## 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: Kvantová informatika Type of study: Follow-up master full-time

Required credits: 120 Elective courses credits: 0 Sum of credits in the plan: 120

Note on the plan:

Name of the block: Compulsory courses in the program

Minimal number of credits of the block: 96

The role of the block: PP

Code of the group: QNI-PP

Name of the group: Compulsory courses of the Quantum Informatics

Requirement credits in the group: In this group you have to gain 96 credits

Requirement courses in the group: In this group you have to complete 12 courses

Credits in the group: 96 Note on the group:

QNI-DIP

Diploma Thesis

Code	Name of the course / Name of the group of courses (in case of groups of courses the list of codes of their members) Tutors, authors and guarantors (gar.)	Completion	Credits	Scope	Semester	Role
QNI-DIP	Diploma Thesis Zdeněk Muzikář	Z	30	270ZP	L,Z	PP
QNI-KKP	Cryptology and Quantum Computing Robert Lorencz	Z,ZK	6	2P+2C	Z	PP
BQM32KOS	Quantum optical communications and networks Leoš Boháč Leoš Boháč Leoš Boháč (Gar.)	Z,ZK	6	2P+2C	L	PP
QNI-QC1	Quantum Computation 1 Marcel Jiřina, Ivo Petr Marcel Jiřina Marcel Jiřina (Gar.)	Z,ZK	6	2P+2C	Z	PP
QNI-QC2	Quantum Computing 2 Ivo Petr, Aurél Gábor Gábris Aurél Gábor Gábris (Gar.)	Z,ZK	6	2P+2C	L	PP
QNI-LOM	Linear Optimization and Methods  Dušan Knop Dušan Knop Dušan Knop (Gar.)	Z,ZK	5	2P+1C	Z	PP
QNI-MPR	Master Project Zdeněk Muzikář Zdeněk Muzikář Zdeněk Muzikář (Gar.)	Z	7		Z,L	PP
QNI-MQI	Mathematics for Quantum Informatics Štěpán Starosta, Tomáš Kalvoda <b>Štěpán Starosta</b> Štěpán Starosta (Gar.)	Z,ZK	6	2P+2C	Z	PP
QNI-PPS	Programming of parallel systems Ivan Šimeček Ivan Šimeček Ivan Šimeček (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, Ondřej Suchý Dušan Knop Dušan Knop (Gar.)	Z,ZK	6	3P+1C	Z	PP
QNI-UKT	Introduction to Quantum Theory Martin Štefaňák Martin Štefaňák Martin Štefaňák (Gar.)	Z,ZK	6	2P+2C	Z	PP

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

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.	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 meth	ods and algorithms of cryptology and their relation to quantum computing. In the first introductory lectures, students will be i	ntroduced to the b	pasic principles				
and algorithms of crypto	ography. Following these topics, students will be introduced to basic cryptanalytic methods. Then some cryptanalytic algorithm	ns running on qua	ntum computers				
will be presented. In this	s context, the problem of security of related cryptographic schemes will be discussed. The next lectures will be devoted to po	st-quantum algori	thms. The last				
lectures deal with cryptosystems using quantum phenomena.							
BQM32KOS	Quantum optical communications and networks	Z,ZK	6				

QNI-QC1 Quantum Computation 1 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

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.

**ONI-LOM** Linear Optimization and Methods Z,ZK

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

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

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.

Information Theory

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

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.

Introduction to Quantum Theory ONI-UKT

 $Z,\overline{ZK}$ 

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

Name of the block: Elective vocational courses in the branch/specialization

Minimal number of credits of the block: 6

The role of the block: VO

Code of the group: QNI-PV-ENG

Name of the group: Compulsory elective english courses of the program Quantum Informatics

Requirement credits in the group: In this group you have to gain at least 6 credits (at most 165)

Requirement courses in the group:

Credits in the group: 6

Note on the group:

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Code	Name of the course / Name of the group of courses (in case of groups of courses the list of codes of their members) Tutors, authors and guarantors (gar.)	Completion	Credits	Scope	Semester	Role
NIE-KRY	Advanced Cryptology Róbert Lórencz, Jiří Buček <b>Jiří Buček</b> Róbert Lórencz (Gar.)	Z,ZK	5	2P+2C	Z	VO
NIE-PDB	Advanced Database Systems Martin Svoboda Martin Svoboda (Gar.)	Z,ZK	5	2P+1C	Z	VO
NIE-PIS	Advanced Information Systems Petra Pavlíčková, Petr Kroha Petra Pavlíčková Petr Kroha (Gar.)	Z,ZK	5	2P+1C	L	VO
NIE-AIB	Algorithms of Information Security Martin Jureček Martin Jureček (Gar.)	Z,ZK	5	2P+1C	Z	VO

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

# program Quantum Informatics

**NIE-KRY** Advanced Cryptology Z,ZK 5

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

NIE-PDB Advanced Database Systems Z,ZK

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

NIE-PIS **Advanced Information Systems** Z,ZK

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

NIE-AIB Algorithms of Information Security Z,ZK

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

NIE-ADP Architecture and Design patterns The objective of this course is to provide students with both work knowledge about the underlying foundations of object-oriented design and analysis as well as with understanding of the challenges, issues, and tradeoffs of advanced software design. In the first part of the course, the students will refresh and deepen their knowledge of object-oriented programming and get familiar with the commonly used object-oriented design patterns that represent the best practices for solving common software design problems. In the second part the students will be introduced to the principles of software architecture design and analysis. This includes the classical architectural styles, component based systems, and some advanced software architectures used in large-scale distributed systems. NIE-SIM Digital Circuit Simulation and Verification Aim of the course is to acquaint the students with principles of digital circuit simulation at RTL (Register Transfer Level) and TLM (Transaction Level Modeling) levels and with the properties of proper tools. The course covers today recent verification methods, too. Distributed Systems and Computing NIF-DSV Z,ZK 5 Students are introduced to methods for coordination of processes in distributed environment characterised by nondeterministic time responses of computing processes and communication channels. They learn basic algorithms that assure correctness of computations realized by a group of loosely coupled processes and mechanisms that support high availability of both data and services, and safety in case of failures. NIE-EPC Z.ZK Effective C++ programming Students learn how to use the modern features of contemporary versions of the C++ programming language for software development. The course focuses on programming effectivity and efficiency in the form of writing maintainable and portable source code and creating correct programs with low memory and processor time requirements. NIE-EHW **Embedded Hardware** Z.ZK 5 The course brings basic laws that govern digital design and basic techniques to use them. It deals with both large and small scale systems. This is the base of advanced embedded systems, that profit from their specialized structure for effective computation and acceleration. Design of fast custom computing machines is discussed, including standardized means of internal communication, parallelism extraction and utilization in special structures and system architectures. NIF-BVS 5 Students gain basic knowledge in selected topics of cryptography and cryptanalysis. The course focuses particularly on efficient implementations of cryptographic primitives in hardware and software (in embedded systems). Students gain a good overview of functionality of (hardware) cryptographic accelerators, smart cards, and resources for securing internal functions of computer systems. Z,ZK **NIE-ESW Embedded Software** Embedded software course acquainted students with the specifics of software development for embedded systems. The course covers the areas from the basic techniques of programming in C language and code optimizations, through typical areas as the reliable software development, embedded operating systems, signal processing, up to sophisticated techniques combined with artificial intelligence. NIF-BKO **Error Control Codes** Z.ZK The course expands the basic knowledge of security codes used in current systems for error detection and correction. It provides the necessary mathematical theory and principles of linear, cyclic codes and codes for the correction of multiple errors, clusters of errors and whole syllables (bytes). Students will also learn how to implement these detections and corrections for different types of transmissions (parallel, serial) when storing data in memory and when transmitting over telecommunication channels NIF-FMF Formal Methods and Specifications Z,ZK 5 Students are able to describe semantics of software formally and to use sound reasoning for construction of correct software. They learn to use some software tools that allow to prove basic properties of software NIE-GPU **GPU Architectures and Programming** Students will gain knowledge of the internal architecture of modern massively parallel GPU processors. They will learn to program them mainly in the CUDA programming environment, which is already a widespread programming technology of GPU processors. As an integral part of the effective computational use of these hierarchical computational structures, students will also learn optimization programming techniques and methods of programming multiprocessor GPU systems. NIE-HWB Hardware Security Z.ZK The course provides the knowledge needed for the analysis and design of computer systems security solutions. Students get an overview of safeguards against abuse of the system using hardware means. They will be able to safely use and integrate hardware components into systems and test them for resistance to attacks. Students will gain knowledge about the cryptographic accelerators, PUF, random number generators, smart cards, biometric devices, and devices for internal security functions of the computer NIF-MKY Mathematics for Cryptology Students will gain deeper knowledge of algebraic procedures solving the most important mathematical problems concerning the security of ciphers. In particular, the course focuses on the problem of solving a system of polynomial equations over a finite field, the problem of factorization of large numbers and the problem of discrete logarithm. The problem of factorization will also be solved on elliptic curves. Students will further become familiar with modern encryption systems based on lattices. Middleware Architectures 1 Students will study new trends, concepts, and technologies in the area of service-oriented architectures. The will gain an overview of information system architecture, web service architecture and aplication servers. The will also study principles and technologies for middleware focused on application integrations, asynchronous communications and high availability of applications. This course replaces the course MIE-MDW. Modern Internet Technologies Students learn advanced networking technologies and protocols for both local area networks and wide area networks. They get acquainted with routing techniques and transfer technologies of modern internet, including multimedia data transfer, with various types of network virtualization, and with last-mile security. NIE-MCC Multicore CPU Computing Z,ZK 5 Students will get acquainted in detail with hardware support and programming technologies for the creation of parallel multithreaded computations on multicore processors with shared and virtually shared memory, which are today the most common computing nodes of powerful computer systems. Students will gain knowledge of architecturally specific optimization techniques used to reduce the decrease in computing power due to the widening performance gap between the computational requirements of multi-core CPUs and memory interface throughput. On specific non-trivial multithreaded programs, students will also learn the basics of the art of creating these applications. NIE-SIB Z,ZK 5 **Network Security** The students will gain theoretical and practical knowledge and experience in the area of current security threats in computer networks, specifically about detection and defense. The course explains basic pricipals of security monitoring, packet-based and flow-based analysis, in order to detect anomalies and suspicious network traffic. The course focuses on explanation and practical examples of various mechanisms of securing network infrastructure and detection in real time. The course covers general principals of handling detected security events (i.e. incident handling and incident response). Normalized Software Systems Students will learn the foundations of normalized systems theory that studies the evolvability of modular structures based on concepts from engineering, such as stability from system theory and entropy from thermodynamics. Students will understand a set of principles that indicate where violations of stability and entropy-related issues occur in any given software architecture. In the second part of the course, students learn how to construct software architectures using a set of 5 design patterns called elements. These elements provide the core functionality of information systems in terms of storing data, executing actions, workflows, connectors, and triggers, while handling violations of the stability and entropy-related principles. This knowledge allows students to realize new levels of evolvability in software architectures

NIE-REV Reverse Engineering

Z,ZK

5

Students will learn fundamentals of reverse engineering of computer software (methods of executing and initializing programs, organization of executable files, work with third-party libraries). Special attention will be paid to C ++. Students will also become familiar with the principles of debugging tools, disassemblers and obfuscation methods. Finally, the course will focus on code compression and decompression and executable file reconstruction.

NIE-SBF System Security and Forensics

Z,ZK

5

Students will be introduced to various aspects of system security (principles of endpoint security, principles of security policies, security models, authentication concepts). Students will also learn about forensic analysis as a tool for investigating security incidents (techniques used by malicious software or attackers, forensic analysis techniques, and the importance of memory or file system artifacts for attack analysis and detection).

NIE-TES Systems Theory

Z,ZK

5

Today, humankind has the ability to develop systems of incredible complexity (e.g., trains, microprocessors, airplanes, nuclear power plants). However, the costs of managing this complexity and of ensuring the correct behavior of a given system have become critical. A key technique for mastering this complexity is the usage of models that describe only those aspects of the systems that are important for the task at hand, and automated tools for analyzing those models. This subject will present theory and algorithms that form the basis for the modeling and analysis of complex systems.

NIE-TSP Testing and Reliability

Z,ZK

5

Students will gain knowledge about circuit testing and about methods for increasing reliability and security. They will get practical skills to be able to prepare a test set with the help of the intuitive path sensitization and to use an ATPG for automatic test generation. They will be able to design easily testable circuits and systems with built-in-self-test equipment. They will be able to compute, analyze, and control the reliability and availability of the designed circuits.

NIE-NUR User Interface Design

Z,ZK

5

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

NIE-VCC Virtualization and Cloud Computing

7 7K

5

Students will gain knowledge of architectures of large computer systems that are used in data centers and computer infrastructure of companies and organizations. They will get acquainted with virtualization principles, tools and technologies that serve to facilitate and automate configuration, testing and monitoring, and to efficiently operate and optimize the performance parameters of modern computer systems. Theoretically and practically, they will get acquainted with containerization as the most effective technology today for the management of complex computer systems and with specific technologies of cloud systems. Finally, they will learn the principles and gain practical skills in the use of modern integration and development tools (Continuous integration and development).

