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: Quantum Infromatics
Type of study: Follow-up master full-time
Required credits: 116
Elective courses credits: 4
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: 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-KKP	**Cryptology and Quantum Computing** ***Róbert Lórencz***	Z,ZK	6	2P+2C	Z	PP
QNI-KOS	**Quantum Optical Communications and Networks**	Z,ZK	6	2P+2C	Z	PP
QNI-QC1	**Quantum Computation 1** ***Marcel Jiřina***	Z,ZK	6	2P+2C	Z	PP
QNI-QC2	**Quantum Computing 2** *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***	Z,ZK	5	2P+1C	Z	PP
QNI-DIP	**Diploma Project** ***Zdeněk Muzikář*** *Zdeněk Muzikář (Gar.)*	Z	30	270ZP	L,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***	Z,ZK	6	2P+2C	Z	PP
QNI-PPS	**Programming of parallel systems** *Pavel Tvrdík* ***Pavel Tvrdík*** *Pavel Tvrdík (Gar.)*	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***	Z,ZK	6	3P+1C	Z	PP
QNI-UKT	**Introduction to Quantum Theory**	Z,ZK	6	2P+2C	Z	PP

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

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-DIP	Diploma Project	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-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: 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**	Z,ZK	6	2P+2C	*	PV
QNI-QEC	**Quantum error correction**	Z,ZK	5	2P+2C	Z	PV
QNI-QOM	**Quantum Optics, Metrology, Sensing and Imaging**	Z,ZK	5	2P+2C	Z	PV
QNI-QML	**Quantum machine learning** ***Daniel Vašata***	Z,ZK	5	2P+1C		PV
QNI-NMK	**Numerical methods for quantum computation**	Z,ZK	5	2P+2C		PV
QNI-OQC	**Optical quantum computing** ***Aurél Gábor Gábris***	Z,ZK	5	2P+1C		PV
QNI-OPM	**Optical measurements**	Z,ZK	6	2P+2C		PV
QNI-OVV	**Optimization for Scientific Computing**	Z,ZK	5	2P+1C		PV
QNI-PNM	**Parallelization of numerical methods**	Z,ZK	5	2P+2C		PV
QNI-PJK	**Programming languages for quantum computing**	Z,ZK	5	2P+1C		PV
QNI-VOT	**Fiber Optic Technology**	Z,ZK	6	2P+2C		PV
QNI-PON	**Selected Topics in Optimization and Numerical mathematics** *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.

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.

