will be taught in blocks, with theoretical part at the beginning of the semester and one practical at the end of the semester/beginning of the exam period. Dates will be determined based on the availability of enrolled students.			
NI-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.			
NI-VOL	Elections	Z,ZK	5
We will cover the basics of (committee) elections and, in general, opinion aggregation.			
NI-VYC	Computability	Z,ZK	4
Classical theory of recursive functions and effective computability.			
NI-VPR	Research Project	Z	5
Student obtains the credits for published scientific outputs. The details are at https://courses.fit.cvut.cz/NI-VPR/en.			
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.			
NI-ZS10	Master internship abroad for 10 credits	Z	10
Each student can once within his / her master's degree have a foreign internship at a foreign university or other foreign scientific and/or research institution. Before the internship the Dean of the FIT, or the vice-dean for study affairs assesses the professional content. The student must provide evidence of the professional content and extent of the internship. Auxiliary courses MI-ZS10, MI-ZS20, MI-ZS30 are used used for the evidence and evaluation of the internship in IS KOS. Every 10 credits correspond to 4 weeks of full-time employment with a foreign institution. The maximum number of credits a student can earn for one internship is 30 credits. This amount can be divided into two subjects if the internship exceeds the academic year's dead-line.			
NI-ZS20	Master internship abroad for 20 credits	Z	20
Each student can once within his / her master's degree have a foreign internship at a foreign university or other foreign scientific and/or research institution. Before the internship the Dean of the FIT, or the vice-dean for study affairs assesses the professional content. The student must provide evidence of the professional content and extent of the internship. Auxiliary courses MI-ZS10, MI-ZS20, MI-ZS30 are used used for the evidence and evaluation of the internship in IS KOS. Every 10 credits correspond to 4 weeks of full-time employment with a foreign institution. The maximum number of credits a student can earn for one internship is 30 credits. This amount can be divided into two subjects if the internship exceeds the academic year's dead-line.			

NI-ZS30	Master internship abroad for 30 credits	Z	30

The course is prezented in chzech language. Each student can once within his / her master's degree have a foreign internship at a foreign university or other foreign scientific and/or research institution. Before the internship the Dean of the FIT, or the vice-dean for study affairs assesses the professional content. The student must provide evidence of the professional content and extent of the internship. Auxiliary courses MI-ZS10, MI-ZS20, MI-ZS30 are used used for the evidence and evaluation of the internship in IS KOS. Every 10 credits correspond to 4 weeks of full-time employment with a foreign institution. The maximum number of credits a student can earn for one internship is 30 credits. This amount can be divided into two subjects if the internship exceeds the academic year's dead-line.

List of courses of this pass:

Code	Name of the course	Completion	Credits
B2M17OPM	Optical Measurements	Z,ZK	6
B2M17VOT	Fiber Optic Technology	Z,ZK	6

The aim of the course is to introduce mechanisms of propagation of optical waves in optical fibers and fiber components. Furthermore, the optical measuring techniques and measuring methods for the characterization of optical fibers will be presented. Lectures include both the design and methodology of measuring transmission parameters for optical communication systems such as numerical aperture, attenuation, dispersion, and measurement of basic characteristics of active and passive elements of optical communication systems - connectors, splices, couplers, refractive indices etc.

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.

FIT-ITI	Modern IT infrastructure	Z,ZK	5

with a very limited and time-invariable range of software or hardware, this subject tries to explain the issue as a whole and in the context of the time. A modern data or computing center is understood here as a complex whole, the individual parts of which must be reconciled from different aspects of the view using current technologies. The proposed solution should thus be capable of continuous and economically optimal operation.

FIT-SEP	World Economy and Business	Z,ZK	4

This course is presented in Czech. 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.

FIT-TOP	Academic writing	Z	2

Publishing is an important and required part of research activity. It is not only about obtaining research results but also about applying them in the form of publication. Writing scientific publications can be useful for students not only in their own publishing activities but also in the preparation of a bachelor's or master's thesis. In the course, students will learn how to write a scientific article, what parts such an article should have, and how the peer review process works. Students will also try their hand at presenting an article and reviewing someone else's article. The course will be taught in blocks, with theoretical part at the beginning of the semester and one practical at the end of the semester/beginning of the exam period. Dates will be determined based on the availability of enrolled students.

FITE-DIF	Differential equations	Z,ZK	5

This course provides a foundational overview of differential equations, starting with basic motivation and examples of ODEs and progressing to essential solution methods like separation of variables. Key theorems on existence and uniqueness establish when solutions can be guaranteed. Linear and system-based ODEs are covered with methods like characteristic polynomial analysis, followed by examples of non-linear models such as predator-prey and epidemiological models to showcase real-world applications. Finally, an introduction to partial differential equations (PDEs) extends these concepts to multi-variable contexts. The course will also cover numerical methods for solving ODEs and PDEs, including implicit and explicit Euler methods, Runge-Kutta methods, and finite element methods for both ODEs and PDEs.

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.

NI-AFP	Applied Functional Programming	KZ	5

This course is presented in Czech. Functional programming represents one of the traditional programming paradigms. Traditional and novel functional programming languages are on the rise nowadays and the functional paradigm becomes an important construct of traditionally imperative languages (C++, C#, Java). As such, mastering this paradigm becomes a necessary competence of a software engineer: the theory and especially the practice.