Name of the block: Compulsory elective courses

Minimal number of credits of the block: 18

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 18 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: 18

Note on the group:

Beware of the knowledge prerequisite of the QNI-QML course. You can enroll only with the previous knowledge, which is discussed in the following bachelor's courses: BI-ML1.21 Strojové

učení 1 BI-ML2.21 Strojové učení 2

Code	Name of the course / Name of the group of courses (in case of groups of courses the list of codes of their members) Tutors, authors and guarantors (gar.)	Completion	Credits	Scope	Semester	Role
QNI-AVM	Adiabatic computing and variational methods  Jakub Mareček Jakub Mareček (Gar.)	Z,ZK	6	2P+2C	*	PV
QNI-QEC	Quantum error correction Václav Potoček, Pavel Rytíř Václav Potoček Václav Potoček (Gar.)	Z,ZK	5	2P+2C	Z	PV
QNI-QOM	Quantum Optics, Metrology, Sensing and Imaging  Igor Jex Igor Jex (Gar.)	Z,ZK	5	2P+2C	Z	PV
QNI-QML	Quantum machine learning Daniel Vašata Daniel Vašata Daniel Vašata (Gar.)	Z,ZK	5	2P+1C	Z	PV
QNI-NMK	Numerical methods for quantum computation Michal Beneš, Michael Valášek, Jiří Fürst Tomáš Kalvoda Michal Beneš (Gar.)	Z,ZK	5	2P+2C	Z	PV
QNI-OQC	Optical quantum computing  Aurél Gábor Gábris Aurél Gábor Gábris (Gar.)	Z,ZK	5	2P+1C	Z	PV
B2M17OPM	Optical Measurements Matěj Komanec, Stanislav Vítek, Stanislav Zvánovec Matěj Komanec Stanislav Zvánovec (Gar.)	Z,ZK	6	2P+2L	L	PV
QNI-OVV	Optimization for Scientific Computing  Michael Valášek Michael Valášek (Gar.)	Z,ZK	5	2P+1C		PV
QNI-PNM	Parallelization of numerical methods Michael Valášek, Jiří Fürst, Tomáš Oberhuber Jiří Fürst Jiří Fürst (Gar.)	Z,ZK	5	2P+2C		PV
QNI-PJK	Programming languages for quantum computing  Jan Janoušek Jan Janoušek (Gar.)	Z,ZK	5	2P+1C	L	PV
B2M17VOT	Fiber Optic Technology Matěj Komanec, Stanislav Zvánovec, Jan Šístek Stanislav Zvánovec Stanislav Zvánovec (Gar.)	Z,ZK	6	2P+2L	Z	PV

	Selected Topics in Optimization and Numerical mathematics Štěpán Starosta, Daniel Vašata, Karel Klouda Karel Klouda Karel Klouda Z,ZK (Gar.)	5	2P+1C	L	PV
naracteristics of the formatics program	e courses of this group of Study Plan: Code=QNI-PV Name=Compulsory elect	tive co	urses of th	ne QNI C	Quantum
NI-AVM Ac	diabatic computing and variational methods		Z,	ZK	6
	patic computing and variational quantum algorithms (VQA). We start with a broad introduction to variational m	ethods in	n physical cher	nistry (e.g.,	for calculating
ound state of small molec	cules) and a recapitulation of advances in theoretical computer science (computational complexity and prob	lems suc	ch as MAXCU	T). We will <sub>l</sub>	present the
QA Conjecture and the un	ique games conjecture. We will present the adiabatic theorem and quantum speedup by quantum annealin	ng (QA). V	Ne will build up	o an under	standing of
•	nms by introducing and analysing, in turn, Variational quantum eigensolver (VQE), Quantum Approximate C		_		
	applications, we will highlight variational solvers for systems of linear equations and variational solvers for N	/larkowitz	portfolio man	agement, v	vith some
	s in benchmarking of VQA.				
l l	uantum error correction		1 '	ZK	5
	a theory for the construction of quantum error-correcting codes. In the introductory part, necessary chapter			•	
	ent the quantum analogy. We will show how coherently stored quantum information can be made robust to l				=
- : :	ault tolerance, based on which quantum computers are able to continuously correct errors arising at runtime	e and thu	is acnieve corr	ect results	even with
roneous bits, gates or mea			7	71/	
	uantum Optics, Metrology, Sensing and Imaging luction to the quantum theory of light and related fundamental principles with an emphasis on practical aspec	te Thou		ZK	5 d ovnoriment
=	ment of specifically quantum mechanical approaches to metrology and imaging in quantum computing and	-	-		-
•	es with photons (absorption, emission, stimulated emission), interference, entanglement, non-classical phe		-	-	
	persion. The various techniques are explained theoretically and also using experiments that demonstrate the		-		or oupprocess
	uantum machine learning	p	<del>·                                      </del>	ZK	5
1 1	introduce students to quantum machine learning. Students will first learn theoretically and practically about	the quar	,		_
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ext. they will explore kerne	el methods, the quantum SVM model, and the use of quantum variational methods in supervised learning so	enarios.	The course wi	Il also intro	duce quantur
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The role of the block: V

Code of the group: QNI-V

Name of the group: Purely Elective Master's Courses in the academic programme 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)	Completion	Credits	Scope	Semester	Role
NI-ATH	Tutors, authors and guarantors (gar.)  AlgorithmicTheories of Games	Z,ZK	4	2P+2C	L	V
NI-AFP	Tomáš Valla Tomáš Valla Tomáš Valla (Gar.)  Applied Functional Programming Robert Pergl, Marek Suchánek, Daniel Němec Robert Pergl Robert Pergl	KZ	5	2P+1C	L	V
NI-VGA	Video Games Architecture	Z,ZK	5	2P+1C	Z	V
NI-APH	Radek Richtr, Jan Matoušek Jan Matoušek Radek Richtr (Gar.)  Architecture of computer games	Z,ZK	4	2P+1C	Z	V
NI-BPS	Wireless Computer Networks	Z,ZK	4	2P+1C	L	
NI-DI O	Alexandru Moucha, Jiří Kašpar <b>Alexandru Moucha</b> Alexandru Moucha (Gar.)	2,21	-	21 +10		
NI-CTF	Capture The Flag Jiří Dostál, Jakub Bartoň, Ladislav Marko, Vojtěch Novák <b>Jiří Dostál</b> Jiří Dostál (Gar.)	KZ	4	3C	Z,L	V
NI-CAP	Cultural and Social Anthropology Alena Libánská, Tomáš Houdek, Jakub Šenovský Alena Libánská Alena Libánská (Gar.)	ZK	2	2P	Z	٧
NI-DPH	Game Design	Z,ZK	5	2P+1C	L	V
NI-DSW	Design Sprint Michal Manda, Ondřej Brém Michal Manda David Pešek (Gar.)	Z	2	30B	Z	٧
NI-PSD	Public Services Design Ondřej Brém, David Pešek, Jan Ladin Jan Ladin Ondřej Brém (Gar.)	KZ	4	1P+2C		V
FITE-DIF	Differential equations Ondřej Bouchala, Antonella Marchesiello, Jan Valdman Tomáš Kalvoda Ondřej Bouchala (Gar.)	Z,ZK	5	2P+2C	L	V
NI-DID	Digital drawing Denisa Nováčková Denisa Nováčková (Gar.)	Z	2	4C	Z,L	٧
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 (Gar.)	Z,ZK	4	2P+1C	L	٧
NI-EVY	Efficient Text Pattern Matching  Jan Holub Jan Holub (Gar.)	Z,ZK	5	2P+1C	Z	٧
NI-ESC	Experimental Project Course  Jan Matoušek, Ondřej Brém Ondřej Brém (Gar.)	KZ	8	0P+30R+52C	, L	٧
NI-GLR	Games and reinforcement learning	Z,ZK	4	2P+2C	L	V
NI-GEN	Code Generators Petr Máj Petr Máj Jan Janoušek (Gar.)	Z,ZK	5	2P+1C	Z	٧
NI-GNN	Graph Neural Networks  Miroslav Čepek Miroslav Čepek (Gar.)	Z,ZK	4	1P+1C	L	٧
NI-GAK	Graph theory and combinatorics  Michal Opler Tomáš Valla Tomáš Valla (Gar.)	Z,ZK	5	2P+2C	L	V
NI-GRI	Grid Computing  André Sopczak, Petr Fiedler Pavel Tvrdík André Sopczak (Gar.)	Z,ZK	5	2P+1C	Z	٧
NI-HCM	Mind Hacking Marcel Jiřina, Josef Holý Marcel Jiřina Marcel Jiřina (Gar.)	ZK	5	2P+1C	Z	٧
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 Solcová 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 (Gar.)	KZ	4	1P+3C	L	٧
NI-IKM	Internet and Classification Methods  Martin Holeňa Martin Holeňa (Gar.)	Z,ZK	4	1P+1C	L	V
NI-IAM	Internet and Multimedia	Z,ZK	4	2P+1C	L	٧
NI-IOT	Internet of Things	Z,ZK	4	2P+1C	L	٧
FITE-EHD	Introduction to European Economic History Tomáš Evan Tomáš Evan (Gar.)	Z,ZK	3	2P+1C	L	V
NI-KTH	Combinatorial Theories of Games Tomáš Valla Tomáš Valla (Gar.)	Z,ZK	4	2P+1C	L	V
NI-KOD	Data Compression Jan Holub Jan Holub (Gar.)	Z,ZK	5	2P+1C	L	V
NI-FMT	Finite model theory	Z,ZK	4	2P+1C	L	٧
NI-CCC	Creative Coding and Computational Art Radek Richtr, Ondřej Brém, Jiří Sebele, Josef Kortan Josef Kortan Radek Richtr (Gar.)	KZ	4	1P+2C	Z,L	V
NI-KYB	Cybernality	ZK	5	2P	Z	V

NI-LSM2	Statistical Modelling Lab  Kamil Dedecius Kamil Dedecius (Gar.)	KZ	5	зС	Z,L	V
NI-MPL	Managerial Psychology Jan Fiala Jan Fiala Jan Fiala (Gar.)	ZK	2	2P	Z,L	V
NI-MSI	Mathematical Structures in Computer Science  Jan Starý	Z,ZK	4	2P+1C	L	V
NI-MZI	Mathematics for data science Štěpán Starosta	Z,ZK	4	2P+1C	L	V
FIT-ITI	Modern IT infrastructure  Ivan Šimeček, Jan Fesl, Tomáš Vondra Ivan Šimeček Ivan Šimeček (Gar.)	Z,ZK	5	2P+1C	Z,L	V
NI-MOP	Modern Object-Oriented Programming in Pharo	KZ	4	3C	Z	V
NI-NLM	Jan Blizničenko Robert Pergl Robert Pergl (Gar.)  Neural Language Models	Z	5	2P+1C	L	V
NI-NMU	New media in art and design Zdeněk Svejkovský Zdeněk Svejkovský (Gar.)	ZK	3	2P+0C	Z	V
NI-OLI	Linux Drivers	Z,ZK	4	2P+2C	L	V
NI-ARI	Miroslav Skrbek, Jaroslav Borecký Jaroslav Borecký Miroslav Skrbek (Gar.)  Computer arithmetic	Z,ZK	4	2P+1C	Z,L	V
NI-PG1	Pavel Kubalik Pavel Kubalik Pavel Kubalik (Gar.)  Computer Grafics 1	ZK	4	2P+1C	L ,	V
	Radek Richtr Radek Richtr Radek Richtr (Gar.)  Enterprise Data Warehouse Systems			1P+1C		-
NI-EDW	Jakub Krejčí, Robert Kotlář <b>Jakub Krejčí</b> Magda Friedjungová (Gar.)  Advanced Virtual Reality	Z,ZK	5		L	V
NI-PVR	Petr Pauš <b>Petr Pauš</b> Petr <b>P</b> auš (Gar.)	KZ	4	2P+1C	Z	V
QNI-PMO	Advanced Optimization Methods / Conic Optimization  Jakub Mareček Jakub Mareček (Gar.)	Z,ZK	6	2P+2C	Z	V
NI-AML	Advanced machine learning Miroslav Čepek, Petr Šimánek, Vojtěch Rybář, Rodrigo Augusto Da Silva Alves, Zdeněk Buk <b>Miroslav Čepek</b> Miroslav Čepek (Gar.)	Z,ZK	5	2P + 1C	L	V
NI-IOS	Advanced techniques in iOS applications	KZ	4	2P+2C	L	V
NI-APT	Advanced Program Testing Pierre Donat-Bouillud Pierre Donat-Bouillud (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 David Šenkýř, Nikolas Jíša David Šenkýř David Šenkýř (Gar.)	Z,ZK	4	2P+1C	L	V
NI-PYT	Advanced Python	KZ	4	зС	Z	V
FIT-ACM1	Programming Practices 1 Tomáš Valla Tomáš Valla (Gar.)	KZ	5	4C	L	V
FIT-ACM2	Programming Practices 2 Tomáš Valla Ondřej Suchý (Gar.)	KZ	5	4C	Z	V
FIT-ACM3	Programming Practices 3 Ondřej Suchý Ondřej Suchý (Gar.)	KZ	5	4C	L	V
FIT-ACM4	Programming Practices 4 Ondřej Suchý Ondřej Suchý (Gar.)	KZ	5	4C	Z	V
FIT-ACM5	Programming Practices 5 Ondřej Suchý Ondřej Suchý (Gar.)	KZ	5	4C	L	V
FIT-ACM6	Programming Practices 6 Ondřej Suchý Ondřej Suchý (Gar.)	KZ	5	4C	L	V
NI-GOL	Programming of distributed systems in GO  Jaroslav Kříž, Róbert Selvek <b>Jaroslav Kříž</b> Jaroslav Kříž (Gar.)	KZ	5	0P+3C	Z	V
NI-PSL	Programming in Scala	Z,ZK	4	2P+1C	Z	V
NI-RUB	Programming in Ruby Cyril Černý Cyril Černý (Gar.)	KZ	4	3C	Z	V
NI-ROZ	Pattern Recognition  Michal Haindl Michal Haindl (Gar.)	Z,ZK	5	2P+1C	Z	V
NI-RUN	Runtime Systems Filip Křikava Filip Křikava (Gar.)	Z,ZK	5	2P+1C	L	V
NI-PLS1	Programming Language Seminar Pierre Donat-Bouillud, Filip Křikava Pierre Donat-Bouillud Pierre Donat-Bouillud (Gar.)	Z	2	0P+1C	Z	V
NI-PLS2	Programming Language Seminar Pierre Donat-Bouillud, Filip Křikava Pierre Donat-Bouillud Pierre Donat-Bouillud (Gar.)	Z	2	0P+1C	L	V
NI-PLS3	Programming Language Seminar Pierre Donat-Bouillud	Z	2	0P+1C	Z	V
NI-PLS4	Programming Language Seminar Pierre Donat-Bouillud, 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