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-AOA	**Completing a professional event** ***Zdeněk Muzikář***	Z	1			V
NI-ATH	**AlgorithmicTheories of Games** *Tomáš Valla, Dušan Knop* ***Tomáš Valla*** *Tomáš Valla (Gar.)*	Z,ZK	4	2P+2C	L	V
NI-AFP	**Applied Functional Programming** *Robert Pergl, Marek Suchánek, Daniel Němec* ***Robert Pergl*** *Robert Pergl (Gar.)*	KZ	5	2P+1C	L	V
NI-APH	**Architecture of computer games** *Adam Vesecký* ***Adam Vesecký*** *Adam Vesecký (Gar.)*	Z,ZK	4	2P+1C	Z	V
NI-BPS	**Wireless Computer Networks** *Alexandru Moucha, Jiří Kašpar* ***Alexandru Moucha*** *Alexandru Moucha (Gar.)*	Z,ZK	4	2P+1C	L	V
NIE-BLO	**Blockchain** *Josef Gattermayer, Marek Bielik, Jakub Růžička, Róbert Lórencz* ***Josef Gattermayer*** *Róbert Lórencz (Gar.)*	Z,ZK	5	1P+2C	Z	V
NI-CTF	**Capture The Flag** *Jiří Dostál, Martin Šutovský, Ivana Trummová, Ladislav Marko, František Kovář* ***Jiří Dostál*** *Jiří Dostál (Gar.)*	KZ	4	3C	Z	V
NI-DPH	**Game Design** ***Adam Vesecký***	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** *Ondřej Brém, David Pešek* ***David Pešek*** *Ondřej Brém (Gar.)*	KZ	4	1P+2C		V
NI-DID	**Digital drawing** *Denisa Nováčková, Eliška Novotná* ***Denisa Nováčková*** *Denisa Nováčková (Gar.)*	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* ***Ondřej Suchý*** *Ondřej Suchý (Gar.)*	Z,ZK	4	2P+1C	L	V
NI-ESC	**Experimental Project Course** *Ondřej Brém, Jan Matoušek* ***Ondřej Brém*** *Ondřej Brém (Gar.)*	KZ	8	0P+30R+52C	L	V
NI-GLR	**Games and reinforcement learning**	Z,ZK	4	2P+2C	L	V
NI-GNN	**Graph Neural Networks** *Miroslav Čepek* ***Miroslav Čepek*** *Miroslav Čepek (Gar.)*	Z,ZK	4	1P+1C	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* ***Miroslav Skrbek*** *Miroslav Skrbek (Gar.)*	KZ	4	1P+3C	L	v
NI-IKM	**Internet and Classification Methods** *Martin Holeňa* ***Martin Holeňa*** *Martin Holeňa (Gar.)*	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
NI-KTH	**Combinatorial Theories of Games** *Tomáš Valla* ***Tomáš Valla*** *Tomáš Valla (Gar.)*	Z,ZK	4	2P+1C	L	v
NI-FMT	**Finite model theory** *Tomáš Jakl* ***Tomáš Jakl*** *Tomáš Jakl (Gar.)*	Z,ZK	4	2P+1C	L	v
NI-CCC	**Creative Coding and Computational Art** *Josef Kortán, Radek Richtr* ***Radek Richtr*** *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-LOM	**Linear Optimization and Methods** *Dušan Knop* ***Dušan Knop*** *Dušan Knop (Gar.)*	Z,ZK	5	2P+1C	Z	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** ***Jan Starý***	Z,ZK	4	2P+1C	L	v
NI-MZI	**Mathematics for data science** ***Štěpán Starosta***	Z,ZK	4	2P+1C	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** *Miroslav Skrbek, Jaroslav Borecký* ***Jaroslav Borecký*** *Miroslav Skrbek (Gar.)*	Z,ZK	4	2P+2C	L	v
NIE-PML	**Personalized Machine Learning** *Rodrigo Augusto Da Silva Alves* ***Karel Klouda*** *Rodrigo Augusto Da Silva Alves (Gar.)*	Z,ZK	5	2P+1C	Z	v
NI-ARI	**Computer arithmetic** *Pavel Kubalík* ***Pavel Kubalík*** *Alois Pluháček (Gar.)*	Z,ZK	4	2P+1C	Z,L	v
NI-PG1	**Computer Grafics 1** *Radek Richtr* ***Radek Richtr*** *Radek Richtr (Gar.)*	ZK	4	2P+1C	L	v
NI-EDW	**Enterprise Data Warehouse Systems** *Jakub Krejčí, Robert Kotlář* ***Jakub Krejčí*** *Magda Friedjungová (Gar.)*	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
NI-AML	**Advanced machine learning** *Miroslav Čepek, Rodrigo Augusto Da Silva Alves, Petr Šimánek, Vojtěch Rybář, Zdeněk Buk* ***Miroslav Čepek*** *Miroslav Čepek (Gar.)*	Z,ZK	5	2P + 1C	L	v