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-APH	Architecture of computer games	Z,ZK	4
Students will gain a basic understanding of the various issues in the field of computer games development, especially from a technical point of view, but also from design and philosophical perspective. They will get a grasp of component-oriented and functional-oriented architecture, game mechanics, decision-making processes and base components that form an integral part of most games. They will also understand the basics of pathfinding, networking and scripting and apply them in practical exercises (labs). An important part of the course is an implementation of a simple game, with a strong focus on nontrivial game mechanics.			
NI-APT	Advanced Program Testing	Z,ZK	5
Testing a program is essential to ensure that a program respects its specification, that changes do not introduce regressions or security issues. The goal of the course is to present advanced program testing techniques, beyond writing unit tests, especially fuzzing and symbolic execution.			
NI-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.			
NI-ATH	AlgorithmicTheories of Games	Z,ZK	4
Traditional game theory is a branch of mathematics, which has broad applications in economy, biology, politics and computer science. This theory studies the behaviour of agents (players) of a certain competitive process by designinng a mathematical model and investigating the strategies. The traditional task of classical game theory is to find the equilibria, which are the states of the game where no player wants to deviate from his strategy. Due to the recent development of computers, internet, social networks, online auctions, advertising, multiagent systems and other concepts the algorithmic point of view is gaining attention. In addition to existential questions we study the problems of efficient computation of various solution concepts. In this course we introduce the basics of game theory of many players, solution concept (usually equilibria) and methods of their computation.			
NI-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.			
NI-CCC	Creative Coding and Computational Art	KZ	4
Students work on practical tasks, get acquainted with creative and yet proven methods of visualizing various types of data. The course freely follows the basic graphics courses (MGA, BLE,) and introduces students to suitable visualization methods for traditional as well as for open data. It combines well-known visualization techniques with artistic methods using modern technologies. The aim is to create an interesting visualization project. It is planned to work closely with IPR CAMP (Center of Architecture and Metropolitan Planning) and IIM (Institute of Intermedia FEL).			
NI-CTF	Capture The Flag	KZ	4
The course is designed to introduce students to CTF competitions and let them gain practical experience in the field of cyber security.			
NI-DDM	Distributed Data Mining	KZ	4
Course focuses on state-of-the-art approaches for distributed data mining and parallelization of machine learning algorithms. Students will gain hands on experience with large scale data processing framework Apache Spark and with existing distributed DM / ML algorithms. They will learn principles of their parallel implementations and will be capable to propose approaches to parallelize other algorithms. The course is prezented in czech language.			
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-DNP	Advanced .NET	Z,ZK	4
Students will acquire an overview of platform .NET and will gain knowledge about technologies ASP.NET Core, Entity Framework Core, .NET MAUI (WPF, UWP), Blazor and also will get notions of Azure DevOps and GIT. Students will get practical experience in semestral work where they will create a client-server application utilizing technologies ASP.NET Core, Entity Framework Core and (Blazor, .NET MAUI or WPF) and also Azure DevOps and GIT.			
NI-DPH	Game Design	Z,ZK	5
The course complements the NI-APH (Architecture of Computer Games) and BI-VHS (Virtual gaming worlds) course, while focusing primarily on game design. It is intended for people interested in deeper knowledge of the principles used for games design, such as: level design, gameplay design, character design, game mechanics design, storytelling, and game development cycle. The students will get an overview of game development from the designer's perspective, from theoretical concepts to practical implementation applied to semestral projects.			
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-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.			
NI-DZO	Digital Image Processing	Z,ZK	4
This course presents a comprehensive overview of modern methods for interactive editing of digital images and video. It mainly deals with practical algorithms that are both easy to implement and have an interesting theoretical basis. Visually attractive applications provide better understanding of basic theoretical background that is also valuable outside the domain of digital image processing. This course will introduce algorithms solving the following practical applications: edge-aware editing, tone mapping, HDR compression, de-blurring in frequency domain, abstraction, hybrid images, gradient domain editing, seamless image stitching and cloning, digital photo-montage, color-to-gray conversion, context enhancement, interactive as-rigid-as-possible image deformation, free-form image registration, texture synthesis, interactive segmentation, colorization, painting, adding depth, alpha matting.			
NI-EDW	Enterprise Data Warehouse Systems	Z,ZK	5
The Enterprise Data Warehouses course focuses on the area of business intelligence. Students will be introduced to business intelligence methods and will gain practical knowledge not only in designing warehouses and various architectures, but also their deployment and maintenance. This course also includes an introduction to the area of reporting and data visualization.			
NI-ESC	Experimental Project Course	KZ	8
"The Design Project course offers a holistic exploration of the design process, providing students with a well-rounded understanding of the principles, methodologies, and tools used in designing technology-driven solutions that are user-centric and industry-relevant. Throughout the semester, students will work on real-world design projects, collaborate with industry experts, and learn to integrate theory with practical application. Through a hands-on, project-based learning approach, students will develop their skills in user-centered design and user experience evaluation, as well as gain experience working in a team to design and prototype a functional solution."			
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-FMT	Finite model theory	Z,ZK	4