FIT-SM1	Machine Learning Seminar 1 Magda Friedjungová, Pavel Kordík Magda Friedjungová Pavel Kordík (Gar.)	Z	4	2C	Z	V
FIT-SM2	Machine Learning Seminar 2 Magda Friedjungová, Pavel Kordík Magda Friedjungová Pavel Kordík (Gar.)	Z	4	2C	L	٧
FIT-SM3	Machine Learning Seminar 3 Magda Friedjungová, Pavel Kordík Magda Friedjungová Pavel Kordík (Gar.)	Z	4	2C	Z	٧
FIT-SM4	Machine Learning Seminar 4 Magda Friedjungová, Pavel Kordík Magda Friedjungová Pavel Kordík (Gar.)	Z	4	2C	L	٧
FIT-SM5	Machine Learning Seminar 5 Magda Friedjungová, Pavel Kordík Magda Friedjungová Pavel Kordík (Gar.)	Z	4	2C	Z	٧
FIT-SM6	Machine Learning Seminar 6 Magda Friedjungová Pavel Kordík (Gar.)	Z	4	2C	L	V
FIT-SM7	Machine Learning Seminar 7 Magda Friedjungová Pavel Kordík (Gar.)	Z	4	2C	Z	٧
FIT-SM8	Machine Learning Seminar 8 Magda Friedjungová Pavel Kordík (Gar.)	Z	4	2C	L	V
NI-SZ1	Knowledge Engineering Seminar Master I Pavel Kordík Magda Friedjungová (Gar.)	Z	4	2C	L,Z	٧
NI-SZ2	Knowledge Engineering Seminar Master II Pavel Kordík Magda Friedjungová (Gar.)	Z	4	2C	L,Z	V
NI-MLP	Machine Learning in Practice Jan Hučin Daniel Vašata Daniel Vašata (Gar.)	Z,ZK	5	2P+1C	Z	٧
NI-SLA	Sublinear algorithms Dušan Knop Dušan Knop (Gar.)	Z,ZK	5	2P+1C	Z	٧
FIT-SEP	World Economy and Business Tomáš Evan Tomáš Evan (Gar.)	Z,ZK	4	2P+2C	L	٧
NI-SEP	World Economy and Business Tomáš Evan Tomáš Evan (Gar.)	Z,ZK	4	2P+1C	Z,L	٧
NI-SYP	Parsing and Compilers Jan Janoušek Jan Janoušek (Gar.)	Z,ZK	5	2P+1C	Z	٧
NI-TVR	Virtual Reality Technology Tomáš Nováček Tomáš Nováček (Gar.)	Z,ZK	3	1P+1C	L,Z	٧
NI-TS1	Theoretical Seminar Master I Dušan Knop, Ondřej Suchý, Michal Opler, Tomáš Valla Tomáš Valla Tomáš Valla (Gar.)	Z	4	2C	Z	V
NI-TS2	Theoretical Seminar Master II Ondřej Suchý, Tomáš Valla Tomáš Valla Tomáš Valla (Gar.)	Z	4	2C	L	٧
NI-TS3	Theoretical Seminar Master III Tomáš Valla	Z	4	2C	Z	٧
NI-TS4	Theoretical Seminar Master IV Ondřej Suchý, Tomáš Valla 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	Z,ZK	5	2P+1C	L	V
FIT-TOP	Academic writing Petr Kroha, Tomáš Nováček Tomáš Nováček (Gar.)	Z	2	10B	Z	V
NI-DVG	Introduction to Discrete and Computational Geometry Maria Saumell Mendiola Maria Saumell Mendiola (Gar.)	Z,ZK	5	2P+1C	L	V
NI-VOL	Elections Dušan Knop Dušan Knop (Gar.)	Z,ZK	5	2P+1C	L	٧
QNI-PON	Selected Topics in Optimization and Numerical mathematics Štěpán Starosta, Daniel Vašata, Karel Klouda Karel Klouda (Gar.)	Z,ZK	5	2P+1C	L	V
NI-VYC	Computability 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
FITE-SEP	World Economy and Business Tomáš Evan Tomáš Evan Tomáš Evan (Gar.)	Z,ZK	4	2P+2C	Z	V
NI-ZS10	Master internship abroad for 10 credits Zdeněk Muzikář Zdeněk Muzikář (Gar.)	Z	10		Z,L	V
NI-ZS20	Master internship abroad for 20 credits Zdeněk Muzikář Zdeněk Muzikář (Gar.)	Z	20		Z,L	V
NI-ZS30	Master internship abroad for 30 credits Zdeněk Muzikář Zdeněk Muzikář (Gar.)	Z	30		Z,L	V
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Characteristics of the courses of this group of Study Plan: Code=QNI-V Name=Purely Elective Master's Courses in the academic programme Quantum Informatics

QNI-PON Selected Topics in Optimization and Numerical mathematics Z,ZK 5
Students will be introduced to special optimization problems that arise in the field of machine learning and artificial intelligence and will extend the basic knowledge of continuous optimization acquired in previous studies. They will also learn about the details of implementing solutions to these problems on a computer and related mathematical concepts, especially from numerical linear algebra.

NI-ATH	AlgorithmicTheories of Games	Z,ZK	4
	is a branch of mathematics, which has broad applications in economy, biology, politics and computer science. This theory st		-
"	mpetitive process by designinng a mathematical model and investigating the strategies. The traditional task of classical gam	•	•
	he game where no player wants to deviate from his strategy. Due to the recent development of computers, internet, social net other concepts the algorithmic point of view is gaining attention. In addition to existential questions we study the problems o		_
	s course we introduce the basics of game theory of many players, solution concept (usually equilibria) and methods of their		ation of various
NI-AFP	Applied Functional Programming	KZ	5
	d in Czech. Functional programming represents one of the traditional programming paradigms. Traditional and novel function	1 1	_
	he functional paradigm becomes an important construct of traditionally imperative languages (C++, C#, Java). As such, mas		
necessary competence	of a software engineer: the theory and especially the practice.		
NI-VGA	Video Games Architecture	Z,ZK	5
	de range of topics, procedures and methodologies related to the development of computer games - from a technical point of		-
	ew. In the lectures, students will be guided through the history of development, the structure of game engines, component are		
	sics, graphics, artificial intelligence and multiplayer. The exercises will then cover selected technological topics in greater details to form of properties demonstrations.	ail, including ways	of implementing
	in the form of practical demonstrations.	7.71/	4
NI-APH	Architecture of computer games cunderstands and the field of computer games development, especially from a technical point of view, but	Z,ZK	4
_	et a grasp of component-oriented and functional-oriented architecture, game mechanics, decision-making processes and basi	=	
	by will also understand the basics of pathfinding, networking and scripting and apply them in practical exercises (labs). An im		-
·	ple game, with a strong focus on nontrivial game mechanics.		
NI-BPS	Wireless Computer Networks	Z,ZK	4
Students will learn abou	it 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 known	wledge of security	/ mechanisms
	nd get skills of configuration of wireless network elements and simulation of wireless networks using suitable tools.		
NI-CTF	Capture The Flag	KZ	4
	to introduce students to CTF competitions and let them gain practical experience in the field of cyber security.		
NI-CAP	Cultural and Social Anthropology	ZK	2
	se aims to acquaint students with the basics of social and cultural anthropology as a scientific discipline dealing with the dive	=	· ·
	h from our "exotic" cultures (topics: kinship, religion, social exclusion, migration, globalization, , material culture, language, h	ealth, history, deat	th, etc) will be
shown. The course is pr NI-DPH		Z,ZK	5
	Game Design ts the NI-APH (Architecture of Computer Games) and BI-VHS (Virtual gaming worlds) course, while focusing primarily on gar	1 ' 1	_
· ·	by ledge of the principles used for games design, such as: level design, gameplay design, character design, game mechanic	_	
	students will get an overview of game development from the designer's perspective, from theoretical concepts to practical in		
projects.			
NI-DSW	Design Sprint	Z	2
Students will work on pr	ojects using the Design Sprint method, developed by Google. THanks to this method the teams are able to go from idea to va	lidated prototype i	n 5 days. During
	will get familiar with the method as participants. Through practical challenges they will try the whole 5 day process starting with the method as participants.	with research and	finishing with
testing the prototypes (p			
NI-PSD	Public Services Design	KZ	4
	e students to specifics of UX, Service design and development for public sector. We will look into the design and developme	•	
	ignesr) as well as clients. In small teams students will work on projects from partner organizations and will try out collaborat ents-designers as well as clients.	on with cheft repr	esemanves.
FITE-DIF	Differential equations	Z,ZK	5
	pundational overview of differential equations, starting with basic motivation and examples of ODEs and progressing to essenti	1 1	
	ms on existence and uniqueness establish when solutions can be guaranteed. Linear and system-based ODEs are covered		•
polynomial analysis, foll	owed by examples of non-linear models such as predator-prey and epidemiological models to showcase real-world applicati	ions. Finally, an int	roduction to
	ions (PDEs) extends these concepts to multi-variable contexts. The course will also cover numerical methods for solving OD	Es and PDEs, incl	uding implicit
-	ids, Runge-Kutta methods, and finite element methods for both ODEs and PDEs.		
NI-DID	Digital drawing	Z	2
	e students to the basic principals of digital drawing and graphical design. Students will gain understanding of composition, p	="	
	y in their own design works. Students will also gain experience in drawing and painting with digital and analog tools. The cou g and painting. The course is organized as a thematic practices covering parts of theory and practical exercise to practice ga	•	e who wants to
NI-DZO	Digital Image Processing	Z,ZK	4
	comprehensive overview of modern methods for interactive editing of digital images and video. It mainly deals with practical	1 ' 1	•
-	interesting theoretical basis. Visually attractive applications provide better understanding of basic theoretical background that is	-	-
of digital image process	ing. This course will introduce algorithms solving the following practical applications: edge-aware editing, tone mapping, HDI	R compression, de	e-blurring in
frequency domain, abst	raction, hybrid images, gradient domain editing, seamless image stitching and cloning, digital photo-montage, color-to-gray o	conversion, contex	t enhancement,
	ossible image deformation, free-form image registration, texture synthesis, interactive segmentation, colorization, painting, a		
NI-DDM	Distributed Data Mining	KZ	4
	e-of-the-art approaches for distributed data mining and parallelization of machine learning algorithms. Students will gain han	•	_
	ork Apache Spark and with existing distributed DM / ML algorithms. They will learn principles of their parallel implementation e other algorithms. The course is prezented in czech language.	is and will be capa	able to propose
NI-PAM	Efficient Preprocessing and Parameterized Algorithms	Z,ZK	4
	ation problems for which no polynomial time algorithms are known (e.g. NP-complete problems). Despite that it is often nece	1 ' 1	
	vill demonstrate that many problems can be solved much more effectively than by naively trying all possible solutions. Often	-	-
	s from practice-e.g., all solutions are relatively small. Parameterized algorithms exploit that by limiting the time complexity exp		
and polynomially in the	input size (which can be huge). Parameterized algorithms also represent a way to formalize the notion of effective polynomia	al time preprocess	ing of the input,
•	the classical complexity. Such a polynomial time preprocessing is then a suitable first step, whatever is the subsequent solutions and the subsequent solutions are suitable first step.		· ·
	ed 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
	e relations to other approaches to hard problems such as moderately exponential algorithms or approximation schemes.	7 71/	-
NI-EVY	Efficient Text Pattern Matching of efficient algorithms for text pattern matching. They learn to use so called succinct data structures that are efficient in both as	Z,ZK	5 mory complexity
	of efficient algorithms for text pattern matching. They learn to use so called succinct data structures that are efficient in both ac the knowledge in design of applications that utilize pattern matching.	vess une and mer	nory complexity.
, be able to use	and the second of approximation and suited pattern indicating.		