NI-IOS	**Advanced techniques in iOS applications** *Rostislav Babáček, Jakub Olejník, Igor Rosocha* ***Martin Půlpitel*** *Martin Půlpitel (Gar.)*	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** *Nikolas Jíša, David Šenkýř* ***David Šenkýř*** *Nikolas Jíša (Gar.)*	Z,ZK	4	2P+1C	Z	v
NI-PYT	**Advanced Python**	KZ	4	3C	Z	v
NIE-PDL	**Practical Deep Learning** *Martin Barus, Yauhen Babakhin* ***Karel Klouda*** *Karel Klouda (Gar.)*	KZ	5	2P+1C	Z	v
NI-GOL	**Programming of distributed systems in GO**	KZ	5	0P+3C	Z	v
NI-PSL	**Programming in Scala** *Jiří Daněček* ***Jiří Daněček*** *Jiří Daněček (Gar.)*	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** *Radek Richtr, Michal Haindl* ***Michal Haindl*** *Michal Haindl (Gar.)*	Z,ZK	5	2P+1C	Z	v
NI-PLS1	**Programming Language Seminar** ***Pierre Donat-Bouillud*** *Pierre Donat-Bouillud (Gar.)*	Z	2	0P+1C	Z	v
NI-PLS2	**Programming Language Seminar** ***Pierre Donat-Bouillud*** *Pierre Donat-Bouillud (Gar.)*	Z	2	0P+1C	L	v
NI-PLS3	**Programming Language Seminar** ***Pierre Donat-Bouillud*** *Pierre Donat-Bouillud (Gar.)*	Z	2	0P+1C	Z	v
NI-PLS4	**Programming Language Seminar** *Pierre Donat-Bouillud, Filip Křikava* ***Pierre Donat-Bouillud*** *Pierre Donat-Bouillud (Gar.)*	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* ***Hana Kubátová*** *Hana Kubátová (Gar.)*	Z	4	2C	L,Z	v
NI-SZ1	**Knowledge Engineering Seminar Master I** ***Pavel Kordík*** *Magda Friedjungová (Gar.)*	Z	4	2C	L,Z	v
NI-SZ2	**Knowledge Engineering Seminar Master II** ***Pavel Kordík*** *Magda Friedjungová (Gar.)*	Z	4	2C	L,Z	v
PI-SCN	**Seminars on Digital Design** *Petr Fišer* ***Petr Fišer*** *Petr Fišer (Gar.)*	ZK	4	2P+1C	Z,L	v
NI-MLP	**Machine Learning in Practice** *Jan Hučín* ***Daniel Vašata*** *Daniel Vašata (Gar.)*	Z,ZK	5	2P+1C	Z	v
BI-ML1.21	**Machine Learning 1** *Karel Klouda, Daniel Vašata* ***Daniel Vašata*** *Daniel Vašata (Gar.)*	Z,ZK	5	2P+2C	Z	v
BI-ML2.21	**Machine Learning 2** *Daniel Vašata* ***Daniel Vašata*** *Daniel Vašata (Gar.)*	Z,ZK	5	2P+2C	L	v
NI-SEP	**World Economy and Business** *Tomáš Evan* ***Tomáš Evan*** *Tomáš Evan (Gar.)*	Z,ZK	4	2P+1C	Z,L	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** *Tomáš Valla, Dušan Knop, Ondřej Suchý* ***Tomáš Valla*** *Tomáš Valla (Gar.)*	Z	4	2C	Z	v
NI-TS2	**Theoretical Seminar Master II** *Tomáš Valla, Ondřej Suchý* ***Tomáš Valla*** *Tomáš Valla (Gar.)*	Z	4	2C	L	v
NI-TS3	**Theoretical Seminar Master III** *Tomáš Valla, Ondřej Suchý* ***Tomáš Valla*** *Tomáš Valla (Gar.)*	Z	4	2C	Z	v
NI-TS4	**Theoretical Seminar Master IV** *Tomáš Valla, Ondřej Suchý* ***Tomáš Valla*** *Ondřej Suchý (Gar.)*	Z	4	2C	L	v
NI-TKA	**Category Theory** *Jan Starý* ***Jan Starý*** *Jan Starý (Gar.)*	Z,ZK	4	2P+1C	L	v
NI-TNN	**Theory of Neural Networks** *Martin Holeňa* ***Martin Holeňa*** *Martin Holeňa (Gar.)*	Z,ZK	5	2P+1C	L	v
NI-CPX	**Complexity Theory** *Dušan Knop, Ondřej Suchý* ***Ondřej Suchý*** *Ondřej Suchý (Gar.)*	Z,ZK	5	3P+1C	Z	v
FI-TOP	**Academic writing** ***Tomáš Nováček***	Z	2	10B	Z	v
NI-DVG	**Introduction to Discrete and Computational Geometry** *Maria Saumell Mendiola* ***Maria Saumell Mendiola*** *Maria Saumell Mendiola (Gar.)*	Z,ZK	5	2P+1C	L	v
NI-VOL	**Elections** *Dušan Knop* ***Dušan Knop*** *Dušan Knop (Gar.)*	Z,ZK	5	2P+1C	L	v
NI-VYC	**Computability** *Jan Starý* ***Jan Starý*** *Jan Starý (Gar.)*	Z,ZK	4	2P+2C	L	v
NI-VPR	**Research Project** *Štěpán Starosta* ***Štěpán Starosta*** *Štěpán Starosta (Gar.)*	Z	5		Z,L	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