The aim of the course is to introduce students to the basics of finite model theory. The original motivation is the questions expressibility and verifiability of logical properties of database systems. Since its inception in the 1970s, the course has evolved rapidly and touched on many other areas of theoretical computer science, such as descriptive complexity theory, the Constraint Satisfaction Problem (CSP), the theory of algorithmic meta-theorems and combinatorics.			
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-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-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.			
NI-GNN	Graph Neural Networks	Z,ZK	4
The course introduces students to advanced artificial intelligence techniques for working with graphs. Lectures will focus on the latest graph neural networks for creating vector representations of nodes, edges and entire graphs. The techniques discussed cover various types of graphs, including time-varying graphs. The last part of the course also covers graph generation and interpretability of graph neural networks. In the exercises, students will try out selected techniques and problems.			
NI-GOL	Programming of distributed systems in GO	KZ	5
NI-GRI	Grid Computing	Z,ZK	5
Grid computing and gain knowledge about the world-wide network and computing infrastructure.			
NI-HCM	Mind Hacking	ZK	5
Cognitive security is an emerging discipline that is closely related to cyber security. While the domain of cyber security is the protection of networks, information systems and assets, the domain of cognitive security is the protection of the human mind from intentional and unintentional digital manipulation. The topic of cognitive security is growing in importance in the context of information warfare, increasing digital dependence and the development of artificial intelligence, where these phenomena from the Internet environment have real societal impacts such as disruption of social cohesion, threats to democracy or war.			
NI-HMI2	History of Mathematics and Informatics	ZK	3
This course is presented in Czech. Selected topics {Infinitesimal calculus, probability, number theory, general algebra, different examples of algorithms, transformations, recursive functions, eliptic curves, etc.) note on possibilities of applications of some mathematical methods in informatics and its development.			
NI-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.			
NI-IAM	Internet and Multimedia	Z,ZK	4
The NI-IAM course is focused on principles and modern technologies for network transmissions of audiovisual (AV) signals. The syllabus includes acquisition of AV signals (input), presentation of AV signals (output), network communication protocols, device interfaces, codecs, data formats and stereoscopy. We will look at practical use case scenarios of real-time audiovisual transmissions. Within the labs, students will practically assemble AV transmission chains using HW and SW technologies and verify the effect of various components on the quality and latency of AV transmissions. Students will learn how to build Internet infrastructure for end-to-end AV transmissions from the recording the scene up to the presentation for audience.			
NI-IBE	Information Security	ZK	2
Students learn information and IS/ICT security management systems (ISMS), methods for information access control, and basic norms and international standards in this area. They understand methods for management of internal and external security threats, for IS/IT security audits, and for application security testing (e.g., penetration testing).			
NI-IKM	Internet and Classification Methods	Z,ZK	4
In this course, the students get acquainted with classification methods used in four important internet, or generally network applications: in spam filtering, in recommendation systems, in malware detection systems and in intrusion detection systems. However, they will learn more than only how classification is performed when solving these four kinds of problems. On the background of these applications, they get an overview of the fundamentals of classification methods. The course is taught in a 2-weeks cycle with 2-hour lectures and 2-hour exercises. During the exercises, the students on the one hand implement simple examples to topics from the lectures, on the other hand consult their semester tasks.			
NI-IOS	Advanced techniques in iOS applications	KZ	4
Students will learn the latest trends in mobile development technologies for iOS platform. Class covers advanced topics, students need to know all the basics from the beginners class BI-IOS.			
NI-IOT	Internet of Things	Z,ZK	4
The subject is focused on the area of hardware and software technologies for the strongly growing computer support of various devices. Its goal is familiarization with available development elements (Raspberry Pi, Arduino Due) and with the language for efficient application development and modification (GNU Forth).			
NI-IVS	Intelligent embedded systems	KZ	4
Intelligent embedded systems course for master's degree is focused on high-level technology embedded systems integrating artificial intelligence. The course is an advance version of the Intelligent embedded system fundamentals course for the bachelor degree. The aim of the course is to teach students humanoid robot programming and advance application development. Lectures provide basis of motion control, sensor reading, application interfaces, robot navigation and development tools. In labs, students develop advanced applications combining knowledge of various courses like nature inspired algorithms, data mining algorithms, image recognition and web technologies			
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-KTH	Combinatorial Theories of Games	Z,ZK	4
Traditional game theory is a branch of mathematics, which has broad applications in economy, biology, politics and computer science. This theory studies the behaviour of agents (players) of a certain competitive process by designinng a mathematical model and investigating the strategies. The traditional task of classical game theory is to find the equilibria, which are the states of the game where no player wants to deviate from his strategy. Historically, the second big development in game theory of two-player full-information combinatorial games, was by Conway, Berlekamp and Guy. They developed a theory, originally used for solving end-games in Go, into a full fledged field. The idea is to evaluate games such that otherwise incompatible games can be added, that is, played simultaneously. This led to the algrebraic approach to study combinatorial games. The third most important step is the work of Beck, who established the theory of positional games (like tic-tac-toe and hex). In analysis of these game, one cannot escape the brute-force traversal of the game tree, which is no efficient. Beck introduced the "false probabilistic method", which aims to tackhle this problem. In this course we build the foundation of the theory of combinatorial and positional			