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		1
experts, and learn to integrate theory with practical application. Through a hands-on, project-based learning approach, students will develop their ski user experience evaluation, as well as gain experience working in a team to design and prototype a functional solution."	is in user-centere	d design and
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 intellig		- I
give you both theoretical and practical background so you can participate in related research activities. Presented in English.		
NI-GEN Code Generators	Z,ZK	5
Advanced techniques of translating programs written in high-level programming languages are essential for understanding the field of systems programming understanding the algorithms and techniques used to translate more complex programming constructs of modern languages employed in systems programming constructs.		,
familiar with both the theoretical and practical aspects of implementing the back-end of optimizing compilers for programming languages.	ogramming. Otaac	into will become
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 n		-
representations of nodes, edges and entire graphs. The techniques discussed cover various types of graphs, including time-varying graphs. The last	part of the course	also covers
graph generation and interpretability of graph neural networks. In the exercises, students will try out selected techniques and problems.  NI-GAK  Graph theory and combinatorics	Z.ZK	5
The goal of the class is to introduce the most important topics in graph theory, combinatorics, combinatorial structures, discrete models and algorithm	, ,	- 1
on undestanding the basic principles but also on applications in problem solving and algorithm design. The topics include: generating functions, selected	topics from graph	and hypergraph
coloring, Ramsey theory, introduction to probabilistic method, properties of various special classes of graphs and combinatorial structures. The theory	y will be also app	lied in the fields
of combinatorics on words, formal languages and bioinformatics.  NI-GRI Grid Computing	Z,ZK	5
Grid computing and gain knowledge about the world-wide network and computing infrastructure.	2,21	3
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, in	nformation syster	ns and assets,
the domain of cognitive security is the protection of the human mind from intentional and unintentional digital manipulation. The topic of cognitive sec		
the context of information warfare, increasing digital dependence and the development of artificial intelligence, where these phenomena from the Interrippacts such as disruption of social cohesion, threats to democracy or war.	net environment n	ave real societal
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 attachment	, , , , , , , , , , , , , , , , , , ,	
various kinds of side channels and they get deeper insight in power attacks. Students learn to implement various profiled and non-profiled attacks and	-	higher-order
attacks. They also get practice in both designing the SCA countermeasures and analyzing the amount and characteristics of the side-channel inform		
NI-HMI2   History of Mathematics and Informatics  This course is presented in Czech. Selected topics {Infinitesimal calculus, probability, number theory, general algebra, different examples of algorithm	ZK   ns_transformation	3 s recursive
functions, eliptic curves, etc.) note on possibilities of applications of some mathematical methods in informatics and its development.	io, iranoiormanon	5, 1004.5115
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 internati		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., pene		4
NI-IVS   Intelligent embedded systems   Intelligent embedded systems course for master's degree is focused on high-level technology embedded systems integrating artificial intelligence. The	KZ   le course is an ad	vance version
of the Intelligent embedded system fundamentals course for the bachelor degree. The aim of the course is to teach students humanoid robot program		
development. Lectures provide basis of motion control, sensor reading, application interfaces, robot navigation and development tools. In labs, students	ts develop advand	ced applications
combining knowledge of various courses like nature inspired algorithms, data mining algorithms, image recognition and web technologies	7.71/	
NI-IKM   Internet and Classification Methods   In this course, the students get acquainted with classification methods used in four important internet, or generally network applications: in spam filter	Z,ZK	dation systems
in malware detection systems and in intrusion detection systems. However, they will learn more than only how classification is performed when solving	-	-
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 lectu	ires 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		
NI-IAM Internet and Multimedia Internet In	Z,ZK	4
presentation of AV signals (output), network communication protocols, device interfaces, codecs, data formats and stereoscopy. We will look at practic		, , , , ,
audiovisual transmissions. Within the labs, students will practically assemble AV transmission chains using HW and SW technologies and verify the	effect of various co	omponents 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 t	the presentation
for audience.  NU IOT Internet of Things	7 7V	4
NI-IOT   Internet of Things   The subject is focused on the area of hardware and software technologies for the strongly growing computer support of various devices. Its goal is fa	Z,ZK   miliarization with	
development elements (Raspberry Pi, Arduino Due) and with the language for efficient application development and modification (GNU Forth).		
FITE-EHD Introduction to European Economic History	Z,ZK	3
The course introduces a selection of themes from the European economic history. It gives the student basic knowledge about forming of the global e		
of the key periods in history. As European countries have been dominant actors in this process it focuses predominantly on their roles in the econom area of Roman Empire to fragmentation of the Middle Ages, from destruction of WWII to the current affairs, the development of modern financial insti	·=	-
does not cover detailed economic history of particular European countries but rather the impact of trade and role of particular events, institutions and	•	
meetings will consist of a mixture of lecture and discussion.		
NI-KTH Combinatorial Theories of Games	Z,ZK	4
Traditional game theory is a branch of mathematics, which has broad applications in economy, biology, politics and computer science. This theory studies (players) of a certain competitive process by designing a mathematical model and investigating the strategies. The traditional task of classical game		- 1
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-players are the states.	-	· ·
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	_	
otherwise incompatible games can be added, that is, played simultaneously. This led to the algrebraic approach to study combinatorial games. The 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		-
is no efficient. Beck introduced the "false probabilistic method", which aims to tackhle this problem. In this course we build the foundation of the theor	_	
games. We focus on theoretical analysis of games and building the theory, not on the programming aspects of game solving algorithms. The course	equires independ	ent 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 the	ory, as well as for	PhD students
looking for research topics.		

NI-KOD	Data Compression	Z,ZK	5
Students are introduced	to the basic principles of data compression. They will learn the necessary theoretical background and get an overview of data	ata compression m	ethods being
•	rerview covers principles of integer coding and of statistical, dictionary, and context data compression methods. In addition, s	tudents learn the	fundamentals of
	methods used in image, audio, and video compression.	1	
NI-FMT	Finite model theory	Z,ZK	4
	s to introduce students to the basics of finite model theory. The original motivation is the questions expressibility and verifiability		
-	otion in the 1970s, the course has evolved rapidly and touched on many other areas of theoretical computer science, such as	descriptive comp	lexity theory, the
	Problem (CSP), the theory of algorithmic meta-theorems and combinatorics.		
NI-CCC	Creative Coding and Computational Art	KZ	4
•	ical tasks, get acquainted with creative and yet proven methods of visualizing various types of data. The course freely follows		
•	udents to suitable visualization methods for traditional as well as for open data. It combines well-known visualization techniq		- 1
(Institute of Intermedia	he aim is to create an interesting visualization project. It is planned to work closely with IPR CAMP (Center of Architecture a	na Metropolitari Fi	aririirig) ariu ilivi
`		71/	5
NI-KYB	Cybernality d with the fundamentals of legislation and international activities in the area of fighting cybercrime. Students will understand t	ZK	-
	tems for computer surveillance and traffic monitoring in the cyberspace. Students will also familiarize themselves with hacker		
=	operation of the state agencies and subjects dealing with defence of the cyberspace (especially CSIRT and CERT teams).	activities and bene	wor. The course
NI-LSM2	Statistical Modelling Lab	KZ	5
	vanced multiple target tracking (MTT). This domain covers simultaneous tracking of multiple targets using radar under the pre		_
	he-art filters, in particular the PHD (Probability Hypothesis Density) and PMBM (Poisson Multi-Bernoulli) filters.	oscilice of clutter, c	video tracking.
NI-MPL	Managerial Psychology	ZK	2
			4
NI-MSI	Mathematical Structures in Computer Science	Z,ZK	
Introduction to category	s of programming languages. Data types as continous lattices, Scott topology. Procedures as continuous mappings. The Sco	tt model of lambda	a calculus.
		7 71/	
NI-MZI	Mathematics for data science	Z,ZK	4
	are introduced to those fields of mathematics that are necessary for understanding standard methods and algorithms used igebra (matrix factorisations, eigenvalues, diagonalization), continuous optimisation (optimisation with constraints, duality prince).		
•	robability theory and statistics.	icipie, gradient me	strious) ariu
FIT-ITI	Modern IT infrastructure	Z,ZK	5
	Modern 11 minastructure ime-invariable range of software or hardware, this subject tries to explain the issue as a whole and in the context of the time. A	1 ' 1	-
· · · · · · · · · · · · · · · · · · ·	complex whole, the individual parts of which must be reconciled from different aspects of the view using current technologies		
	inuous and economically optimal operation.	o. The proposed c	Joint Circuit
NI-MOP	Modern Object-Oriented Programming in Pharo	KZ	4
_	nming is currently one of the most widespread paradigms of software creation, especially enterprise information systems, wh	1	-
	modern applications. In this course, we build on the knowledge acquired in the course BI-OOP and aim to further deepen the		
	dern pure object system Pharo (https://pharo.org). The course focuses on individual approach to students, their developmen	-	
addition to deepening o	bject programming skills, which are generally applicable in other OO languages, students will also gain the opportunity to wo	ork on interesting p	projects and OO
technologies in terms o	f semestral work with the possibility of cooperation with practice and related bachelor, diploma, postgraduate our direct involved	vement in the Pha	ro Consortium.
NI-NLM	Neural Language Models	Z	5
In this course, students	will learn the technical foundations of the Transformer architecture as well as the practical aspects of using language models	. The goal of the co	ourse is to teach
students how to use lar	guage 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		ain goal is to
familiarize the student v	vith the largest possible range of creative approaches in new media. The subject emphasizes dialogue with students, especia	ally in lectures dev	oted to specific
art projects.			
NI-OLI	Linux Drivers	Z,ZK	4
The Linux operating sys	stem is an important operating system for personal computer and also for embedded systems. Systems on chip and combinin	g powerful process	sors and FPGAs
increase the variability	of peripheral subsystems requiring specific software drivers. This course is an advanced course in the Linux driver developm	ent for master's st	udents. The
course provides knowle	dge of Linux operating system architecture, principles of development of various types drivers, including practical experience	,	
NI-ARI	Computer arithmetic	Z,ZK	4
Students will learn vario	ous 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 gr	aphic courses (mainly BI-PGA and BI-PGR) and the knowledge from these courses is deepened by state-of-the-art knowledge	e. The course is de	signed for those
	computer graphics. Students will gain practical knowledge with realistic texturing and raytracing methods. An integral part of t		-
articles and their subse	quent implementation. The course will be followed by a course PG2 supplementing the knowledge of PG1 on other areas an	d topics of comput	ter graphics.
NI-EDW	Enterprise Data Warehouse Systems	Z,ZK	5
•	arehouses course focuses on the area of business intelligence. Students will be introduced to business intelligence methods		- 1
	arehouses and various architectures, but also their deployment and maintenance. This course also includes an introduction to	o the area of repor	rting and data
visualization.			
NI-PVR	Advanced Virtual Reality	KZ	. 4
	advanced parts of the virtual reality. It is a continuation of the already running graphic objects, especially the creation of 3D m		-
•	dents to their application in virtual reality. Lectures will focus on virtual reality technology, its use in various applications and will a		•
<del>-</del>	(mainly Unity3D). The course is freely connected with the subject VHS (virtual game worlds), students will be able to apply the stly create a complex game for VR.	e knowledge gaine	ed in this subject
		7 71/	
QNI-PMO  Motivating examples Co	Advanced Optimization Methods / Conic Optimization   Onic optimization: Convex cones, Primal and dual conic problems, Spectrahedra and LMIs, Spectrahedral shadows, SDP dua	Z,ZK	6 P solvers Exact
	ensional polynomial optimization: Measures and moments, Riesz functional, moment and localizing matrices, Lasserres hier	=	
	ck to the motivating examples. Infinite-dimensional polynomial optimization. Extensions to time-varying coefficients. The moti		•
NI-AML	Advanced machine learning	Z,ZK	5
	Advanced machine learning students to selected advanced topics of machine learning and artificial intelligence. The topics present techniques in the field o		-
	interconnection of physical laws with the field of machine learning. The aim of the exercise is to familiarize students with the		-
,	The production of the state of		