NI-AOA	Completing a professional event	Z	1

The subject is participation in a one-off professional event, usually a lecture by a foreign guest of the FIT CTU, concluded with a workshop, a test, drafting a report, etc.Such an event must be approved in advance by the vice-dean for pedagogical activities or the vice-dean for science and research and is presented within the FIT through a website, infomail, etc.

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-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.

NIE-BLO	Blockchain	Z,ZK	5
Students will understand the foundations of blockchain technology, smart contract programming, and gain an overview of most notable blockchain platforms. They will be able to design, code and deploy a secure decentralized application, and assess whether integration of a blockchain is suitable for a given problem. The course places an increased emphasis on the relationship between blockchains and information security. It is concluded with a defense of a research or applied semester project, which prepares the students for implementing or supervising implementation of blockchain-based solutions in both academia and business.			
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.			
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-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-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-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).			

<table>
<tr><td>NI-IVS</td><td>Intelligent embedded systems</td><td>KZ</td><td>4</td></tr>
<tr><td colspan="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</td></tr>
<tr><td>NI-IKM</td><td>Internet and Classification Methods</td><td>Z,ZK</td><td>4</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>NI-IAM</td><td>Internet and Multimedia</td><td>Z,ZK</td><td>4</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>NI-IOT</td><td>Internet of Things</td><td>Z,ZK</td><td>4</td></tr>
<tr><td colspan="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).</td></tr>
<tr><td>NI-KTH</td><td>Combinatorial Theories of Games</td><td>Z,ZK</td><td>4</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>NI-FMT</td><td>Finite model theory</td><td>Z,ZK</td><td>4</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>NI-CCC</td><td>Creative Coding and Computational Art</td><td>KZ</td><td>4</td></tr>
<tr><td colspan="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).</td></tr>
<tr><td>NI-KYB</td><td>Cybernality</td><td>ZK</td><td>5</td></tr>
<tr><td colspan="4">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).</td></tr>
<tr><td>NI-LSM2</td><td>Statistical Modelling Lab</td><td>KZ</td><td>5</td></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td>NI-LOM</td><td>Linear Optimization and Methods</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td>NI-MPL</td><td>Managerial Psychology</td><td>ZK</td><td>2</td></tr>
<tr><td>NI-MSI</td><td>Mathematical Structures in Computer Science</td><td>Z,ZK</td><td>4</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>NI-MZI</td><td>Mathematics for data science</td><td>Z,ZK</td><td>4</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>NI-MOP</td><td>Modern Object-Oriented Programming in Pharo</td><td>KZ</td><td>4</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>NI-NLM</td><td>Neural Language Models</td><td>Z</td><td>5</td></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td>NI-NMU</td><td>New media in art and design</td><td>ZK</td><td>3</td></tr>
<tr><td colspan="4">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.</td></tr>
</table>

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.			
NIE-PML	Personalized Machine Learning	Z,ZK	5
Personalized machine learning (PML) is a sub-field of machine learning that aims to create models and predictions based on the unique characteristics and behaviors of individual entities. While PML is commonly used in applications such as recommender systems, which recommend items to users based on their personal interests, its principles can be applied to a wide range of other fields, including education, medicine, and chemical engineering. In this course, we will explore the latest PML methods from theoretical, algorithmic, and practical perspectives. Specifically, we will focus on cutting-edge models that are of interest to both the research and commercial communities.			
NI-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.			
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.			
NIE-PDL	Practical Deep Learning	KZ	5
This course is designed to provide students with a comprehensive understanding of Deep Learning using PyTorch, a popular open-source machine learning framework. Throughout the course, students will develop practical skills in building and training deep neural networks, using PyTorch to solve real-world problems in fields such as computer vision and natural language processing.			
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-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.			