games. We focus on theoretical analysis of games and building the theory, not on the programming aspects of game solving algorithms. The course requires independent work, ability to mathematically analyse, think and proof. The course is also suitable for bachelors student in the third year, who attended introduction to graph theory, as well as for PhD students looking for research topics.

NI-KYB	Cybernality	ZK	5

Students get acquainted with the fundamentals of legislation and international activities in the area of fighting cybercrime. Students will understand the classification of attacks and have an overview of systems for computer surveillance and traffic monitoring in the cyberspace. Students will also familiarize themselves with hacker activities and behavior. The course will also discuss the cooperation of the state agencies and subjects dealing with defence of the cyberspace (especially CSIRT and CERT teams).

NI-LSM2	Statistical Modelling Lab	KZ	5

The topic of LSM2 is advanced multiple target tracking (MTT). This domain covers simultaneous tracking of multiple targets using radar under the presence of clutter, or video tracking. We aim at the state-of-the-art filters, in particular the PHD (Probability Hypothesis Density) and PMBM (Poisson Multi-Bernoulli) filters.

NI-MLP	Machine Learning in Practice	Z,ZK	5

Applying machine learning methods to real projects in practice involves many other necessary tasks - from understanding the intentions of the client to, ideally, technical implementation. The course guides students through all phases of a project according to the standard CRISP-DM methodology, not only theoretically but also practically. The aim is to experience real data processing and learn how to describe the whole process from exploration to evaluation of the model performance in the form of a clear and understandable report.

NI-MOP	Modern Object-Oriented Programming in Pharo	KZ	4

Object-oriented programming is currently one of the most widespread paradigms of software creation, especially enterprise information systems, where its ability to natural abstraction is used to build complex modern applications. In this course, we build on the knowledge acquired in the course BI-OOP and aim to further deepen the skills of design and implementation of object systems in modern pure object system Pharo (https://pharo.org). The course focuses on individual approach to students, their development needs and areas of interest. In addition to deepening object programming skills, which are generally applicable in other OO languages, students will also gain the opportunity to work on interesting projects and OO technologies in terms of semestral work with the possibility of cooperation with practice and related bachelor, diploma, postgraduate our direct involvement in the Pharo Consortium.

NI-MPL	Managerial Psychology	ZK	2
NI-MSI	Mathematical Structures in Computer Science	Z,ZK	4

Mathematical semantics of programming languages. Data types as continous lattices, Scott topology. Procedures as continuous mappings. The Scott model of lambda calculus. Introduction to category theory.

NI-MZI	Mathematics for data science	Z,ZK	4

In this course, students are introduced to those fields of mathematics that are necessary for understanding 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-NLM	Neural Language Models	Z	5

In this course, students will learn the technical foundations of the Transformer architecture as well as the practical aspects of using language models. The goal of the course is to teach students how to use language models to solve problems, make informed risk assessments, and work critically with the scientific literature.

NI-NMU	New media in art and design	ZK	3

The course introduces students to the issue of using new media in artistic and design work. Key topics are moving image, internet, computer game and sound. The main goal is to familiarize the student with the largest possible range of creative approaches in new media. The subject emphasizes dialogue with students, especially in lectures devoted to specific art projects.

NI-OLI	Linux Drivers	Z,ZK	4

The Linux operating system is an important operating system for personal computer and also for embedded systems. Systems on chip and combining powerful processors and FPGAs increase the variability of peripheral subsystems requiring specific software drivers. This course is an advanced course in the Linux driver development for master's students. The course provides knowledge of Linux operating system architecture, principles of development of various types drivers, including practical experience.

NI-PAM	Efficient Preprocessing and 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.

NI-PG1	Computer Grafics 1	ZK	4

The course builds on graphic courses (mainly BI-PGA and BI-PGR) and the knowledge from these courses is deepened by state-of-the-art knowledge. The course is designed for those interested in advanced computer graphics. Students will gain practical knowledge with realistic texturing and raytracing methods. An integral part of the course is the study of scientific articles and their subsequent implementation. The course will be followed by a course PG2 supplementing the knowledge of PG1 on other areas and topics of computer graphics.

NI-PLS1	Programming Language Seminar	Z	2

The Programming Language Seminar aims to introduce students to research in programming languages. It has the format of a reading group in which we discuss scientific papers about programming languages and related fields. Participating students are expected to present a paper of their interest and actively participate in the discussions. The reading group is a joint venue between FIT and MFF CUNI. It is open to all students and researchers interested in programming languages.

NI-PLS2	Programming Language Seminar	Z	2

The Programming Language Seminar aims to introduce students to research in programming languages. It has the format of a reading group in which we discuss scientific papers about programming languages and related fields. Participating students are expected to present a paper of their interest and actively participate in the discussions. The reading group is a joint venue between FIT and MFF CUNI. It is open to all students and researchers interested in programming languages.

NI-PLS3	Programming Language Seminar	Z	2

The Programming Language Seminar aims to introduce students to research in programming languages. It has the format of a reading group in which we discuss scientific papers about programming languages and related fields. Participating students are expected to present a paper of their interest and actively participate in the discussions. The reading group is a joint venue between FIT and MFF CUNI. It is open to all students and researchers interested in programming languages.

NI-PLS4	Programming Language Seminar	Z	2

The Programming Language Seminar aims to introduce students to research in programming languages. It has the format of a reading group in which we discuss scientific papers about programming languages and related fields. Participating students are expected to present a paper of their interest and actively participate in the discussions. The reading group is a joint venue between FIT and MFF CUNI. It is open to all students and researchers interested in programming languages.

NI-PSD	Public Services Design	KZ	4

The course will introduce students to specifics of UX, Service design and development for public sector. We will look into the design and development process from the perspective of suppliers (devs and designesr) as well as clients. In small teams students will work on projects from partner organizations and will try out collaboration with client representatives. Course is aimed at students-designers as well as clients.