	Advanced techniques in iOS applications	KZ	+
Students will learn the BI-IOS.	atest trends in mobile development technologies for iOS platform. Class covers advanced topics, students need to know all th	e basics from the	beginners class
NI-APT	Advanced Program Testing	Z,ZK	5
	sential to ensure that a program respects its specification, that changes do not introduce regressions or security issues. The $\mathfrak g$	, , , , , , , , , , , , , , , , , , ,	- 1
1	ing techniques, beyond writing unit tests, especially fuzzing and symbolic execution.	9	process
NI-PVS	Advanced embedded systems	Z,ZK	4
	on ARM processors and microcontrollers and their usage in wide range of applications. The course includes a series of advan		
_	age devices, motor control, system control and industrial communication. The students obtain both theoretical and also practic	cal experiences w	ith embedded
systems.	Advanced NICT	7 71/	4
NI-DNP	Advanced .NET noverview of platform .NET and will gain knowledge about technologies ASP.NET Core, Entity Framework Core, .NET MAUI	Z,ZK	4 or and also will
	evOps and GIT. Students will get practical experience in semestral work where they will create a client-server application utiliz		
	and (Blazor, .NET MAUI or WPF) and also Azure DevOps and GIT.		
NI-PYT	Advanced Python	KZ	4
	is to learn various advanced techniques and methods in Python. The course indirectly continues where Programming in Pyth		
teachers from Red Hat.	s only tutorials, everything is demonstrated on examples. Classification is based on work in class as well as semestral coursew	ork. The course is	lead by external
FIT-ACM1	Programming Practices 1	KZ	5
!	se for preparing talented student for representation in international programming contests.	112	Ü
FIT-ACM2	Programming Practices 2	KZ	5
This is a selective cour	se for preparing talented student for representation in international programming contests.	'	
FIT-ACM3	Programming Practices 3	KZ	5
	se for preparing talented student for representation in international programming contests.		
FIT-ACM4	Programming Practices 4	KZ	5
	se for preparing talented student for representation in international programming contests.	V7	-
FIT-ACM5 This is a selective cour	Programming Practices 5 se for preparing talented student for representation in international programming contests.	KZ	5
FIT-ACM6	Programming Practices 6	KZ	5
	se for preparing talented student for representation in international programming contests.	112	Ü
NI-GOL	Programming of distributed systems in GO	KZ	5
NI-PSL	Programming in Scala	Z,ZK	4
	the modern programming language Scala which exploits object-functional paradigm. Scala comprises advance language feat		
	y. 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. F	Play, Cassandra,
Scalaz, etc. NI-RUB	Programming in Ruby	KZ	4
ואו-חטס			
This course is presente		KZ	4
This course is presente	d in Czech.	<u>'</u>	5
NI-ROZ		Z,ZK	5
NI-ROZ The aim of the module	d in Czech.  Pattern Recognition	Z,ZK tatistical approach	5 n to pattern
NI-ROZ The aim of the module recognition. Students w NI-RUN	d in Czech.  Pattern Recognition is to give a systematic account of the major topics in pattern recognition with emphasis on problems and applications of the sill learn the fundamental concepts and methods of pattern recognition, including probability models, parameter estimation, an Runtime Systems	Z,ZK tatistical approach their numerical Z,ZK	5 n to pattern aspects.
NI-ROZ The aim of the module recognition. Students w NI-RUN This course is an introdu	d in Czech.  Pattern Recognition is to give a systematic account of the major topics in pattern recognition with emphasis on problems and applications of the sill learn the fundamental concepts and methods of pattern recognition, including probability models, parameter estimation, an Runtime Systems  In the world of virtual machines (VM) for high-level programming languages. There are two goals: Give you hands-on experience.	Z,ZK tatistical approach their numerical Z,ZK ence in design and	5 n to pattern aspects. 5 d implementation
NI-ROZ The aim of the module recognition. Students w NI-RUN This course is an introduof a compiler and a VM	d in Czech.  Pattern Recognition is to give a systematic account of the major topics in pattern recognition with emphasis on problems and applications of the sill learn the fundamental concepts and methods of pattern recognition, including probability models, parameter estimation, an Runtime Systems  In the world of virtual machines (VM) for high-level programming languages. There are two goals: Give you hands-on experies from scratch, including Abstract Syntax Tree (AST) interpretation Byte code (BC) design and interpretation AST to BC compiler.	Z,ZK tatistical approach their numerical Z,ZK ence in design and lation Memory ma	5 n to pattern aspects. 5 d implementation anagement
NI-ROZ The aim of the module recognition. Students w NI-RUN This course is an introdu of a compiler and a VM Just-in-time compilation	d in Czech.  Pattern Recognition is to give a systematic account of the major topics in pattern recognition with emphasis on problems and applications of the sill learn the fundamental concepts and methods of pattern recognition, including probability models, parameter estimation, an Runtime Systems  In the world of virtual machines (VM) for high-level programming languages. There are two goals: Give you hands-on experience.	Z,ZK tatistical approach their numerical Z,ZK ence in design and lation Memory ma	5 n to pattern aspects. 5 d implementation anagement
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NI-ROZ The aim of the module recognition. Students w NI-RUN This course is an introdu of a compiler and a VM Just-in-time compilation Dynamic optimizations, NI-PLS1 The Programming Lang	Pattern Recognition is to give a systematic account of the major topics in pattern recognition with emphasis on problems and applications of the sill learn the fundamental concepts and methods of pattern recognition, including probability models, parameter estimation, an Runtime Systems Inction to the world of virtual machines (VM) for high-level programming languages. There are two goals: Give you hands-on experted from scratch, including Abstract Syntax Tree (AST) interpretation Byte code (BC) design and interpretation AST to BC compit and some optimization techniques Through a series of guest lectures, introduce you to various advanced topics and implement speculations, and deoptimizations Language implementation frameworks Read-world VMs  Programming Language Seminar programming languages. It has the format of a reading group in which	Z,ZK Itatistical approach Ind their numerical Z,ZK Itatistical approach Z,ZK Itatistical approach Itation design and Itation Memory mations of real-work Itation we discuss scientifications	5 n to pattern aspects. 5 d implementation anagement d VMs, including 2 entific papers
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NI-ROZ The aim of the module recognition. Students w. NI-RUN This course is an introdu of a compiler and a VM Just-in-time compilation Dynamic optimizations, NI-PLS1 The Programming Lang about programming lang is a joint venue betwee NI-PLS2 The Programming Lang about programming lang is a joint venue betwee NI-PLS3 The Programming Lang about programming lang is a joint venue betwee NI-PLS4 The Programming Lang about programming lang is a joint venue betwee NI-PLS4 The Programming Lang about programming lang is a joint venue betwee NI-SCE1 The Seminar of Computare approached individual articles and other profesemester. NI-SCE2 The Seminar of Computare approached individual articles and other profesemester.	Autern Recognition is to give a systematic account of the major topics in pattern recognition with emphasis on problems and applications of the sill learn the fundamental concepts and methods of pattern recognition, including probability models, parameter estimation, an Runtime Systems  ction to the world of virtual machines (VM) for high-level programming languages. There are two goals: Give you hands-on experie from scratch, including Abstract Syntax Tree (AST) interpretation Byte code (BC) design and interpretation AST to BC compi and some optimization techniques Through a series of guest lectures, introduce you to various advanced topics and implement speculations, and deoptimizations Language implementation frameworks Read-world VMs  Programming Language Seminar  Juage Seminar aims to introduce students to research in programming languages. It has the format of a reading group in whice guages and related fields. Participating students are expected to present a paper of their interest and actively participate in the FTT and MFF CUNI. It is open to all students and researchers interested in programming languages.  Programming Language Seminar  Juage Seminar aims to introduce students to research in programming languages. It has the format of a reading group in whice guages and related fields. Participating students are expected to present a paper of their interest and actively participate in the FTT and MFF CUNI. It is open to all students and researchers interested in programming languages.  Programming Language Seminar  Juage Seminar aims to introduce students to research in programming languages. It has the format of a reading group in whice guages and related fields. Participating students are expected to present a paper of their interest and actively participate in the FTT and MFF CUNI. It is open to all students are expected to present a paper of their interest and actively participate in the FTT and MFF CUNI. It is open to all students are expected to present a paper of their interest and actively par	Z,ZK tatistical approach of their numerical Z,ZK ence in design and lation Memory material attions of real-work  Z ch we discuss science discussions. The discussions. The ch we discuss science discussions. The ch we discuss acide discussions. The che subject is work the s	5 n to pattern aspects.  5 d implementation anagement d VMs, including  2 entific papers e reading group  2 entific papers e reading group  2 entific papers e reading group  4 entific papers e reading group  5 entific papers e reading group  4 entific papers e reading group  4 entific papers e reading group
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FIT-SM1	Machine Learning Seminar 1	Z	4
= -	experienced researchers and focuses on reviewing and understanding State-of-the-Art (SOTA) research papers in Machine L	_	
	earch papers from top institutes and groups worldwide Understand the latest breakthroughswhat is being developed in leadi rly reading and presenting scientific literature. The work in this seminar will prepare you to attend (and profit from) top interna	•	
	ell as FIT's own Summer Research Program (VyLet).	tional WE711 come	crices and
FIT-SM2	Machine Learning Seminar 2	Z	4
This seminar is led by e	experienced researchers and focuses on reviewing and understanding State-of-the-Art (SOTA) research papers in Machine L	earning and AI. Yo	u will learn to:
	earch papers from top institutes and groups worldwide Understand the latest breakthroughswhat is being developed in leading	-	
• • • • • • • • • • • • • • • • • • • •	rly reading and presenting scientific literature. The work in this seminar will prepare you to attend (and profit from) top internat ell as FIT's own Summer Research Program (VyLet).	tional ML/AI confe	rences and
FIT-SM3	Machine Learning Seminar 3	Z	4
	experienced researchers and focuses on reviewing and understanding State-of-the-Art (SOTA) research papers in Machine L	. – .	•
= -	earch papers from top institutes and groups worldwide Understand the latest breakthroughswhat is being developed in leadi	_	
methodology for proper	rly reading and presenting scientific literature. The work in this seminar will prepare you to attend (and profit from) top international research and profit from the profit	tional ML/AI confe	rences and
	ell as FIT's own Summer Research Program (VyLet).		
FIT-SM4	Machine Learning Seminar 4	Z	4
= -	experienced researchers and focuses on reviewing and understanding State-of-the-Art (SOTA) research papers in Machine L earch papers from top institutes and groups worldwide Understand the latest breakthroughswhat is being developed in leadi	_	
	rly reading and presenting scientific literature. The work in this seminar will prepare you to attend (and profit from) top internat	-	
	ell as FIT's own Summer Research Program (VyLet).		
FIT-SM5	Machine Learning Seminar 5	Z	4
•	experienced researchers and focuses on reviewing and understanding State-of-the-Art (SOTA) research papers in Machine L	ŭ	
	earch papers from top institutes and groups worldwide Understand the latest breakthroughswhat is being developed in leadi	•	
	rly reading and presenting scientific literature. The work in this seminar will prepare you to attend (and profit from) top internat ell as FIT's own Summer Research Program (VyLet).	tional ML/Al confe	rences and
FIT-SM6	Machine Learning Seminar 6	Z	4
	experienced researchers and focuses on reviewing and understanding State-of-the-Art (SOTA) research papers in Machine L	. – .	•
= -	earch papers from top institutes and groups worldwide Understand the latest breakthroughswhat is being developed in leading	_	
methodology for proper	rly reading and presenting scientific literature. The work in this seminar will prepare you to attend (and profit from) top international research and profit from the profit	tional ML/AI confe	rences and
	ell as FIT's own Summer Research Program (VyLet).		
FIT-SM7	Machine Learning Seminar 7	Z	4
<del>-</del>	experienced researchers and focuses on reviewing and understanding State-of-the-Art (SOTA) research papers in Machine L earch papers from top institutes and groups worldwide Understand the latest breakthroughswhat is being developed in leadi	-	
	rly reading and presenting scientific literature. The work in this seminar will prepare you to attend (and profit from) top internat	-	
	ell as FIT's own Summer Research Program (VyLet).		
FIT-SM8	Machine Learning Seminar 8	Z	4
<del>-</del>	experienced researchers and focuses on reviewing and understanding State-of-the-Art (SOTA) research papers in Machine L	-	
, ,	earch papers from top institutes and groups worldwide Understand the latest breakthroughswhat is being developed in leadi rly reading and presenting scientific literature. The work in this seminar will prepare you to attend (and profit from) top interna	O	
	ell as FIT's own Summer Research Program (VyLet).	tional WE711 come	crices and
NI-SZ1	Knowledge Engineering Seminar Master I	Z	4
•	ll present a research paper from a top institute / research group to your peers. You will learn what is being cooked in top research		
	arn how to properly present and read scientific papers. The work in the seminar will prepare you to attend (and profit from) top ma	achine learning and	d Al conferences
	as well as FIT's own Summer Research Program (VyLet).	-	
NI-SZ2 On this seminar you wi	Knowledge Engineering Seminar Master II present a research paper from a top institute / research group to your peers. You will learn what is being cooked in top research	Z   Z	4 he world
	arn how to properly present and read scientific papers. The work in the seminar will prepare you to attend (and profit from) top ma		
• •	as well as FIT's own Summer Research Program (VyLet).	J J	
NI-MLP	Machine Learning in Practice	Z,ZK	5
Applying machine learn	ing methods to real projects in practice involves many other necessary tasks - from understanding the intentions of the client to	, ideally, technical	implementation.
ŭ	dents through all phases of a project according to the standard CRISP-DM methodology, not only theoretically but also practic	•	
ni-SLA	arn how to describe the whole process from exploration to evaluation of the model performance in the form of a clear and unc		
	Sublinear algorithms methods to tackle algorithms working in sublinear space.	Z,ZK	5
FIT-SEP	World Economy and Business	Z,ZK	4
	ed in Czech. The course introduces students of technical university to the international business. It does that predominantly by	1 ' 1	-
and key regions of world	d economy. Students get to know about different religions and cultures, necessary for doing business in diverse societies as we	II as indexes of eco	nomic freedom,
•	nic development, which are needed for the right investment decision. Seminars help to improve on the knowledge in the form	of discussions bas	ed on individual
	to take bachelor level of this course BIE-SEP as a prerequisite.	7.71/	4
NI-SEP	World Economy and Business ed in Czech. However, there is an English variant in the program Informatics (N1801 / 4793). The course introduces students or	Z,ZK	4
•	It does that predominantly by comparing individual countries and key regions of world economy. Students get to know about o		· .
	siness in diverse societies as well as indexes of economic freedom, corruption and economic development, which are needed	=	
Seminars help to impro	ove on the knowledge in the form of discussions based on individual readings. It is advised to take bachelor level of this cours	e BIE-SEP as a pr	erequisite.
NI-SYP	Parsing and Compilers	Z,ZK	5
· · · · · · · · · · · · · · · · · · ·	n the knowledge of fundamentals of automata theory, formal language and formal translation theories. Students gain knowledge	of various variants	and applications
	introduced to special applications of parsers, such as incremental and parallel parsing.	771	
NI-TVR Students will be introdu	Virtual Reality Technology Leed to the basic concepts of virtual reality. Techniques for displaying virtual worlds (CAVE, HMD,) and the possibilities of c	Z,ZK	/atars (nosition
	, eye tracking) will be discussed. Furthermore, the concepts of mixed and augmented reality will be introduced. Finally, ways o	=	
reality will be presented		5	J - 17-

Theoretical Seminar Master I 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. Theoretical Seminar Master II 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. Theoretical Seminar Master III 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 Theoretical seminar is intended for students which want to come in deeper contact with contemporary theoretical computer science. It is mostly a classical reading group. The students are treated individually and concern themselves with interesting topics from the latest research in the area. Therefore, an integral part of the course is a work with scientific papers and other scholarly literature. The capacity is limited by the the potentials of the teachers of the seminar. NI-TKA **Category Theory** Z,ZK 4 Theory of Neural Networks Z,ZK Artificial neural networks are now the foundation of artificial intelligence and the fastest-growing area of machine learning. This course introduces their theoretical foundations. It begins with general conceptsstructure, active dynamics, and adaptive dynamics (i.e., learning). Then it covers the theoretical basis of the most common types of artificial neural networks, from the perceptron of the 1950s to the transformer of 2017. Finally, using function approximation theory, it rigorously explains the most important theoretical result: the universal approximation capability of neural networks. FIT-TOP Academic writing Publishing is an important and required part of research activity. It is not only about obtaining research results but also about applying them in the form of publication. Writing scientific publications can be useful for students not only in their own publishing activities but also in the preparation of a bachelor's or master's thesis. In the course, students will learn how to write a scientific article, what parts such an article should have, and how the peer review process works. Students will also try their hand at presenting an article and reviewing someone else's article. The course will be taught in blocks, with theoretical part at the beginning of the semester and one practical at the end of the semester/beginning of the exam period. Dates will be determined based on the availability of enrolled students. Introduction to Discrete and Computational Geometry Z.ZK NI-DVG 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 Z Research Project 5 Student obtains the credits for published scientific outputs. The details are at https://courses.fit.cvut.cz/NI-VPR/en. FITE-SEP 4 World Economy and Business Z,ZK The course introduces students of technical university to the international business. It does that predominantly by comparing individual countries and key regions of world economy. Students get to know about different religions and cultures, necessary for doing business in diverse societies as well as indexes of economic freedom, corruption and economic development, which are needed for the right investment decision. Seminars help to improve on the knowledge in the form of discussions based on individual readings. It is advised to take bachelor level of this course BIE-SEP as a prerequisite. NI-ZS10 Master internship abroad for 10 credits 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 Ζ 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 Ζ 30 The course is prezented in chzech language. Each student can once within his / her master's degree have a foreign internship at a foreign university or other foreign scientific and/or research institution. Before the internship the Dean of the FIT, or the vice-dean for study affairs assesses the professional content. The student must provide evidence of the professional content and extent of the internship. Auxiliary courses MI-ZS10, MI-ZS20, MI-ZS30 are used used for the evidence and evaluation of the internship in IS KOS. Every 10 credits correspond to 4 weeks of full-time employment with a foreign institution. The maximum number of credits a student can earn for one internship is 30 credits. This amount can be divided into two subjects if the internship exceeds the academic year's dead-line.