<table>
<tr><td>NI-PLS4</td><td>Programming Language Seminar</td><td>Z</td><td>2</td></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td>NI-SCE1</td><td>Computer Engineering Seminar Master I</td><td>Z</td><td>4</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>NI-SCE2</td><td>Computer Engineering Seminar Master II</td><td>Z</td><td>4</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>NI-SZ1</td><td>Knowledge Engineering Seminar Master I</td><td>Z</td><td>4</td></tr>
<tr><td colspan="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).</td></tr>
<tr><td>NI-SZ2</td><td>Knowledge Engineering Seminar Master II</td><td>Z</td><td>4</td></tr>
<tr><td colspan="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).</td></tr>
<tr><td>PI-SCN</td><td>Seminars on Digital Design</td><td>ZK</td><td>4</td></tr>
<tr><td colspan="4">This subject deals with problems of realization and implementation of digital circuits - both combinational and sequential. Basic means of description of digital circuits and basic logic synthesis and optimization algorithms are described. Basics of EDA (Electronic Design Automation) systems are given, together with combinatorial problems emerging in EDA.</td></tr>
<tr><td>NI-MLP</td><td>Machine Learning in Practice</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td>BI-ML1.21</td><td>Machine Learning 1</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">The goal of this course is to introduce students to the basic methods of machine learning. They get theoretical understanding and practical working knowledge of regression and classification models in the supervised learning scenario and clustering models in the unsupervised scenario. Students will be aware of the relationships between model bias and variance, and know the fundamentals of assessing model quality. Moreover, they learn the basic techniques of data preprocessing and multidimensional data visualization. In practical demonstrations, pandas and scikit libraries in Python will be used.</td></tr>
<tr><td>BI-ML2.21</td><td>Machine Learning 2</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">The goal of this course is to introduce students to the selected advanced methods of machine learning. In the supervised learning scenario, they, in particular, learn kernel methods and neural networks. In the unsupervised learning scenario students learn the principal component analysis and other dimensionality reduction methods. Moreover, students get the basic principles of reinforcement learning and natural language processing.</td></tr>
<tr><td>NI-SEP</td><td>World Economy and Business</td><td>Z,ZK</td><td>4</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>NI-TVR</td><td>Virtual Reality Technology</td><td>Z,ZK</td><td>3</td></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td>NI-TS1</td><td>Theoretical Seminar Master I</td><td>Z</td><td>4</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>NI-TS2</td><td>Theoretical Seminar Master II</td><td>Z</td><td>4</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>NI-TS3</td><td>Theoretical Seminar Master III</td><td>Z</td><td>4</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>NI-TS4</td><td>Theoretical Seminar Master IV</td><td>Z</td><td>4</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>NI-TKA</td><td>Category Theory</td><td>Z,ZK</td><td>4</td></tr>
</table>