NI-PSL	Programming in Scala	Z,ZK	4
The course introduces the modern programming language Scala which exploits object-functional paradigm. Scala comprises advance language features - e.g.pattern matching and advance standard library. Scala enables to use of applications functional patterns e.g. H-List, Monads, etc. Scala is used by many powerful frameworks and libraries e.g. Play, Cassandra, Scalaz, etc.			
NI-PVR	Advanced Virtual Reality	KZ	4
The course introduces advanced parts of the virtual reality. It is a continuation of the already running graphic objects, especially the creation of 3D models in Blender, and among other things, it introduces students to their application in virtual reality. Lectures will focus on virtual reality technology, its use in various applications and will also deal with creating applications in available 3D engines (mainly Unity3D). The course is freely connected with the subject VHS (virtual game worlds), students will be able to apply the knowledge gained in this subject in virtual reality, or directly create a complex game for VR.			
NI-PVS	Advanced embedded systems	Z,ZK	4
The course is focused on ARM processors and microcontrollers and their usage in wide range of applications. The course includes a series of advanced topics like security support, working with mass storage devices, motor control, system control and industrial communication. The students obtain both theoretical and also practical experiences with embedded systems.			
NI-PYT	Advanced Python	KZ	4
The goal of this course is to learn various advanced techniques and methods in Python. The course indirectly continues where Programming in Python (BI-PYT) left of. The course is very hands-on and it has only tutorials, everything is demonstrated on examples. Classification is based on work in class as well as semestral coursework. The course is lead by external teachers from Red Hat.			
NI-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.			
NI-RUB	Programming in Ruby	KZ	4
This course is presented in Czech.			
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-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.			
NI-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.			
NI-SEP	World Economy and Business	Z,ZK	4
This course is presented in Czech. However, there is an English variant in the program Informatics (N1801 / 4793). 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.			
NI-SLA	Sublinear algorithms	Z,ZK	5
We will introduce three methods to tackle algorithms working in sublinear space.			
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-SZ1	Knowledge Engineering Seminar Master I	Z	4
On this seminar you will present a research paper from a top institute / research group to your peers. You will learn what is being cooked in top research labs around the world. Additionally, you will learn how to properly present and read scientific papers. The work in the seminar will prepare you to attend (and profit from) top machine learning and AI conferences and summer schools, as well as FIT's own Summer Research Program (VyLet).			
NI-SZ2	Knowledge Engineering Seminar Master II	Z	4
On this seminar you will present a research paper from a top institute / research group to your peers. You will learn what is being cooked in top research labs around the world. Additionally, you will learn how to properly present and read scientific papers. The work in the seminar will prepare you to attend (and profit from) top machine learning and AI conferences and summer schools, as well as FIT's own Summer Research Program (VyLet).			
NI-TKA	Category Theory	Z,ZK	4
NI-TNN	Theory of Neural Networks	Z,ZK	5
Artificial neural networks are now the foundation of artificial intelligence and the fastest-growing area of machine learning. This course introduces their theoretical foundations. It begins with general conceptsstructure, active dynamics, and adaptive dynamics (i.e., learning). Then it covers the theoretical basis of the most common types of artificial neural networks, from the perceptron of the 1950s to the transformer of 2017. Finally, using function approximation theory, it rigorously explains the most important theoretical result: the universal approximation capability of neural networks.			
NI-TS1	Theoretical Seminar Master I	Z	4
Theoretical seminar is intended for students which want to come in deeper contact with contemporary theoretical computer science. It is mostly a classical reading group. The students are treated individually and concern themselves with interesting topics from the latest research in the area. Therefore, an integral part of the course is a work with scientific papers and other scholarly literature. The capacity is limited by the the potentials of the teachers of the seminar.			
NI-TS2	Theoretical Seminar Master II	Z	4
Theoretical seminar is intended for students which want to come in deeper contact with contemporary theoretical computer science. It is mostly a classical reading group. The students are treated individually and concern themselves with interesting topics from the latest research in the area. Therefore, an integral part of the course is a work with scientific papers and other scholarly literature. The capacity is limited by the the potentials of the teachers of the seminar.			