#### List of courses of this pass:

Code	Name of the course	Completion	Credits
B2M17OPM	Optical Measurements	Z,ZK	6

	Fiber Optic Technology	Z,ZK	6
methods for the cha	rse is to introduce mechanisms of propagation of optical waves in optical fibers and fiber components. Furthermore, the optical measure		_
evetome cuch ac nu	aracterization of optical fibers will be presented. Lectures include both the design and methodology of measuring transmission parame Imerical aperture, attenuation, dispersion, and measurement of basic characteristics of active and passive elements of optical commu		
Systems such as no	splices, couplers, refractive indices etc.	riication systems -	connectors,
DOMOGRAC		7 71/	
BQM32KOS	Quantum optical communications and networks	Z,ZK	6
FIT-ACM1	Programming Practices 1	KZ	5
	This is a selective course for preparing talented student for representation in international programming contests.		1
FIT-ACM2	Programming Practices 2	KZ	5
	This is a selective course for preparing talented student for representation in international programming contests.		
FIT-ACM3	Programming Practices 3	KZ	5
	This is a selective course for preparing talented student for representation in international programming contests.		
FIT-ACM4	Programming Practices 4	KZ	5
	This is a selective course for preparing talented student for representation in international programming contests.		1
FIT-ACM5	Programming Practices 5	KZ	5
1117101110	This is a selective course for preparing talented student for representation in international programming contests.	112	
FIT-ACM6		KZ	5
FIT-ACIVIO	Programming Practices 6 This is a selective course for preparing talented student for representation in international programming contests.	NZ.	5
CIT ITI		7 71/	_
FIT-ITI	Modern IT infrastructure	Z,ZK	5
=	and time-invariable range of software or hardware, this subject tries to explain the issue as a whole and in the context of the time. A mo		-
is understood here	e as a complex whole, the individual parts of which must be reconciled from different aspects of the view using current technologies.	The proposed solu	tion should
	thus be capable of continuous and economically optimal operation.		1
FIT-SEP	World Economy and Business	Z,ZK	4
This course is pre-	sented in Czech. The course introduces students of technical university to the international business. It does that predominantly by co	omparing individua	al countries
and key regions of v	world economy. Students get to know about different religions and cultures, necessary for doing business in diverse societies as well as	indexes of econor	nic freedom,
corruption and eco	nomic development, which are needed for the right investment decision. Seminars help to improve on the knowledge in the form of di	scussions based of	on individual
	readings. It is advised to take bachelor level of this course BIE-SEP as a prerequisite.		
FIT-SM1	Machine Learning Seminar 1	Z	4
This seminar is led	d by experienced researchers and focuses on reviewing and understanding State-of-the-Art (SOTA) research papers in Machine Lear	rning and AI. You v	vill learn to:
<ul> <li>Critically analyz</li> </ul>	e research papers from top institutes and groups worldwide Understand the latest breakthroughswhat is being developed in leading	g research labs I	Master the
methodology for	properly reading and presenting scientific literature. The work in this seminar will prepare you to attend (and profit from) top internation	onal ML/AI confere	ences and
	summer schools, as well as FIT's own Summer Research Program (VyLet).		
FIT-SM2	Machine Learning Seminar 2	Z	4
This seminar is led	d by experienced researchers and focuses on reviewing and understanding State-of-the-Art (SOTA) research papers in Machine Lear	ning and Al. You v	vill learn to:
- Critically analyze	e research papers from top institutes and groups worldwide Understand the latest breakthroughswhat is being developed in leading	g research labs I	Master the
methodology for	properly reading and presenting scientific literature. The work in this seminar will prepare you to attend (and profit from) top internation	onal ML/AI confere	ences and
	summer schools, as well as FIT's own Summer Research Program (VyLet).		
FIT-SM3	Machine Learning Seminar 3	Z	4
	d by experienced researchers and focuses on reviewing and understanding State-of-the-Art (SOTA) research papers in Machine Lear	rning and Al. You v	vill learn to:
	e research papers from top institutes and groups worldwide Understand the latest breakthroughswhat is being developed in leading		viii icai ii io.
	e research papers from top institutes and groups worldwide. • Onderstand the latest breaktinoughswhat is being developed in leading	•	
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methodology for		g research labs I	Master the
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else's article. The course will be taught in blocks, with theoretical part at the beginning of the semester and one practical at the end of the semester/beginning of the exam period. Dates will be determined based on the availability of enrolled students. FITE-DIF Differential equations Z.ZK 5 This course provides a foundational overview of differential equations, starting with basic motivation and examples of ODEs and progressing to essential solution methods like separation of variables. Key theorems on existence and uniqueness establish when solutions can be guaranteed. Linear and system-based ODEs are covered with methods like characteristic polynomial analysis, followed by examples of non-linear models such as predator-prey and epidemiological models to showcase real-world applications. Finally, an introduction to partial differential equations (PDEs) extends these concepts to multi-variable contexts. The course will also cover numerical methods for solving ODEs and PDEs, including implicit and explicit Euler methods, Runge-Kutta methods, and finite element methods for both ODEs and PDEs. FITE-EHD Introduction to European Economic History The course introduces a selection of themes from the European economic history. It gives the student basic knowledge about forming of the global economy through the description of the key periods in history. As European countries have been dominant actors in this process it focuses predominantly on their roles in the economic history. From large economic area of Roman Empire to fragmentation of the Middle Ages, from destruction of WWII to the current affairs, the development of modern financial institutions is deciphered. The course does not cover detailed economic history of particular European countries but rather the impact of trade and role of particular events, institutions and organizations in history. Class meetings will consist of a mixture of lecture and discussion. FITE-SEP World Economy and Business 7.7K The course introduces students of technical university to the international business. It does that predominantly by comparing individual countries and key regions of world economy. Students get to know about different religions and cultures, necessary for doing business in diverse societies as well as indexes of economic freedom, corruption and economic development, which are needed for the right investment decision. Seminars help to improve on the knowledge in the form of discussions based on individual readings. It is advised to take bachelor level of this course BIE-SEP as a prerequisite. NI-AFP Applied Functional Programming 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 5 The course introduces students to selected advanced topics of machine learning and artificial intelligence. The topics present techniques in the field of recommendation systems, image processing, control and interconnection of physical laws with the field of machine learning. The aim of the exercise is to familiarize students with the methods discussed. NI-APH Architecture of computer games 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. **Advanced Program Testing** 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 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 guestions 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. Wireless Computer Networks 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 Cultural and Social Anthropology The one-semester course aims to acquaint students with the basics of social and cultural anthropology as a scientific discipline dealing with the diversity of the world - examples from anthropological research from our "exotic" cultures (topics: kinship, religion, social exclusion, migration, globalization, , material culture, language, health, history, death, etc ...) will be shown. The course is presented in Czech. Creative Coding and Computational Art Students work on practical tasks, get acquainted with creative and yet proven methods of visualizing various types of data. The course freely follows the basic graphics courses (MGA, BLE,) and introduces students to suitable visualization methods for traditional as well as for open data. It combines well-known visualization techniques with artistic methods using modern technologies. The aim is to create an interesting visualization project. It is planned to work closely with IPR CAMP (Center of Architecture and Metropolitan Planning) and IIM (Institute of Intermedia FEL). NI-CTF Capture The Flag K7 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 ΚZ 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 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 Advanced .NET 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. Game Design 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 impler projects.	nentation applied to	semestral
NI-DSW	Design Sprint	Z	2
	on projects using the Design Sprint method, developed by Google. THanks to this method the teams are able to go from idea to valida udents will get familiar with the method as participants. Through practical challenges they will try the whole 5 day process starting wit testing the prototypes (plus final presentation).		1
NI-DVG	Introduction to Discrete and Computational Geometry	Z,ZK	5
	s to introduce the students to the discipline of Discrete and Computational Geometry. The main goal of the course is to get familiar with of this discipline, and to be able to solve simple algorithmic problems with a geometric component.		
NI-DZO	Digital Image Processing	Z,ZK	4
•	ents a comprehensive overview of modern methods for interactive editing of digital images and video. It mainly deals with practical alg		, ,
-	e an interesting theoretical basis. Visually attractive applications provide better understanding of basic theoretical background that is als processing. This course will introduce algorithms solving the following practical applications: edge-aware editing, tone mapping, HDR		
	abstraction, hybrid images, gradient domain editing, seamless image stitching and cloning, digital photo-montage, color-to-gray conv	-	- 1
	gid-as-possible image deformation, free-form image registration, texture synthesis, interactive segmentation, colorization, painting, ac		
NI-EDW	Enterprise Data Warehouse Systems	Z,ZK	5
•	ta Warehouses course focuses on the area of business intelligence. Students will be introduced to business intelligence methods and ing warehouses and various architectures, but also their deployment and maintenance. This course also includes an introduction to the visualization.		- 1
NI-ESC	Experimental Project Course	KZ	8
	ct course offers a holistic exploration of the design process, providing students with a well-rounded understanding of the principles, n	•	
	ology-driven solutions that are user-centric and industry-relevant. Throughout the semester, students will work on real-world design pro n to integrate theory with practical application. Through a hands-on, project-based learning approach, students will develop their skills	=	- 1
experts, and lear	user experience evaluation, as well as gain experience working in a team to design and prototype a functional solution."	iii usei-centereu u	esign and
NI-EVY	Efficient Text Pattern Matching	Z,ZK	5
	edge of efficient algorithms for text pattern matching. They learn to use so called succinct data structures that are efficient in both access		complexity.
	They will be able to use the knowledge in design of applications that utilize pattern matching.		
NI-FMT	Finite model theory	Z,ZK	. 4
	rse is to introduce students to the basics of finite model theory. The original motivation is the questions expressibility and verifiability of inception in the 1970s, the course has evolved rapidly and touched on many other areas of theoretical computer science, such as des		
systems. Office its	Constraint Satisfaction Problem (CSP), the theory of algorithmic meta-theorems and combinatorics.	criptive complexity	trieory, trie
NI-GAK	Graph theory and combinatorics	Z,ZK	5
-	ss is to introduce the most important topics in graph theory, combinatorics, combinatorial structures, discrete models and algorithms.		- 1
_	e basic principles but also on applications in problem solving and algorithm design. The topics include: generating functions, selected top		
colorling, harrisey	theory, introduction to probabilistic method, properties of various special classes of graphs and combinatorial structures. The theory w of combinatorics on words, formal languages and bioinformatics.	nii be also applied i	ii tile lielus
NI-GEN	Code Generators	Z,ZK	5
Advanced technic	lues of translating programs written in high-level programming languages are essential for understanding the field of systems progran	nming. This primaril	ly involves
understanding the	algorithms and techniques used to translate more complex programming constructs of modern languages employed in systems progr	•	will become
NI CLD	familiar with both the theoretical and practical aspects of implementing the back-end of optimizing compilers for programming languages and reinforcement learning.		4
NI-GLR The field of reinfo	Games and reinforcement learning groups and reinforcement learning common learning is very hot recently, because of advances in deep learning, recurrent neural networks and general artificial intelligen	Z,ZK   ce. This course is in	4 ntended 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
	oduces students to advanced artificial intelligence techniques for working with graphs. Lectures will focus on the latest graph neural n		-
representations	of nodes, edges and entire graphs. The techniques discussed cover various types of graphs, including time-varying graphs. The last p graph generation and interpretability of graph neural networks. In the exercises, students will try out selected techniques and pro		so covers
NI-GOL	Programming of distributed systems in GO	KZ	5
NI-GRI	Grid Computing	Z,ZK	5
	Grid computing and gain knowledge about the world-wide network and computing infrastructure.	_,	
NI-HCM	Mind Hacking	ZK	5
	is an emerging discipline that is closely related to cyber security. While the domain of cyber security is the protection of networks, info	-	
	nitive security is the protection of the human mind from intentional and unintentional digital manipulation. The topic of cognitive secur mation warfare, increasing digital dependence and the development of artificial intelligence, where these phenomena from the Internet	, , , ,	
the context of infor	impacts such as disruption of social cohesion, threats to democracy or war.	chivino il montriave i	cai sociciai
NI-HMI2	History of Mathematics and Informatics	ZK	3
	esented in Czech. Selected topics {Infinitesimal calculus, probability, number theory, general algebra, different examples of algorithm	s, transformations,	recursive
This course is p			
	functions, eliptic curves, etc.) note on possibilities of applications of some mathematical methods in informatics and its develop		4
NI-HSC	Side-Channel Analysis in Hardware	Z,ZK	4 niliar with
NI-HSC This course is de		Z,ZK ks. Students get fan	niliar with
NI-HSC This course is devarious kinds of s	Side-Channel Analysis in Hardware edicated to so-called side-channel information leakage in hardware devices. It focuses on both theoretical analysis and practical attack ide channels and they get deeper insight in power attacks. Students learn to implement various profiled and non-profiled attacks and hey also get practice in both designing the SCA countermeasures and analyzing the amount and characteristics of the side-channel	Z,ZK ks. Students get fan get familiar with hig	niliar with gher-order e.
NI-HSC This course is devarious kinds of sattacks. NI-IAM	Side-Channel Analysis in Hardware edicated to so-called side-channel information leakage in hardware devices. It focuses on both theoretical analysis and practical attack ide channels and they get deeper insight in power attacks. Students learn to implement various profiled and non-profiled attacks and They also get practice in both designing the SCA countermeasures and analyzing the amount and characteristics of the side-channel  Internet and Multimedia	Z,ZK ks. Students get fan get familiar with hig information leakage Z,ZK	niliar with gher-order e. 4
NI-HSC This course is devarious kinds of sattacks.  NI-IAM The NI-IAM cour	Side-Channel Analysis in Hardware edicated to so-called side-channel information leakage in hardware devices. It focuses on both theoretical analysis and practical attack ide channels and they get deeper insight in power attacks. Students learn to implement various profiled and non-profiled attacks and 'hey also get practice in both designing the SCA countermeasures and analyzing the amount and characteristics of the side-channel  Internet and Multimedia se is focused on principles and modern technologies for network transmissions of audiovisual (AV) signals. The syllabus includes acq	Z,ZK  ks. Students get fan get familiar with hig information leakage Z,ZK uisition of AV signa	niliar with gher-order e.  4 Is (input),
NI-HSC This course is devarious kinds of sattacks.  NI-IAM The NI-IAM cour	Side-Channel Analysis in Hardware edicated to so-called side-channel information leakage in hardware devices. It focuses on both theoretical analysis and practical attack ide channels and they get deeper insight in power attacks. Students learn to implement various profiled and non-profiled attacks and They also get practice in both designing the SCA countermeasures and analyzing the amount and characteristics of the side-channel  Internet and Multimedia	Z,ZK  ks. Students get fan get familiar with hig information leakage Z,ZK uisition of AV signa se case scenarios	niliar with gher-order e.  4 Is (input), of real-time
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NI-HSC This course is devarious kinds of sattacks.  NI-IAM The NI-IAM courpresentation of AV audiovisual transithe quality and late	Side-Channel Analysis in Hardware edicated to so-called side-channel information leakage in hardware devices. It focuses on both theoretical analysis and practical attack ide channels and they get deeper insight in power attacks. Students learn to implement various profiled and non-profiled attacks and they also get practice in both designing the SCA countermeasures and analyzing the amount and characteristics of the side-channel  Internet and Multimedia se is focused on principles and modern technologies for network transmissions of audiovisual (AV) signals. The syllabus includes acq signals (output), network communication protocols, device interfaces, codecs, data formats and stereoscopy. We will look at practical unissions. Within the labs, students will practically assemble AV transmission chains using HW and SW technologies and verify the efficiency of AV transmissions. Students will learn how to build Internet infrastructure for end-to-end AV transmissions from the recording the for audience.	Z,ZK  As Students get fan get familiar with hig information leakage Z,ZK uisition of AV signa se case scenarios ect of various comp e scene up to the p	niliar with hher-order e.  4 Is (input), of real-time nonents on resentation
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NI-HSC This course is de various kinds of sattacks.  NI-IAM The NI-IAM cour presentation of AV audiovisual transithe quality and late  NI-IBE Students learn infe	Side-Channel Analysis in Hardware edicated to so-called side-channel information leakage in hardware devices. It focuses on both theoretical analysis and practical attack ide channels and they get deeper insight in power attacks. Students learn to implement various profiled and non-profiled attacks and they also get practice in both designing the SCA countermeasures and analyzing the amount and characteristics of the side-channel  Internet and Multimedia se is focused on principles and modern technologies for network transmissions of audiovisual (AV) signals. The syllabus includes acq signals (output), network communication protocols, device interfaces, codecs, data formats and stereoscopy. We will look at practical unissions. Within the labs, students will practically assemble AV transmission chains using HW and SW technologies and verify the efficiency of AV transmissions. Students will learn how to build Internet infrastructure for end-to-end AV transmissions from the recording the for audience.	Z,ZK  as. Students get fan get familiar with hig information leakage Z,ZK  uisition of AV signa se case scenarios ect of various comp e scene up to the p  ZK al standards in this	niliar with hyber-order e.  4 Ils (input), of real-time conents on resentation  2 area. They