NI-TNN	Theory of Neural Networks	Z,ZK	5
In this course, we study neural networks from the point of view of the theory of function approximation and from the point of view of probability theory. At first, we recall basic concepts pertaining to artificial neural Networks, such as neurons and connections between them, types of neurons from the point of view of signal transmission, network topology, somatic and synaptic mappings, network training, and the role of time in neural networks. In connection with network topology, we get acquainted with its transformation into a canonical topology, and in connection with somatic and synaptic mappings, with their composition into mappings computed by the Network, Finally in connection with training, we pay attention to the problem of overtraining and to the fact that training is actually a specific optimization task, recalling the most typical objective functions and the most important optimization methods employed for neural network training. We will see the meaninig of all these concepts in the context of common kinds of forward neural networks. Within the topic approximation approach to neural networks, we first notice the connection of neural networks to expressing functions of many variables using functions of fewer variables (Kolmogorov theorem, Vituškin theorem). Afterwards, we will see how the universal approximation capacity of neural networks can be mathematically formalized as the sets of mappings computed by neural networks being dense in important Banach spaces of functions, in particular in the spaces of continuous functions, spaces of functions integrable with respect to a finite measure, spaces of functions with continuous derivatives, and Sobolev spaces. Within the topic probabilistic approach, we first get acquainted with training based on expectation and training based on a random sample, and with probabilistic assumptions about training data with which those two kinds of neural networks can be employed. We will see how it is possible to get an estimate of the conditional expectancy of network outputs conditioned by its inputs using the expectancy based learning. We recall the strong and the weak law of large numbers and get acquainted with an analogy of the strong law of large numbers for neural networks and with the assumptions for its validity. Finally, we recall the central limit theorem, get acquinted with its analogy for neural networks, with the assumptions for its validity and with the hypothesis tests based on it. We will see how those tests can be employed to search for the topology of the network.			
NI-CPX	Complexity Theory	Z,ZK	5
Students will learn about the fundamental classes of problems in the complexity theory and different models of algoritms and about implications of the theory concerning practical (in)tractability of difficult problems.			
FI-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 one lecture at the beginning of the semester and one practicum in the middle of the semester. 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.			
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
BI-ML1.21	Machine Learning 1	Z,ZK	5
The goal of this course is to introduce students to the basic methods of machine learning. They get theoretical understanding and practical working knowledge of regression and classification models in the supervised learning scenario and clustering models in the unsupervised scenario. Students will be aware of the relationships between model bias and variance, and know the fundamentals of assessing model quality. Moreover, they learn the basic techniques of data preprocessing and multidimensional data visualization. In practical demonstrations, pandas and scikit libraries in Python will be used.			
BI-ML2.21	Machine Learning 2	Z,ZK	5
The goal of this course is to introduce students to the selected advanced methods of machine learning. In the supervised learning scenario, they, in particular, learn kernel methods and neural networks. In the unsupervised learning scenario students learn the principal component analysis and other dimensionality reduction methods. Moreover, students get the basic principles of reinforcement learning and natural language processing.			

FI-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 one lecture at the beginning of the semester and one practicum in the middle of the semester. Dates will be determined based on the availability of enrolled students.			
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-AOA	Completing a professional event	Z	1
The subject is participation in a one-off professional event, usually a lecture by a foreign guest of the FIT CTU, concluded with a workshop, a test, drafting a report, etc.Such an event must be approved in advance by the vice-dean for pedagogical activities or the vice-dean for science and research and is presented within the FIT through a website, infomail, etc.			
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-CPX	Complexity Theory	Z,ZK	5
Students will learn about the fundamental classes of problems in the complexity theory and different models of algoritms and about implications of the theory concerning practical (in)tractability of difficult problems.			
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.			