NI-TS3	Theoretical Seminar Master III	Z	4
Theoretical seminar is intended for students which want to come in deeper contact with contemporary theoretical computer science. It is mostly a classical reading group. The students are treated individually and concern themselves with interesting topics from the latest research in the area. Therefore, an integral part of the course is a work with scientific papers and other scholarly literature. The capacity is limited by the the potentials of the teachers of the seminar.			
NI-TS4	Theoretical Seminar Master IV	Z	4
Theoretical seminar is intended for students which want to come in deeper contact with contemporary theoretical computer science. It is mostly a classical reading group. The students are treated individually and concern themselves with interesting topics from the latest research in the area. Therefore, an integral part of the course is a work with scientific papers and other scholarly literature. The capacity is limited by the the potentials of the teachers of the seminar.			
NI-TVR	Virtual Reality Technology	Z,ZK	3
Students will be introduced to the basic concepts of virtual reality. Techniques for displaying virtual worlds (CAVE, HMD, ...) and the possibilities of controlling virtual avatars (position tracking, hand tracking, eye tracking) will be discussed. Furthermore, the concepts of mixed and augmented reality will be introduced. Finally, ways of using virtual and augmented reality will be presented.			
NI-VGA	Video Games Architecture	Z,ZK	5
The course covers a wide range of topics, procedures and methodologies related to the development of computer games - from a technical point of view, but also from a design and philosophical point of view. In the lectures, students will be guided through the history of development, the structure of game engines, component and functional architecture typical of game development, physics, graphics, artificial intelligence and multiplayer. The exercises will then cover selected technological topics in greater detail, including ways of implementing some game mechanics, in the form of practical demonstrations.			
NI-VOL	Elections	Z,ZK	5
We will cover the basics of (committee) elections and, in general, opinion aggregation.			
NI-VPR	Research Project	Z	5
Student obtains the credits for published scientific outputs. The details are at https://courses.fit.cvut.cz/NI-VPR/en.			
NI-VYC	Computability	Z,ZK	4
Classical theory of recursive functions and effective computability.			
NI-ZS10	Master internship abroad for 10 credits	Z	10
Each student can once within his / her master's degree have a foreign internship at a foreign university or other foreign scientific and/or research institution. Before the internship the Dean of the FIT, or the vice-dean for study affairs assesses the professional content. The student must provide evidence of the professional content and extent of the internship. Auxiliary courses MI-ZS10, MI-ZS20, MI-ZS30 are used used for the evidence and evaluation of the internship in IS KOS. Every 10 credits correspond to 4 weeks of full-time employment with a foreign institution. The maximum number of credits a student can earn for one internship is 30 credits. This amount can be divided into two subjects if the internship exceeds the academic year's dead-line.			
NI-ZS20	Master internship abroad for 20 credits	Z	20
Each student can once within his / her master's degree have a foreign internship at a foreign university or other foreign scientific and/or research institution. Before the internship the Dean of the FIT, or the vice-dean for study affairs assesses the professional content. The student must provide evidence of the professional content and extent of the internship. Auxiliary courses MI-ZS10, MI-ZS20, MI-ZS30 are used used for the evidence and evaluation of the internship in IS KOS. Every 10 credits correspond to 4 weeks of full-time employment with a foreign institution. The maximum number of credits a student can earn for one internship is 30 credits. This amount can be divided into two subjects if the internship exceeds the academic year's dead-line.			
NI-ZS30	Master internship abroad for 30 credits	Z	30
The course is prezented in chzech language. Each student can once within his / her master's degree have a foreign internship at a foreign university or other foreign scientific and/or research institution. Before the internship the Dean of the FIT, or the vice-dean for study affairs assesses the professional content. The student must provide evidence of the professional content and extent of the internship. Auxiliary courses MI-ZS10, MI-ZS20, MI-ZS30 are used used for the evidence and evaluation of the internship in IS KOS. Every 10 credits correspond to 4 weeks of full-time employment with a foreign institution. The maximum number of credits a student can earn for one internship is 30 credits. This amount can be divided into two subjects if the internship exceeds the academic year's dead-line.			
NIE-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.			
NIE-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.			
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-BKO	Error Control Codes	Z,ZK	5
The course expands the basic knowledge of security codes used in current systems for error detection and correction. It provides the necessary mathematical theory and principles of linear, cyclic codes and codes for the correction of multiple errors, clusters of errors and whole syllables (bytes). Students will also learn how to implement these detections and corrections for different types of transmissions (parallel, serial) when storing data in memory and when transmitting over telecommunication channels.			
NIE-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.			
NIE-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.			
NIE-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.			