NI-IKM Internet and Classification Methods	Z,ZK 4
In this course, the students get acquainted with classification methods used in four important internet, or generally network applications: in sp in malware detection systems and in intrusion detection systems. However, they will learn more than only how classification is performed w	
On the background of these applications, they get an overview of the fundamentals of classification methods. The course is taught in a 2-we	-
exercises. During the exercises, the students on the one hand implement simple examples to topics from the lectures, on the other h	
NI-IOS   Advanced techniques in iOS applications Students will learn the latest trends in mobile development technologies for iOS platform. Class covers advanced topics, students need to kn	ow all the basics from the beginners class
BI-IOS.	on an are succession are segument states
NI-IOT Internet of Things	Z,ZK 4
The subject is focused on the area of hardware and software technologies for the strongly growing computer support of various devices.  development elements (Raspberry Pi, Arduino Due) and with the language for efficient application development and more	•
NI-IVS Intelligent embedded systems	KZ 4
Intelligent embedded systems course for master's degree is focused on high-level technology embedded systems integrating artificial intelligent	igence. 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 rob development. Lectures provide basis of motion control, sensor reading, application interfaces, robot navigation and development tools. In lab	
combining knowledge of various courses like nature inspired algorithms, data mining algorithms, image recognition ar	
NI-KOD Data Compression	Z,ZK 5
Students are introduced to the basic principles of data compression. They will learn the necessary theoretical background and get an overvused in practice. The overview covers principles of integer coding and of statistical, dictionary, and context data compression methods. In ad	- 1
lossy data compression methods used in image, audio, and video compression.	dution, students learn the fundamentals of
NI-KTH Combinatorial Theories of Games	Z,ZK 4
Traditional game theory is a branch of mathematics, which has broad applications in economy, biology, politics and computer science. This	
(players) of a certain competitive process by designinng a mathematical model and investigating the strategies. The traditional task of class which are the states of the game where no player wants to deviate from his strategy. Historically, the second big development in game theory	
games, was by Conway, Berlekamp and Guy. They developed a theory, originally used for solving end-games in Go, into a full fledged field.	ŭ
otherwise incompatible games can be added, that is, played simultaneously. This led to the algrebraic approach to study combinatorial gar 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 br	· · · · · · · · · · · · · · · · · · ·
is no efficient. Beck introduced the "false probabilistic method", which aims to tackhle this problem. In this course we build the foundation of	•
games. We focus on theoretical analysis of games and building the theory, not on the programming aspects of game solving algorithms. The	
to mathematically analyse, think and proof. The course is also suitable for bachelors student in the third year, who attended introduction to looking for research topics.	graph theory, as well as for PhD students
NI-KYB Cybernality	ZK 5
Students get acquainted with the fundamentals of legislation and international activities in the area of fighting cybercrime. Students will under	
have an overview of systems for computer surveillance and traffic monitoring in the cyberspace. Students will also familiarize themselves with will also discuss the cooperation of the state agencies and subjects dealing with defence of the cyberspace (especially CS	
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 unde	er 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 Mul	· · · · · · · · · · · · · · · · · · ·
NI-MLP   Machine Learning in Practice  Applying machine learning methods to real projects in practice involves many other necessary tasks - from understanding the intentions of the	Z,ZK 5
The course guides students through all phases of a project according to the standard CRISP-DM methodology, not only theoretically but als	-
data processing and learn how to describe the whole process from exploration to evaluation of the model performance in the form of	
NI-MOP   Modern Object-Oriented Programming in Pharo Object-oriented programming is currently one of the most widespread paradigms of software creation, especially enterprise information syste	ems, 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 deep	
of object systems in modern pure object system Pharo (https://pharo.org). The course focuses on individual approach to students, their dev	-
addition to deepening object programming skills, which are generally applicable in other OO languages, students will also gain the opportun technologies in terms of semestral work with the possibility of cooperation with practice and related bachelor, diploma, postgraduate our dir	
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 mapping Introduction to category theory.	js. The Scott model of lambda calculus.
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 algorithm	ns 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	
students how to use language models to solve problems, make informed risk assessments, and work critically with the	
NI-NMU   New media in art and design  The course introduces students to the issue of using new media in artistic and design work. Key topics are moving image, internet, compu	ter 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	-
art projects.	
NI-OLI   Linux Drivers The Linux operating system is an important operating system for personal computer and also for embedded systems. Systems on chip and computer and also for embedded systems.	Z,ZK 4
increase the variability of peripheral subsystems requiring specific software drivers. This course is an advanced course in the Linux driver	
course provides knowledge of Linux operating system architecture, principles of development of various types drivers, inclu-	
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 a exactly in practice. We will demonstrate that many problems can be solved much more effectively than by naively trying all possible solution	· · · · · · · · · · · · · · · · · · ·
(parameter) of the inputs from practice-e.g., all solutions are relatively small. Parameterized algorithms exploit that by limiting the time comple	exity 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 properties of the	olynomial 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 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. Programming Language Seminar 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 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 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 ΚZ 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. Programming in Scala NI-PSI Z,ZK 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. Advanced Virtual Reality NI-PVR K7 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 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 ΚZ 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 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 K7 This course is presented in Czech. NI-RUN Runtime Systems Z.ZK 5 This course is an introduction to the world of virtual machines (VM) for high-level programming languages. There are two goals: Give you hands-on experience in design and implementation of a compiler and a VM from scratch, including Abstract Syntax Tree (AST) interpretation Byte code (BC) design and interpretation AST to BC compilation Memory management Just-in-time compilation and some optimization techniques Through a series of guest lectures, introduce you to various advanced topics and implementations of real-world VMs, including Dynamic optimizations, speculations, and deoptimizations Language implementation frameworks Read-world VMs Computer Engineering Seminar Master I 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 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 Z,ZK World Economy and Business 4 This course is presented in Czech. However, there is an English variant in the program Informatics (N1801 / 4793). The course introduces students of technical university to the international business. It does that predominantly by comparing individual countries and key regions of world economy. Students get to know about different religions and cultures, necessary for doing business in diverse societies as well as indexes of economic freedom, corruption and economic development, which are needed for the right investment decision. Seminars help to improve on the knowledge in the form of discussions based on individual readings. It is advised to take bachelor level of this course BIE-SEP as a prerequisite. NI-SLA Sublinear algorithms Z,ZK We will introduce three methods to tackle algorithms working in sublinear space.

NI-SYP	Parsing and Compilers	Z,ZK	5
The module builds i	ipon the knowledge of fundamentals of automata theory, formal language and formal translation theories. Students gain knowledge of various properties are students as a superior of the contraction of the	arious variants and	applications
	of LR parsing and are introduced to special applications of parsers, such as incremental and parallel parsing.		
NI-SZ1	Knowledge Engineering Seminar Master I	Z	4
	you will present a research paper from a top institute / research group to your peers. You will learn what is being cooked in top resea		
Additionally, you wil	I learn how to properly present and read scientific papers. The work in the seminar will prepare you to attend (and profit from) top machin	ne learning and AI o	onferences
	and summer schools, as well as FIT's own Summer Research Program (VyLet).		
NI-SZ2	Knowledge Engineering Seminar Master II	Z	4
	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		
Additionally, you wil	I learn how to properly present and read scientific papers. The work in the seminar will prepare you to attend (and profit from) top machin	ne learning and AI o	onferences
	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
	works are now the foundation of artificial intelligence and the fastest-growing area of machine learning. This course introduces their the		- 1
-	eptsstructure, active dynamics, and adaptive dynamics (i.e., learning). Then it covers the theoretical basis of the most common types		
from the percept	ron of the 1950s to the transformer of 2017. Finally, using function approximation theory, it rigorously explains the most important the approximation capability of neural networks.	oretical result: the	universai
NII TO1		Z	4
NI-TS1	Theoretical Seminar Master I		
	r is intended for students which want to come in deeper contact with contemporary theoretical computer science. It is mostly a classic ally and concern themselves with interesting topics from the latest research in the area. Therefore, an integral part of the course is a		
are treated marvida	other scholarly literature. The capacity is limited by the the potentials of the teachers of the seminar.	WORK WITH SCIENTING	papers and
NI-TS2	Theoretical Seminar Master II	7	4
- 1	r is intended for students which want to come in deeper contact with contemporary theoretical computer science. It is mostly a classic	l	
	ally and concern themselves with interesting topics from the latest research in the area. Therefore, an integral part of the course is a		
	other scholarly literature. The capacity is limited by the the potentials of the teachers of the seminar.		
NI-TS3	Theoretical Seminar Master III	7	4
	r is intended for students which want to come in deeper contact with contemporary theoretical computer science. It is mostly a classic	ı — ı al reading group. Ti	he students
	ally and concern themselves with interesting topics from the latest research in the area. Therefore, an integral part of the course is a		
	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 semina	r is intended for students which want to come in deeper contact with contemporary theoretical computer science. It is mostly a classic	al reading group. T	he students
are treated individu	ally 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
	troduced to the basic concepts of virtual reality. Techniques for displaying virtual worlds (CAVE, HMD,) and the possibilities of cont	-	
tracking, hand tra	cking, eye tracking) will be discussed. Furthermore, the concepts of mixed and augmented reality will be introduced. Finally, ways of	using virtual and a	ugmented
NII VOA	reality will be presented.	7.71	
NI-VGA	Video Games Architecture	Z,ZK	5
	a wide range of topics, procedures and methodologies related to the development of computer games - from a technical point of vie of view. In the lectures, students will be guided through the history of development, the structure of game engines, component and fu		- 1
	of view. In the lectures, statems will be guided through the history of development, the structure of game engines, component and it., , physics, graphics, artificial intelligence and multiplayer. The exercises will then cover selected technological topics in greater detail, it		
game acvelopment	some game mechanics, in the form of practical demonstrations.	loldding ways of in	picinicitaling
NI-VOL	Elections	Z,ZK	5
IVI VOL	We will cover the basics of (committee) elections and, in general, opinion aggregation.	2,21	
NI-VPR	Research Project	Z	5
141 41 11	Student obtains the credits for published scientific outputs. The details are at https://courses.fit.cvut.cz/NI-VPR/en.		9
NI-VYC	Computability	Z,ZK	4
141 7 10	Classical theory of recursive functions and effective computability.	2,21	
NI-ZS10	Master internship abroad for 10 credits	Z	10
	once within his / her master's degree have a foreign internship at a foreign university or other foreign scientific and/or research institu	l I	
	the vice-dean for study affairs assesses the professional content. The student must provide evidence of the professional content and ex		- 1
	MI-ZS20, MI-ZS30 are used used for the evidence and evaluation of the internship in IS KOS. Every 10 credits correspond to 4 week		· · ·
a foreign institution	on. 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 ex	ceeds 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 institu	tion. Before the inte	ernship the
	the vice-dean for study affairs assesses the professional content. The student must provide evidence of the professional content and experience of the pro		
	MI-ZS20, MI-ZS30 are used used for the evidence and evaluation of the internship in IS KOS. Every 10 credits correspond to 4 week		-
a foreign institution	on. 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 ex	ceeas tne
NI 7000	academic year's dead-line.	7	
NI-ZS30	Master internship abroad for 30 credits	Z	30
	ented in chzech language. Each student can once within his / her master's degree have a foreign internship at a foreign university or . Before the internship the Dean of the FIT, or the vice-dean for study affairs assesses the professional content. The student must provice	<del>-</del>	
	of the internship. Auxiliary courses MI-ZS10, MI-ZS20, MI-ZS30 are used used for the evidence and evaluation of the internship in IS KO		
	ime employment with a foreign institution. The maximum number of credits a student can earn for one internship is 30 credits. This al	•	
	subjects if the internship exceeds the academic year's dead-line.		-
NIE-ADP	Architecture and Design patterns	Z,ZK	5
	s course is to provide students with both work knowledge about the underlying foundations of object-oriented design and analysis as		
-	ues, and tradeoffs of advanced software design. In the first part of the course, the students will refresh and deepen their knowledge o		- 1
and get familiar with	n the commonly used object-oriented design patterns that represent the best practices for solving common software design problems.	n the second part t	he students
will be introduced to	the principles of software architecture design and analysis. This includes the classical architectural styles, component based systems	, and some advanc	ed software
	architectures used in large-scale distributed systems.		