<table>
<tr><td>NI-DZO</td><td>Digital Image Processing</td><td>Z,ZK</td><td>4</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>NI-EDW</td><td>Enterprise Data Warehouse Systems</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td>NI-ESC</td><td>Experimental Project Course</td><td>KZ</td><td>8</td></tr>
<tr><td colspan="4">"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."</td></tr>
<tr><td>NI-FMT</td><td>Finite model theory</td><td>Z,ZK</td><td>4</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>NI-GLR</td><td>Games and reinforcement learning</td><td>Z,ZK</td><td>4</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>NI-GNN</td><td>Graph Neural Networks</td><td>Z,ZK</td><td>4</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>NI-GOL</td><td>Programming of distributed systems in GO</td><td>KZ</td><td>5</td></tr>
<tr><td>NI-GRI</td><td>Grid Computing</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">Grid computing and gain knowledge about the world-wide network and computing infrastructure.</td></tr>
<tr><td>NI-HCM</td><td>Mind Hacking</td><td>ZK</td><td>5</td></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td>NI-HMI2</td><td>History of Mathematics and Informatics</td><td>ZK</td><td>3</td></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td>NI-HSC</td><td>Side-Channel Analysis in Hardware</td><td>Z,ZK</td><td>4</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>NI-IAM</td><td>Internet and Multimedia</td><td>Z,ZK</td><td>4</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>NI-IBE</td><td>Information Security</td><td>ZK</td><td>2</td></tr>
<tr><td colspan="4">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).</td></tr>
<tr><td>NI-IKM</td><td>Internet and Classification Methods</td><td>Z,ZK</td><td>4</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>NI-IOS</td><td>Advanced techniques in iOS applications</td><td>KZ</td><td>4</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>NI-IOT</td><td>Internet of Things</td><td>Z,ZK</td><td>4</td></tr>
<tr><td colspan="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).</td></tr>
<tr><td>NI-IVS</td><td>Intelligent embedded systems</td><td>KZ</td><td>4</td></tr>
<tr><td colspan="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</td></tr>
<tr><td>NI-KTH</td><td>Combinatorial Theories of Games</td><td>Z,ZK</td><td>4</td></tr>
<tr><td colspan="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</td></tr>
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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-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.			
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-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-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
In this course, we study neural networks from the point of view of the theory of function approximation and from the point of view of probability theory. At first, we recall basic concepts pertaining to artificial neural Networks, such as neurons and connections between them, types of neurons from the point of view of signal transmission, network topology, somatic and synaptic mappings, network training, and the role of time in neural networks. In connection with network topology, we get acquainted with its transformation into a canonical topology, and in connection with somatic and synaptic mappings, with their composition into mappings computed by the Network, Finally in connection with training, we pay attention to the problem of overtraining and to the fact that training is actually a specific optimization task, recalling the most typical objective functions and the most important optimization methods employed for neural network training. We will see the meaninig of all these concepts in the context of common kinds of forward neural networks. Within the topic approximation approach to neural networks, we first notice the connection of neural networks to expressing functions of many variables using functions of fewer variables (Kolmogorov theorem, Vituškin theorem). Afterwards, we will see how the universal approximation capacity of neural networks can be mathematically formalized as the sets of mappings computed by neural networks being dense in important Banach spaces of functions, in particular in the spaces of continuous functions, spaces of functions integrable with respect to a finite measure, spaces of functions with continuous derivatives, and Sobolev spaces. Within the topic probabilistic approach, we first get acquainted with training based on expectation and training based on a random sample, and with probabilistic assumptions about training data with which those two kinds of neural networks can be employed. We will see how it is possible to get an estimate of the conditional expectancy of network outputs conditioned by its inputs using the expectancy based learning. We recall the strong and the weak law of large numbers and get acquainted with an analogy of the strong law of large numbers for neural networks and with the assumptions for its validity. Finally, we recall the central limit theorem, get acquinted with its analogy for neural networks, with the assumptions for its validity and with the hypothesis tests based on it. We will see how those tests can be employed to search for the topology of the network.			

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-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-BLO	Blockchain	Z,ZK	5
Students will understand the foundations of blockchain technology, smart contract programming, and gain an overview of most notable blockchain platforms. They will be able to design, code and deploy a secure decentralized application, and assess whether integration of a blockchain is suitable for a given problem. The course places an increased emphasis on the relationship between blockchains and information security. It is concluded with a defense of a research or applied semester project, which prepares the students for implementing or supervising implementation of blockchain-based solutions in both academia and business.			
NIE-PDL	Practical Deep Learning	KZ	5
This course is designed to provide students with a comprehensive understanding of Deep Learning using PyTorch, a popular open-source machine learning framework. Throughout the course, students will develop practical skills in building and training deep neural networks, using PyTorch to solve real-world problems in fields such as computer vision and natural language processing.			
NIE-PML	Personalized Machine Learning	Z,ZK	5
Personalized machine learning (PML) is a sub-field of machine learning that aims to create models and predictions based on the unique characteristics and behaviors of individual entities. While PML is commonly used in applications such as recommender systems, which recommend items to users based on their personal interests, its principles can be applied to a wide range of other fields, including education, medicine, and chemical engineering. In this course, we will explore the latest PML methods from theoretical, algorithmic, and practical perspectives. Specifically, we will focus on cutting-edge models that are of interest to both the research and commercial communities.			
PI-SCN	Seminars on Digital Design	ZK	4
This subject deals with problems of realization and implementation of digital circuits - both combinational and sequential. Basic means of description of digital circuits and basic logic synthesis and optimization algorithms are described. Basics of EDA (Electronic Design Automation) systems are given, together with combinatorial problems emerging in EDA.			
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 Project	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-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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