NIE-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.			
NIE-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.			
NIE-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.			
NIE-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.			
NIE-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.			
NIE-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.			
NIE-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 memory, which are today the most common computing nodes of powerful computer systems. Students will gain knowledge of architecturally specific optimization techniques used to reduce the decrease in computing power due to the widening performance 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.			
NIE-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.			
NIE-MTI	Modern Internet Technologies	Z,ZK	5
Students learn advanced networking technologies and protocols for both local area networks and wide area networks. They get acquainted with routing techniques and transfer technologies of modern internet, including multimedia data transfer, with various types of network virtualization, and with last-mile security.			
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.			
NIE-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.			
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-PIS	Advanced Information Systems	Z,ZK	5
Students learn the notion of business process logic and its formalization, with business process roles, business rules, and data processing, with the notion of service oriented company, enterprise services and service solution of business logic. They get acquainted with these notions also for the other types of ISs. They learn about agility and adaptivity and using of artificial intelligence methods for implementation of these ideas in ISs. They understand modern object-oriented methodologies for modelling of business processes, business rules, processed data, and enterprise ISs. They will get the rules and technologies for successful implementation of IS.			
NIE-REV	Reverse Engineering	Z,ZK	5
Students will learn fundamentals of reverse engineering of computer software (methods of executing and initializing programs, organization of executable files, work with third-party libraries). Special attention will be paid to C ++. Students will also become familiar with the principles of debugging tools, disassemblers and obfuscation methods. Finally, the course will focus on code compression and decompression and executable file reconstruction.			
NIE-SBF	System Security and Forensics	Z,ZK	5
Students will be introduced to various aspects of system security (principles of endpoint security, principles of security policies, security models, authentication concepts). Students will also learn about forensic analysis as a tool for investigating security incidents (techniques used by malicious software or attackers, forensic analysis techniques, and the importance of memory or file system artifacts for attack analysis and detection).			
NIE-SIB	Network Security	Z,ZK	5
The students will gain theoretical and practical knowledge and experience in the area of current security threats in computer networks, specifically about detection and defense. The course explains basic pricipals of security monitoring, packet-based and flow-based analysis, in order to detect anomalies and suspicious network traffic. The course focuses on explanation and practical examples of various mechanisms of securing network infrastructure and detection in real time. The course covers general principals of handling detected security events (i.e. incident handling and incident response).			
NIE-SIM	Digital Circuit Simulation and Verification	Z,ZK	5
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 today recent verification methods, too.			
NIE-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.		
NIE-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.		
NIE-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).		
QNI-AVM	Adiabatic computing and variational methods	Z,ZK	6
	The course introduces adiabatic computing and variational quantum algorithms (VQA). We start with a broad introduction to variational methods in physical chemistry (e.g., for calculating ground state of small molecules) and a recapitulation of advances in theoretical computer science (computational complexity and problems such as MAXCUT). We will present the EQA Conjecture and the unique games conjecture. We will present the adiabatic theorem and quantum speedup by quantum annealing (QA). We will build up an understanding of variational quantum algorithms by introducing and analysing, in turn, Variational quantum eigensolver (VQE), Quantum Approximate Optimization Algorithm (QAOA), and their Warm-started variants. As applications, we will highlight variational solvers for systems of linear equations and variational solvers for Markowitz portfolio management, with some discussion of the challenges in benchmarking of VQA.		
QNI-CPX	Complexity Theory	Z,ZK	6
	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.		
QNI-DIP	Diploma Thesis	Z	30
	Independent work of the student under the guidance of the thesis supervisor. Teaching is based on individual consultations with the thesis supervisor or other consultants. The scope of teaching 30 ECTS (i.e. about 900 hours) includes consultations, preparation of theoretical and practical parts of the thesis, writing, preparation for defence and defence of the thesis before the commission. The course supervisor guarantees the quality of the Masters thesis assignment and its compliance with the graduate profile.		
QNI-KKP	Cryptology and Quantum Computing	Z,ZK	6
	The course covers methods and algorithms of cryptology and their relation to quantum computing. In the first introductory lectures, students will be introduced to the basic principles and algorithms of cryptography. Following these topics, students will be introduced to basic cryptanalytic methods. Then some cryptanalytic algorithms running on quantum computers will be presented. In this context, the problem of security of related cryptographic schemes will be discussed. The next lectures will be devoted to post-quantum algorithms. The last lectures deal with cryptosystems using quantum phenomena.		
QNI-KOS	Quantum Optical Communications and Networks	Z,ZK	6
	The course focuses on the basic principles and technologies for building and using quantum networks. Students will learn about the key components of quantum networks, including quantum repeaters, routers and switches, and their role in creating a scalable quantum Internet. Emphasis will be placed on quantum cryptography systems. Students will also learn the fundamentals of optics, optical networks, and classical cryptography as they relate to quantum key distribution (QKD) and quantum networks. The course will cover types and architectures of QKD systems (including practical implementation of quantum protocols) according to international standards, key generation and distribution in these systems, and integration of QKD with classical communication systems. Students will also have the opportunity to explore satellite and FSO QKD systems and integrated quantum photonics and electronics.		
QNI-LOM	Linear Optimization and Methods	Z,ZK	5
	Students learn the applications of optimization methods in computer science, economics, and industry. They are aware of practical importance of linear and integer programming. They are able to work with optimization software and are familiar with languages used in programming of that software. They get skills in formalization of optimization problems in computer science (such as scheduling of tasks to processors, analysis of network flows), distribution and allocation of resources (transportation problems, travelling salesman problems, etc.), issues from economics, and modelling of conflicts via the game theory. They get an overview of computational complexity of optimization problems. They get orientation in algorithms in linear programming.		
QNI-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.		
QNI-MQI	Mathematics for Quantum Informatics	Z,ZK	6
	Linear algebra on finite dimensional spaces with scalar product, Hilbert spaces, Dirac's bra-ket formalism, normal, Hermitian and unitary operators, operator spectrum, orthonormalization, diagonalization, matrix exponential, tensor product of vector spaces and operators. Discrete Fourier transform and fast Fourier transform.		
QNI-NMK	Numerical methods for quantum computation	Z,ZK	5
	The course is devoted to numerical solution of boundary-value problems and intial-boundary-value problems for ordinary and partial differential equations. It explains finite-difference, finite-element and finite-volume methods for elliptic, parabolic and hyperbolic partial differential equations. Students are introduced to the recent advances in methods solving the mentioned problems.		
QNI-OPM	Optical measurements	Z,ZK	6
	The aim of this course is to acquaint students with optical measurement methods from the detection of microparticles, non-regulation and surface breaches, through the use of fiber optics in areas where it is not possible to use standard electronic sensors, or in places with increased risk of explosion and in hospitals, lidars used in intelligent transport infrastructures, to macroscopic sensing (remote sensing) of the Earth, atmosphere and space. The inclusion of these measurement methods requires in particular an understanding of the physical mechanisms on which they are based, as well as knowledge of measurement procedures and specifics in data processing and reconstruction.		
QNI-OQC	Optical quantum computing	Z,ZK	5
	The course covers the basic theoretical methods and concepts for optical quantum computing, complemented by on hands-on exercise and applications using quantum programming libraries, Strawberry Fields and Piquasso. Theoretical concepts include measurement-based quantum computation, Gaussian Boson Sampling, and quantum supremacy. Applications feasible on current and near-term hardware include recent generative and discriminative machine-learning algorithms, as well as molecular vibration simulations.		
QNI-OVV	Optimization for Scientific Computing	Z,ZK	5
	The content of the course is an explanation of numerical methods for solving nonlinear optimization, convex optimization, stochastic optimization, optimal control, applications for QC, genetic and evolutionary programming, machine learning, deep neural networks. Students are also introduced to modern trends in solving these problems.		