NIE-AIB Algorithms of Information Security Z,ZK 5 Students will get acquainted with the algorithms of secure key generation and cryptographic error (not only biometric) data processing. Furthermore, students will learn the mathematical principles of cryptographic protocols (identification, authentication, and signature schemes). Another part of the course is dedicated to malware detection and the use of machine learning in detection systems. The last topic includes practical steganographic methods and attacks on steganographic systems. NIE-AM1 Middleware Architectures 1 Z,ZK 5 Students will study new trends, concepts, and technologies in the area of service-oriented architectures. The will gain an overview of information system architecture, web service architecture and aplication servers. The will also study principles and technologies for middleware focused on application integrations, asynchronous communications and high availability of applications. This course replaces the course MIE-MDW. NIE-BKO **Error Control Codes** Z,ZK The course expands the basic knowledge of security codes used in current systems for error detection and correction. It provides the necessary mathematical theory and principles of linear, cyclic codes and codes for the correction of multiple errors, clusters of errors and whole syllables (bytes). Students will also learn how to implement these detections and corrections for different types of transmissions (parallel, serial) when storing data in memory and when transmitting over telecommunication channels. **Embedded Security** Students gain basic knowledge in selected topics of cryptography and cryptanalysis. The course focuses particularly on efficient implementations of cryptographic primitives in hardware and software (in embedded systems). Students gain a good overview of functionality of (hardware) cryptographic accelerators, smart cards, and resources for securing internal functions of computer systems. Distributed Systems and Computing Z,ZK Students are introduced to methods for coordination of processes in distributed environment characterised by nondeterministic time responses of computing processes and communication channels. They learn basic algorithms that assure correctness of computations realized by a group of loosely coupled processes and mechanisms that support high availability of both data and services, and safety in case of failures. **Embedded Hardware** The course brings basic laws that govern digital design and basic techniques to use them. It deals with both large and small scale systems. This is the base of advanced embedded systems, that profit from their specialized structure for effective computation and acceleration. Design of fast custom computing machines is discussed, including standardized means of internal communication, parallelism extraction and utilization in special structures and system architectures **NIE-EPC** Effective C++ programming Students learn how to use the modern features of contemporary versions of the C++ programming language for software development. The course focuses on programming effectivity and efficiency in the form of writing maintainable and portable source code and creating correct programs with low memory and processor time requirements **NIE-ESW Embedded Software** Embedded software course acquainted students with the specifics of software development for embedded systems. The course covers the areas from the basic techniques of programming in C language and code optimizations, through typical areas as the reliable software development, embedded operating systems, signal processing, up to sophisticated techniques combined with artificial intelligence. Formal Methods and Specifications Z,ZK 5 Students are able to describe semantics of software formally and to use sound reasoning for construction of correct software. They learn to use some software tools that allow to prove basic properties of software. NIE-GPU GPU Architectures and Programming 7.7K 5 Students will gain knowledge of the internal architecture of modern massively parallel GPU processors. They will learn to program them mainly in the CUDA programming environment, which is already a widespread programming technology of GPU processors. As an integral part of the effective computational use of these hierarchical computational structures, students will also learn optimization programming techniques and methods of programming multiprocessor GPU systems. NIE-HWB Hardware Security 7.7K 5 The course provides the knowledge needed for the analysis and design of computer systems security solutions. Students get an overview of safeguards against abuse of the system using hardware means. They will be able to safely use and integrate hardware components into systems and test them for resistance to attacks. Students will gain knowledge about the cryptographic accelerators, PUF, random number generators, smart cards, biometric devices, and devices for internal security functions of the computer. NIE-KRY Advanced Cryptology Students will learn the essentials of cryptanalysis and the mathematical principles of constructing symmetric and asymmetric ciphers. They will know the mathematical principles of random number generators. They will have an overview of cryptanalysis methods, elliptic curve cryptography and quantum cryptography, which they can apply to the integration of their own systems or to the creation of their own software solutions. **NIE-MCC** Multicore CPU Computing Z,ZK 5 Students will get acquainted in detail with hardware support and programming technologies for the creation of parallel multithreaded computations on multicore processors with shared and virtually shared memory, which are today the most common computing nodes of powerful computer systems. Students will gain knowledge of architecturally specific optimization techniques used to reduce the decrease in computing power due to the widening performance gap between the computational requirements of multi-core CPUs and memory interface throughput. On specific non-trivial multithreaded programs, students will also learn the basics of the art of creating these applications. NIE-MKY Mathematics for Cryptology Z,ZK 5 Students will gain deeper knowledge of algebraic procedures solving the most important mathematical problems concerning the security of ciphers. In particular, the course focuses on the problem of solving a system of polynomial equations over a finite field, the problem of factorization of large numbers and the problem of discrete logarithm. The problem of factorization will also be solved on elliptic curves. Students will further become familiar with modern encryption systems based on lattices NIE-MTI Modern Internet Technologies Z,ZK 5 Students learn advanced networking technologies and protocols for both local area networks and wide area networks. They get acquainted with routing techniques and transfer technologies of modern internet, including multimedia data transfer, with various types of network virtualization, and with last-mile security. Normalized Software Systems Students will learn the foundations of normalized systems theory that studies the evolvability of modular structures based on concepts from engineering, such as stability from system theory and entropy from thermodynamics. Students will understand a set of principles that indicate where violations of stability and entropy-related issues occur in any given software architecture. In the second part of the course, students learn how to construct software architectures using a set of 5 design patterns called elements. These elements provide the core functionality of information systems in terms of storing data, executing actions, workflows, connectors, and triggers, while handling violations of the stability and entropy-related principles. This knowledge allows students to realize new levels of evolvability in software architectures. NIE-NUR User Interface Design Z,ZK 5 Students will understand the theorical background of human-computer interaction and user interface (UI) design, will learn formal description of UIs, formal user models, the fundamental notions and procesures. They get acquainted with graphical, speech, and multimodal UIs. Thanks to the gained knowledge, the students will be able to design advanced UIs. **NIE-PDB** Advanced Database Systems Z,ZK Students orient themselves in problems of evaluation and optimization of SQL queries. The next part of the course deals with new concepts of database machines (so called NoSQL databases), with the related new data models (XML, graph databases, column databases) and languages for working with them (XQuery, XPath, CYPHER, Gremlin). The last part of the course deals with performance evaluation of database machines. This course is equivalent to the course MIE-PDB.

**NIE-PIS Advanced Information Systems** Z,ZK 5 Students learn the notion of business process logic and its formalization, with business process roles, business rules, and data processing, with the notion of service oriented company, enterprise services and service solution of business logic. They get acquainted with these notions also for the other types of ISs. They learn about agility and adaptivity and using of artificial intelligence methods for implementation of these ideas in ISs. They understand modern object-oriented methodologies for modelling of business processes, business rules, processed data, and enterprise ISs. They will get the rules and technologies for successful implementation of IS. NIE-REV Reverse Engineering Students will learn fundamentals of reverse engineering of computer software (methods of executing and initializing programs, organization of executable files, work with third-party libraries). Special attention will be paid to C++. Students will also become familiar with the principles of debugging tools, disassemblers and obfuscation methods. Finally, the course will focus on code compression and decompression and executable file reconstruction. System Security and Forensics Students will be introduced to various aspects of system security (principles of endpoint security, principles of security policies, security models, authentication concepts). Students will also learn about forensic analysis as a tool for investigating security incidents (techniques used by malicious software or attackers, forensic analysis techniques, and the importance of memory or file system artifacts for attack analysis and detection). NIE-SIB **Network Security** Z,ZK The students will gain theoretical and practical knowledge and experience in the area of current security threats in computer networks, specifically about detection and defense. The course explains basic pricipals of security monitoring, packet-based and flow-based analysis, in order to detect anomalies and suspicious network traffic. The course focuses on explanation and practical examples of various mechanisms of securing network infrastructure and detection in real time. The course covers general principals of handling detected security events (i.e. incident handling and incident response). Digital Circuit Simulation and Verification Aim of the course is to acquaint the students with principles of digital circuit simulation at RTL (Register Transfer Level) and TLM (Transaction Level Modeling) levels and with the properties of proper tools. The course covers today recent verification methods, too. Z,ZK **NIE-TES** Systems Theory 5 Today, humankind has the ability to develop systems of incredible complexity (e.g., trains, microprocessors, airplanes, nuclear power plants). However, the costs of managing this complexity and of ensuring the correct behavior of a given system have become critical. A key technique for mastering this complexity is the usage of models that describe only those aspects of the systems that are important for the task at hand, and automated tools for analyzing those models. This subject will present theory and algorithms that form the basis for the modeling and analysis of complex systems. **NIE-TSP** Testing and Reliability Students will gain knowledge about circuit testing and about methods for increasing reliability and security. They will get practical skills to be able to prepare a test set with the help of the intuitive path sensitization and to use an ATPG for automatic test generation. They will be able to design easily testable circuits and systems with built-in-self-test equipment. They will be able to compute, analyze, and control the reliability and availability of the designed circuits. NIE-VCC Z,ZK Virtualization and Cloud Computing 5 Students will gain knowledge of architectures of large computer systems that are used in data centers and computer infrastructure of companies and organizations. They will get acquainted with virtualization principles, tools and technologies that serve to facilitate and automate configuration, testing and monitoring, and to efficiently operate and optimize the performance parameters of modern computer systems. Theoretically and practically, they will get acquainted with containerization as the most effective technology today for the management of complex computer systems and with specific technologies of cloud systems. Finally, they will learn the principles and gain practical skills in the use of modern integration and development tools (Continuous integration and development). QNI-AVM Adiabatic computing and variational methods Z,ZK 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. Diploma Thesis 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. Cryptology and Quantum Computing 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-LOM Linear Optimization and Methods Z,ZK 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 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 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
	ted to numerical solution of boundary-value problems and intial-boundary-value problems for ordinary and partial differential equatior d finite-volume methods for elliptic, parabolic and hyperbolic partial differential equations. Students are introduced to the recent advar	•	
iiiile-element an	mentioned problems.	nces in methods so	Diving the
QNI-OQC	Optical quantum computing	Z.ZK	5
	the basic theoretical methods and concepts for optical quantum computing, complemented by on hands-on exercise and applications	s using quantum pr	rogramming
	y Fields and Piquasso. Theoretical concepts include measurement-based quantum computation, Gaussian Boson Sampling, and qua	· · · · · · · · · · · · · · · · · · ·	
	on current and near-term hardware include recent generative and discriminative machine-learning algorithms, as well as molecular vi		
QNI-OVV	Optimization for Scientific Computing	Z,ZK	5
	course is an explanation of numerical methods for solving nonlinear optimization, convex optimization, stochastic optimization, optima iic and evolutionary programming, machine learning, deep neural networks. Students are also introduced to modern trends in solving		ons for QC,
QNI-PJK	Programming languages for quantum computing	Z,ZK	5
	odels for quantum computing: quantum Turing machine, QRAM, lambda calculus with qubits. Higher programming languages for quar	· '	
languages	(Silq), functional languages (QML, Quipper). ). In the seminars the student will learn the basics of programming in the higher program	mming language S	ilq.
QNI-PMO	Advanced Optimization Methods / Conic Optimization	Z,ZK	6
	es. Conic optimization: Convex cones, Primal and dual conic problems, Spectrahedra and LMIs, Spectrahedral shadows, SDP duality,		
	e-dimensional polynomial optimization: Measures and moments, Riesz functional, moment and localizing matrices, Lasserres hierarc		
QNI-PNM	aces, Back to the motivating examples. Infinite-dimensional polynomial optimization. Extensions to time-varying coefficients. The motivation of numerical methods	Z,ZK	5
	course is an explanation of numerical methods for solving mathematical models with a focus on their parallelization and the use of the		
	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 i	introduced to special optimization problems that arise in the field of machine learning and artificial intelligence and will extend the bas	sic knowledge of co	ontinuous
optimization acquire	ed in previous studies. They will also learn about the details of implementing solutions to these problems on a computer and related matle	hematical concepts	s, especially
0	from numerical linear algebra.		
QNI-PPS	Programming of parallel systems	Z,ZK	6
-	pre processors and GPU accelerators have become common components of computing clusters and high-performance computing sys programming are essential for every computer scientist. The aim of this course is to introduce students to the architectures and programming are essential for every computer scientist.	_	
· ·	ared memory, GPU accelerators, or with distributed memory. To effectively use these modern computing systems, it is essential to comb	_	· ·
•	Students will gain knowledge of the relevant programming models, languages and environments. They will become familiar with fundar	•	
be able to analyze	$the \ limitations, \ efficiency, \ and \ scalability \ of \ parallel \ solutions \ to \ selected \ problems \ on \ high-performance \ computing \ systems. \ In \ additional \ and \ scalability \ of \ parallel \ solutions \ to \ selected \ problems \ on \ high-performance \ computing \ systems.$	on to the necessar	ry 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 introduc	Quantum Computation 1 ces the student to basic principles of quantum computation and shows the difference between classical and quantum mechanics. Quantum	um computation us	es quantum
The course introduction circuits, which will b	Quantum Computation 1 ces the student to basic principles of quantum computation and shows the difference between classical and quantum mechanics. Quantue demonstrated in the Qiskit SDK. The course will gradually introduce the student to such concepts the state of a quantum system and its	um computation us s visualization, mea	es quantum asurements,
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