QNI-PJK	Programming languages for quantum computing	Z,ZK	5
Computational models for quantum computing: quantum Turing machine, QRAM, lambda calculus with qubits. Higher programming languages for quantum computation: imperative languages (Silq), functional languages (QML, Quipper).). In the seminars the student will learn the basics of programming in the higher programming language Silq.			
QNI-PMO	Advanced Optimization Methods / Conic Optimization	Z,ZK	6
Motivating examples. Conic optimization: Convex cones, Primal and dual conic problems, Spectrahedra and LMIs, Spectrahedral shadows, SDP duality, Numerical SDP solvers, Exact SDP solvers. Finite-dimensional polynomial optimization: Measures and moments, Riesz functional, moment and localizing matrices, Lasserres hierarchy, Global optimum recovery, Software interfaces, Back to the motivating examples. Infinite-dimensional polynomial optimization. Extensions to time-varying coefficients. The motivating examples revisited.			
QNI-PNM	Parallelization of numerical methods	Z,ZK	5
The content of the course is an explanation of numerical methods for solving mathematical models with a focus on their parallelization and the use of these methods in QC. Students are also introduced to modern trends in the field of solving these problems.			
QNI-PON	Selected Topics in Optimization and Numerical mathematics	Z,ZK	5
Students will be introduced to special optimization problems that arise in the field of machine learning and artificial intelligence and will extend the basic knowledge of continuous optimization acquired in previous studies. They will also learn about the details of implementing solutions to these problems on a computer and related mathematical concepts, especially from numerical linear algebra.			
QNI-PPS	Programming of parallel systems	Z,ZK	6
Nowadays, multi-core processors and GPU accelerators have become common components of computing clusters and high-performance computing systems, so knowledge and skills related to parallel programming are essential for every computer scientist. The aim of this course is to introduce students to the architectures and programming methods of parallel computers with shared memory, GPU accelerators, or with distributed memory. To effectively use these modern computing systems, it is essential to combine parallelization techniques at all three levels. Students will gain knowledge of the relevant programming models, languages and environments. They will become familiar with fundamental parallel algorithms and be able to analyze the limitations, efficiency, and scalability of parallel solutions to selected problems on high-performance computing systems. In addition to the necessary theory in lectures, students will gain practical experience and skills in programming in OpenMP, CUDA and MPI environments.			
QNI-QC1	Quantum Computation 1	Z,ZK	6
The course introduces the student to basic principles of quantum computation and shows the difference between classical and quantum mechanics. Quantum computation uses quantum circuits, which will be demonstrated in the Qiskit SDK. The course will gradually introduce the student to such concepts the state of a quantum system and its visualization, measurements, basic gates and their composition, and the so-called entanglement. The student will be introduced to the BB84 and E91 protocols as demonstrations of the properties of quantum states. The course will also cover quantum teleportation, quantum oracle queries, the Deutsch-Jozsa algorithm, the quantum Fourier transform, the phase estimation algorithm, and the Shor algorithm.			
QNI-QC2	Quantum Computing 2	Z,ZK	6
Quantum Computing 2 focuses on advanced quantum algorithms and their implementations: the Grover algorithm and its applications, quantum algorithms solving linear algebra problems, HHL for solving systems of linear equations. In the course we also introduce students to variational methods and error correction.			
QNI-QEC	Quantum error correction	Z,ZK	5
In this course, we will build a theory for the construction of quantum error-correcting codes. In the introductory part, necessary chapters from the classical theory will be summarized, atop of which we then present the quantum analogy. We will show how coherently stored quantum information can be made robust to loss and noise. We conclude the course by arriving at the principle of fault tolerance, based on which quantum computers are able to continuously correct errors arising at runtime and thus achieve correct results even with erroneous bits, gates or measurements.			
QNI-QML	Quantum machine learning	Z,ZK	5
The aim of the course is to introduce students to quantum machine learning. Students will first learn theoretically and practically about the quantum representation of classical data. Next, they will explore kernel methods, the quantum SVM model, and the use of quantum variational methods in supervised learning scenarios. The course will also introduce quantum neural networks and quantum generative adversarial models in unsupervised learning scenarios. The primary focus of the course is quantum algorithms for classical data. The exercises will use the pandas and qiskit libraries for Python to work with data and models.			
QNI-QOM	Quantum Optics, Metrology, Sensing and Imaging	Z,ZK	5
Students are given an introduction to the quantum theory of light and related fundamental principles with an emphasis on practical aspects. They acquire the theoretical and experimental foundations for the development of specifically quantum mechanical approaches to metrology and imaging in quantum computing and communications. Specific problems discussed include elementary processes with photons (absorption, emission, stimulated emission), interference, entanglement, non-classical phenomena with photons, methods of suppressing optical aberrations and dispersion. The various techniques are explained theoretically and also using experiments that demonstrate these principles in practice.			
QNI-TIN	Information Theory	Z,ZK	6
The course focuses on the mathematical description of a random message source, its coding and transmission of the source through a noisy channel. The coding problem is addressed probabilistically, the relation of the mean length of the optimal code with the entropy and entropy rate of the random source is emphasized. In the case of the noisy channel we focus on the set of typical sequences and its appropriate coding by self-correcting codes. The course includes a reminder of necessary concepts such as conditional distributions, goodness-of-fit and independence tests, and an introduction to random chains.			
QNI-UKT	Introduction to Quantum Theory	Z,ZK	6
interpretation of quantum theory are explained using simple models mainly from finite-dimensional quantum mechanics. Emphasis is placed on further applications of quantum theory to information processing and communication. Possible physical realizations of a qubit, description of multipartite systems, quantum entanglement and its applications are discussed. The course concludes with a description of continuous quantum systems in infinite-dimensional Hilbert spaces, in particular the linear harmonic oscillator as a description of the mode of a quantized electromagnetic field.			
QNI-VOT	Fiber Optic Technology	Z,ZK	6
The aim of the course is to introduce the mechanisms of optical wave propagation in optical fibres and fibre components. Furthermore, the knowledge of optical measurement techniques and measurement methods for the characterisation of optical fibres. The content includes both methodologies for measuring design and transmission parameters for optical communication systems such as numerical aperture, attenuation, dispersion, as well as measurements of basic characteristics of active and passive elements of optical communication systems - connectors, couplers, coupling elements, refractive indices.			

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